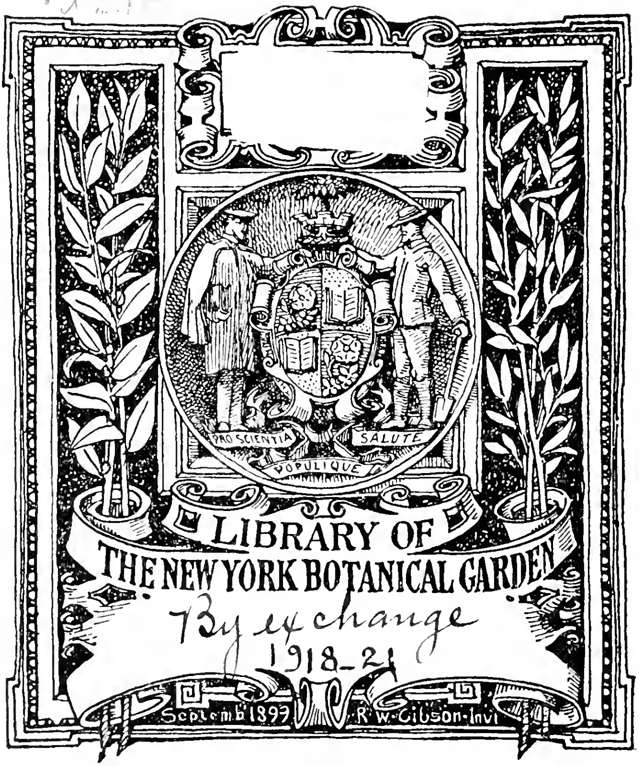
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VOLUME IX

of the

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Publications

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AND

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Tucson, Arizona, 1918-1921

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UNIVERSITY OF ARIZONA
COLLEGE OF AGRICULTURE

Agricultural Experiment Station

Bulletin No. 85

A STUDY OF MARKETING CONDITIONS

in the

SALT RIVER VALLEY, ARIZONA

By J. H. COLLINS,

Investigator in Market Surveys, Bureau of Markets, United States Department of Agriculture

UNIVERSITY OF ARIZONA AND U. S. DEPARTMENT OF AGRICULTURE CO-OPERATING.

Tucson, Arizona, March 1, 1918.

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Address, THE EXPERIMENT STATION,
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Fig 1—Pima cotton at the Tempe gin, Salt River Valley

A STUDY OF MARKETING CONDITIONS

in the

SALT RIVER VALLEY, ARIZONA

BY J. H. COLLINS,

Investigator in Market Surveys, Bureau of Markets, United States Department of Agriculture.

INTRODUCTION

That portion of Maricopa County, Arizona, known as the Salt River Valley, since the completion of the Roosevelt Dam in 1911, has enjoyed a position of considerable prominence among irrigated districts of the Far West. It would appear that a commercial study of the agriculture of this area should be of major importance to those interested in western irrigation agriculture. The investigation outlined in this report while ostensibly embracing Maricopa County in its entirety has been confined for obvious reasons to the intensively farmed district within the County. Since more than four-fifths of the irrigated area lies in the Valley of the Salt River, it has seemed advisable to refer to the entire area under consideration as the Salt River Valley. This decision has been strengthened by a realization of the fact that this terminology carries a greater significance outside the State of Arizona, where persons who have heard of this Valley do not readily connect it in their minds with the less well known County of which it is a part. The irrigated area lying below the confluence of the Salt and Gila Rivers known as the Buckeye and Arlington Valleys, together with scattered areas in outlying portions of the district, comprising a total of about 30,000 acres, are often considered as not belonging to the Salt River Valley proper. The distinction, however, is a rather fine one, and since the agriculture of these areas belongs essentially to the entire district it has seemed best to avoid confusion by ignoring unnecessary distinctions. The term Salt River Valley as used in this bulletin refers to all lands which, because of topographical relations, would naturally be a part of the entire Valley and should be distinguished from the Salt River Project whose lands constitute only a portion of the Salt River Valley and are watered exclusively from irrigation works constructed by the United States Government.

Several interesting economic conditions make a study of marketing conditions in the Salt River Valley a matter of keen interest to the student of the commercial side of agriculture. This compact and fertile Valley affords an excellent study of a clearly defined agricultural unit. Surrounded on all sides by desert and with no similar area of any consequence within more than 200 miles, the Salt River Valley is practically an independent unit. Another important fact is that for the area embraced, this Valley has a more diversified form of agriculture than can be found in most other areas of like size. Records compiled for the years 1916 and 1917 show that more than 16 crops were produced with aggregate acreages exceeding 500 acres each. This classification takes no recognition of the varied nature of the livestock interests of the Valley and does not take into consideration other forms of agricultural wealth. The farms of the Salt River Valley are tilled by farmers from all parts of the world. Many of these farmers are comparatively recent additions to the population of the Valley and hence the communal and commercial interests of the producers have not yet become fused so that community action is the regular and accepted procedure. Then, too, it must be remembered that the commercial problem has only recently come to the front as such. In this respect the Salt River Valley differs materially from many of the irrigated districts of California. The latter state has long been a region of surplus production and the problem of finding an outlet for products not saleable locally has been for some time a pressing one for the California grower. The result has been that many of California's problems have been worked out through years of experience, and most of the older communities in that state have established a proper commercial procedure. This procedure is now in the formative stage in Arizona.

While irrigation by white settlers in the Salt River Valley dates back to about 1867, the district is comparatively new in commercial development. The advent of Federal assistance in 1902-1904 marked the beginning of the present regime in the Valley. The Roosevelt Dam was completed in 1911, and at that late date came the emergence of the Salt River Valley as an established region of surplus production, together with the problems attending such a changed condition.

Many of the newer order of farmers came from the humid districts of the East and Middle West and found themselves facing conditions with which they had had little or no previous experience. The period of expansion immediately following the opening of the Government Project was largely a period of rearrangement so far as agricultural plans and activities were concerned. The natural questions which first arose in the minds of Valley farmers concerned themselves with the most profitable form of agriculture to be adopted. Fertile soils and excellent climatic conditions have operated to give full sway to a period of what might be termed experimental research on the part of producers and State and Federal experiment stations. Having thoroughly established the fact that a great range of activity is permitted under natural conditions, it has been gradually becoming more apparent that future profits must lie in a coordination of activities and a systematizing of the entire agriculture of the Valley. The present era is therefore one of readjustment and to that extent has made a commercial study of interest and importance.

This study of marketing conditions was made during the crop season of 1917 and the recommendations made in this bulletin and the conclusions reached have to do with conditions as they exist. It has been necessary in some cases to overstep the boundaries of a survey devoted purely to marketing problems. It often has been found impossible to segregate the financial and commercial problems from other factors which have entered into a consideration of the farmers' returns for products sold. There has been, therefore, no attempt to eliminate those extraneous matters which at first glance might not appear pertinent to the value of the work. A commercial viewpoint of the entire problem has necessitated a complete survey of the field.

Geography and Topography In view of the fact that the geographical location of Maricopa County and the internal arrangement of the irrigated territory within this County have a bearing on the commercial phases of agriculture, it seems best briefly to review these conditions.

Reference to a map will show that Maricopa County is located in the south-central part of Arizona. The irrigated areas which collectively constitute the Salt River Valley, range in altitude from about 950 feet to 1250 feet. The average altitude is about 1100 feet.

The main body of irrigated land is irregularly oblong in shape and extends from the Agua Fria River on the west to the Eastern Canal which lies east of Gilbert and Chandler. The approximate total length of this oblong district is about 36 miles, while its average width is about 12 miles. Another strip of land lying below the confluence of the Salt and Gila Rivers with an average width of three miles and extending for about 20 miles along the Gila River constitutes the Buckeye and Arlington Valleys. The main body of irrigated land is roughly divided into two nearly equal parts by the Salt River. Phoenix, the commercial center of this territory is also the geographical center of the irrigated district. The entire district may be divided arbitrarily into several groups based on sources of water supply. The Salt River Project comprises an area of about 205,000 acres, constituting by far the largest individual unit in the Valley. Another area of about 21,000 acres lying immediately south and west of Tempe also receives water from canals constructed by the Government, but the land owners in this territory are not members of the Salt River Valley Water Users' Association. Their water supply is based on old water rights existing before the inauguration of the Salt River Project. Water is brought to this land by Project canals, the land owners through a co-operative association paying a certain annual rental for the use of these Project canals. Another district of about 2500 acres lying north and east of Mesa and known locally as the Lehi District is also watered from Project canals on approximately the same basis as are the lands operated under the Tempe rights. It thus will be seen that a total of about 230,000 acres consisting of (1) the Salt River Project, (2) lands operated under the Tempe rights, and (3) the Lehi District, are all irrigated from water impounded by the Roosevelt Dam and furnished through canals constructed by the Government. The Buckeye and Arlington districts referred to in a previous paragraph, together comprise about 20,000 acres and are watered from the Gila River. As a matter of fact, a large portion of the waters flowing through the channel of the Gila River in this territory consists of seepage and surplus waters from the irrigation of the larger Valley above and does not really constitute the normal flow of the Gila River from regular sources. An area which lies in the delta between the New River and the Agua Fria, and northwest of the Salt River Project is known as the Marinette District. This land derives its water supply from the flood waters of the Agua Fria supplemented by water pumped from wells during periods when the gravity flow is not sufficient adequately to supply this territory. A scattered acreage which lies southeast of the Salt River Project in the vicinity of Higley, comprising an aggregate acreage of about 2000 acres, is watered by pumps. A recent development immediately south of Chandler has brought about 5000 acres under irrigation through the installation of pumping machinery. An additional acreage is being reclaimed in this district. It will be noticed that by far the greater part of the farm land is irrigated from the gravity flow and that pumping or supplementary pumping cares for a relatively small percentage of the total area being farmed.

There seems to be no particular specialization of crops in any of the above mentioned districts which collectively constitute the Salt River Valley. However, a study of crop conditions for the season of 1917 leads to the conclusion that for reasons other than the arbitrary division of territory according to water supply, there is a rather ill defined specialization. For instance, it is found that while alfalfa hay is shipped in commercial quantities from all points in the Valley, there is a more pronounced development of this particular industry on the south side of the Salt River Project. Shipments from the towns of Mesa, Gilbert and Chandler constitute more than 50% of the total hay shipments from Maricopa County. Citrus and deciduous fruits while produced in scattered acreages over the entire Valley are produced more extensively on the higher lands of the north side. In a strip of territory extending from Glendale to Scottsdale and lying near the Arizona Canal, we find the greater portion of the fruit development in the Salt River Valley. Cantaloupes are produced in fairly restricted areas around Glendale, Mesa and Phoenix. Long staple cotton, while universally grown throughout the entire territory, probably finds its greatest development on the south side. The grain acreage is scattered but there is a more or less marked consolidation of the grain producing territory in the western part of the north side and on the south side in the vicinity of Tempe. Alfalfa seed production is largely confined to the Buckeye Valley. Potatoes are grown in commercial quantities only in the western and northwestern sections of the north side. Watermelons are produced around Phoenix and Glendale. All this crop specialization, however, has very little to do with the arbitrary division of the territory according to water supply. Climatic and soil conditions in most cases have been the deciding factors in the cropping scheme.

CLIMATIC CONDITIONS The climate of the Salt River Valley is marked by extremes in both the daily and annual range of temperatures with very little rainfall and a small amount of humidity. The summers are long and hot while the winters are mild and dry with only occasional freezing temperatures. Records of the Weather Bureau at Phoenix show that an average of 267 days in the year receives more than 80 per cent of the possible amount of sunshine. Data compiled by the Phoenix office of the Weather Bureau shows that for the period from 1905 to 1916 the lowest recorded temperature was 16° while the highest was 117°.

The growing season is longer than in almost any other irrigated district. Reports of the United States Weather Bureau show that the growing season, that is, the season between killing frosts, is approximately ten months at Phoenix.

There is a fairly wide variation in extreme winter temperatures in certain portions of the Valley. The areas having the highest altitudes lying near the foothills are of course less subject to frost. In fact, the frost risk in certain of these favorably located districts is so small that citrus groves have been a decided commercial success. There is no area in the entire Valley which can be considered as strictly frost proof but the risk in what might be termed the citrus belt is not too great for commercial success. In general, climatic conditions in the Salt River Valley have admitted of a very great diversification of production. Practically all of the staple crops which have ever been grown under irrigated conditions can be produced in this section successfully. The extreme length of the growing season coupled with the hot summers and mild winters have permitted the growing of certain important special crops whose success is dependent upon climatic conditions. There is perhaps no more favorable location in the United States for the production of long staple cotton. Dates bear abundantly and many of the finer varieties seem to find the Salt River Valley a natural habitat. Olives, figs and citrus fruits are successful by reason of the comparatively mild winters.

An annual rainfall of slightly more than eight inches is distributed rather irregularly throughout the year, the least occurring in April, May and June and the heaviest in July. Rains occur occasionally during the winter months. The comparatively small rainfall makes it possible to produce and cure alfalfa hay of excellent color. Occasional unexpected rains during the spring and early summer months cause some damage to both hay and grain. It so happens that the rainiest season of the year is coincident with the harvesting period for cantaloupes. The problem is not as serious practically as it appears from casual observation. There have been, however, some decided losses of melons caused by unwelcome rainfall. A rain during the cantaloupe picking season may result in many of them cracking open in the field and considerable quantities of those which appear superficially to be undamaged do not stand up well under shipment. Rainy periods, even during the month of July, are usually far enough apart so that most of the merchantable melons can be safely loaded for market. The dangers of unexpected rain during the summer months have deterred many apricot and peach growers from attempting to dry any considerable portion of their output. The condition of the dried fruit market, however, during the 1917 season induced many growers to try drying their fruit and in general the results were satisfactory. It is possible that the dangers attending such a procedure have been magnified in the minds of the growers and it is probable that if market conditions warrant there will be an even greater quantity dried during succeeding seasons.

SOIL CONDITIONS There are in general about six types of soils existing in relatively large areas throughout the agricultural district in the Salt River Valley. The Maricopa Gravelly Loam lies near the outskirts of the Project and occurs in largest quantity around Peoria and along the Arizona Canal in the vicinity of Camelback Mountain. Most of the citrus development in the Valley occurs on this type of land. The Maricopa Sandy Loam constitutes the greater portion of the soil on the south side surrounding Mesa and Gilbert. There is also a considerable area of this soil on the north side adjoining the Maricopa Gravelly Loam. A slightly heavier soil known as Glendale Loess constitutes nearly one-third of the soil area on the north side of the Salt River Project and lies in the center of the north side. The Maricopa Loam, a still heavier loam soil, lies in irregular patches north and west of Phoenix and south of Tempe. A relatively inconsiderable area of clay loam and some heavy adobe soil which lies immediately around Phoenix and just south of Tempe constitute the principal other types of soil in the Valley.

This variation in soil types has been reflected more or less in the character of the crops produced on those soils and has resulted in some crop specialization on soil types particularly fitted to certain crops. For example, most of the commercial potato acreage lies in the lighter loam soils west of Glendale. The same territory also produces most of the bean crop of the Valley. Cotton, grain and alfalfa are largely grown irrespective of soil types, while it appears that dates do well on soil which is too alkaline to produce other crops. There are certain districts in the Valley having alkaline soils, but the greater portion of the Valley is free from this defect.

TRANSPORTATION FACILITIES. Present facilities for crop transportation are adequate, although the Salt River Valley is not reached by the main line of any railroad. The Arizona Eastern, which connects with the main east and west line of the Southern Pacific system at Maricopa, and a branch of the Santa Fe System, known as the Santa Fe, Prescott and Phoenix Railroad, which joins the main line of the Santa Fe at Ash Fork, Arizona, connect the Valley with outside markets. While the advantages of a main trunk line are obvious the transportation problem for this district is not an acute one because of this lack.

The Arizona Eastern Railway being a subsidiary property of the Southern Pacific Company, and the Santa Fe, Prescott and Phoenix Railroad being a part of the Santa Fe System, the Salt River Valley is furnished the same class of service as is furnished elsewhere throughout the country by these two systems. In so far as concerns the transportation of perishable commodities under refrigeration from distant markets, the Pacific Fruit Express Company furnishes the necessary cars for the Arizona Eastern, and the Santa Fe Refrigerator Despatch Company furnishes the necessary cars for shippers on the Santa Fe, Prescott and Phoenix Railroad. In its efficiency the service is the same as that furnished elsewhere in sections served by these refrigerator car lines. An interurban electric line 10 miles long extends from Phoenix to Glendale and traverses an important fruit and trucking belt. Considerable quantities of fruits and vegetables are transferred from this line to the steam lines at Phoenix and Glendale. The total railroad mileage within the irrigated district alone is about 100 miles. One principal line enters the Valley at Marinette in the northwest corner of the main irrigated district and passing through Peoria and Glendale terminates at Phoenix. The other carrier enters the irrigated district at a point about 9 miles south of Tempe and also has a terminus at Phoenix. Branches of the latter road also extend from Phoenix westward to Hassayampa through the Buckeye Valley and Eastward through Tempe and Mesa, to points beyond. At Mesa a further subdivision occurs, one line extending south through Chandler and passing out of the irrigated territory at the edge of the cotton district, while the other branch extends in a southeasterly direction through Gilbert and leaves the irrigated territory in the vicinity of Higley. The most remote points in the Valley are about 12 miles from transportation facilities, while the average distance from farm to loading station is from 4 to 6 miles. There are within the farming district about 10 billing stations and about 15 non-agency stations, or a total of about 25 loading points for farm products. Refrigerator cars are iced at Mesa, Phoenix and Glendale. Icing facilities have been sufficient in the past for refrigerator shipments from Phoenix and Glendale, but during the 1917 cantaloupe season icing equipment at Mesa was taxed to capacity during rush periods.

In so far as the Arizona Eastern Railway is concerned, it never has a solid train load of cantaloupes ready to move at any one time. It keeps in touch with the despatcher's force on the main line of the Southern Pacific and whenever it is possible for an eastbound train to pick up any cantaloupes at Maricopa, the requisite number of cars are sent down from Mesa to Maricopa in an "extra" for that purpose.

Freight rates on agricultural products are still more or less in process of readjustment and although complete tariff schedules are in effect, there doubtless will be some revision in the future. Surplus production of certain crops is a relatively new phase of agriculture in the Salt River Valley and it may take some time for the carriers to adjust themselves to changing conditions. There doubtless will be more favorable commodity rates offered on certain products, notably potatoes, when the acreage becomes of sufficient importance to constitute a valuable source of income to the railroads.

LAND VALUES In general it may be said that prices for good farming land in the Salt River Valley are moderate when consideration is given to the various factors which influence land values. The fertility of the soil in this territory would naturally have a decided influence on prices. Another factor which has considerable commercial significance is the long growing season. Since the completion of the Roosevelt Dam, the question of an adequate supply of water for most of the land in the Valley has been settled, and water-right litigation has been reduced to a minimum. There has been, of course, a considerable rise in values since the completion of the Salt River Project. The extension of the area which could be devoted to the production of citrus fruits and olives and the success which the long staple cotton growers have attained during the past season have had a tendency to increase general farm prices. Irrigated land ready for crop sells at from $100 to $500 per acre. The average price for good land, however, will range from $150 to $200 per acre. Under the Reclamation Project the water cost is to be repaid the Government on liberal time arrangements. It will be seen from this statement that livestock production, dairy farming, and general farming can be successfully carried on without the necessity for carrying too heavy an overhead charge for land rentals. It seems altogether likely that livestock production, dairying and general farming will continue to be the most important forms of agriculture in the Salt River Valley, although the long staple cotton industry has come into distinct prominence during the 1917 season. At present land prices are not sufficiently high to prohibit diversification. This is evidenced by the fact that there is great diversification throughout the entire Valley. The Salt River Valley has gained immeasurably from the fact that land values have not been inflated unduly and it thus has been possible for the farmer to have a wide latitude in his attempts to determine the most profitable crops to produce.

STORAGE FACILITIES Storage facilities for farm products are largely in the hands of private individuals. There are practically no farmers' co-operative warehouses or storage in this district. This is significant in view of the fact that large quantities of farm products are produced which would normally go into storage for periods ranging from one to six months. Commercial storages for grain are operated by millers, seed merchants and others whose business is the buying and selling of grain. These warehouses have individual capacities ranging from 3,000,000 pounds to 8,000,000 pounds. The total storage capacity of the commercial grain warehouses operated by the seven principal grain handlers is approximately 65,000,000 pounds. There is only one grain elevator in the Valley, the balance of the storage space providing only for grain stored in sacks. Other elevators are now building to fill present deficiencies. Estimating the average yield of barley to be 1,800 pounds per acre and the average yield of wheat to be 1,500 pounds per acre, it will be seen that present storage space is adequate to care for a grain crop from about 40,000 acres. Any sudden increase in acreage above that noted would necessitate farm storage or the building of additional warehouse space. There are four grain warehouses in Phoenix, two in Mesa, four in Tempe and two in Glendale. Grain producers in the Buckeye District are farthest removed from storage facilities. It is difficult to estimate the quantities of grain normally stored on the farm, but at most it is a relatively small percentage of the total crop. There is need for adequate grain storage space at some point in the Buckeye Valley. It also would save considerable hauling if a grain warehouse should be built at some point about six or seven miles west of Phoenix on the railroad which serves the Buckeye Valley.

The usual charge for grain storage is five cents per 100 pounds for the season. One of the disadvantages of the public storage to the small grain producer who has good grain, is that unless he has a reasonably large quantity to store, his grain is stacked with that of other farmers, and in case of withdrawal for sale he might have returned to him grain other than that which he placed in storage. The large grain producer can usually arrange at the warehouse to have his grain kept in a separate stack, which can be inspected by buyers if necessary.

Hay warehouses are located at Gilbert, Peoria, Glendale, Phoenix, Tempe and Mesa. Only a relatively small proportion of the hay produced in the Salt River Valley is baled and placed under cover. There are a number of large hay sheds owned by some of the larger alfalfa growers and capable of storing relatively large quantities of baled hay on the farm. Most of the hay crop in the Valley, however, is stacked in the open and either fed loose from the stack or baled later for shipment. There are no covered storages other than those on the farms which are available for the hay producer. While, of course, the cheapest method of storing hay is the stack method, it is evident that additional hay storage space for good baled hay would be profitable for the farmers. Cold storage space for perishable commodities is available in Glendale, Phoenix and Mesa. Practically all of the space which is utilized for storing of dairy products or fruits and vegetables is used by local creameries or wholesale dealers. Storage by farmers or farmers' associations is practically unheard of.

At the present time the storage question is one which should be given attention. During the average season the farmer who stores his grain at harvest time and sells it at a later period often benefits from such a practice. The same statement applies to hay. The 1917 season was, of course, an exceptional one, but the fact remains that hay prices at the time of the first cutting of alfalfa averaged around $12, while October prices approximated $25 per ton. Certain farmers who held part of their surplus for a later market have nearly doubled their income by such procedure. This, of course, brings up the question of the advisability of building additional hay storage space and there seems little doubt that considerable additional space can be utilized by the producers of high grade baled alfalfa hay.

INDUSTRIES ALLIED WITH AGRICULTURE While the Salt River Valley is essentially unorganized for either production or marketing, there has been built up a fairly permanent series of allied industries which naturally accompany any large agricultural enterprise. In 1917 there were three creameries and one evaporating plant to care for dairy products; one canning plant and one sugar factory (both of which were inoperative during 1917); four flour mills to care for grain products; eight cotton gins and one cotton oil mill to care for cotton products; and two pickling plants for olives. During the 1916 season four creameries instead of three were in operation, but at the time of writing three creameries and one evaporating plant were handling larger quantities of butter fat than had been handled when the fourth creamery was in operation. A second evaporating plant was in process of construction during 1917. The total number of cotton gins in 1916 was five.

Some interesting changes have occurred during the five years ending in 1917. During this period there was a very rough and unsystematic rearrangement of agricultural activities. Dairying gradually has been coming into its own as one of the primary sources of farm wealth in the Salt River Valley. This gradual growth of the dairy industry appears to have been merely a healthy development of a profitable industry. Long staple cotton prior to 1917 occupied a comparatively modest place in the general planting scheme. The sudden increase in demand and the success attending the experimental growing of the two leading long staple cottons in the Salt River Valley, caused a phenomenal increase in the acreage planted in 1917. The production of market hay has fluctuated from season to season, while the total acreage in alfalfa for the five years ending in 1917 was fairly constant. During the growing season the farmer usually has had his choice of selling large quantities of his hay for shipment or feeding it to stock on the farm. The condition of the baled hay market usually determines whether or not any considerable quantity of hay is shipped. Grain production has varied directly with the market price at harvest time. A season of low prices has almost invariably been succeeded by a period of decreased acreage. The livestock industry has been a fairly constant quantity, although war demands have curtailed the normal increase which might be expected along this line. The most notable fact concerning the livestock industry in 1917 was the great decrease in the number of hogs over previous seasons. Data compiled by the United States Reclamation Service shows a decrease on the Project in 1917 of about 60 per cent in the total number of hogs.

It is not strictly correct to state that there has been no community action in the Salt River Valley. There always has been a realization of the fact that community effort is desirable, but activities up to the time of writing have been sporadic and not part of any organized plan. Two types of organization have been attempted in the past. A few efforts have been made to bring the growers of certain communities together for co-operative selling. In some instances these efforts have met with some measure of success, but in general such organizations have failed through lack of strength. Another type of organization, designed not especially for marketing, but for general community betterment, has been tried out with fair success. A number of Farm Improvement Associations have been organized a few years at various points in the Valley. These, together with other farmers' organizations, are being made the basis of a County Farm Bureau, with wide and useful functions, but not developed at this time as a special marketing organization.

The existence of these various community groups is desirable chiefly because they can be revived temporarily if necessary and made to serve as nuclei for concerted action. In many cases, they constitute the only tangible bond which unites the producers of a community and it has been possible in the past to make use of their existence to reach the individual through his connection with the association.

As might be expected, attempts also have been made to organize producers along more strictly commercial lines. During the 1917 season there were in existence three or four such farmers' marketing associations. Their membership at best is limited and their existence is largely due to the efforts of a few individuals. Practically all these organizations have been built up entirely around the ideas of their farmer organizers, who have not had the benefit of expert advice or counsel in planning the organization. A few have remained in existence for periods ranging from one to three years, while some have gone through various forms of reorganization and are still in existence. In all cases, there has been a definite and decided problem to solve and the organizers have gone at the solution of this problem in the most direct way. The goal to be attained has been always prominently before them, but it is unfortunate that their plans have not been definite enough in some instances to secure desirable results. With one or two exceptions, these farmers' marketing associations are such only in name. They are weak because their individual and collective obligations have been ill stated in their constitutions and by-laws, and such contracts as have been entered into have not been sufficiently binding to stand up under adverse conditions. As might be expected, also, few of them have made adequate provisions for proper financing.*

One or two small marketing associations, however, stand out from the rest so far as strength and stability are concerned. The association which handled practically all of the commercial lettuce crop of the Valley in 1917 was well organized and well managed in many respects. The strength of this organization rests largely upon the fact that they have narrowed their field of operations to certain specific purposes and have not attempted to handle more than could be satisfactorily handled through an association which necessarily had a limited membership. The citrus growers' association has never adopted a systematic selling plan. This is the one important inconsistency in connection with this organization. The association has been, however, the prime factor in holding the citrus interests together and for this reason alone can be said to have fulfilled its mission.

SPECIFIC MARKETING CONDITIONS

GRAIN The Salt River Valley is not a region of surplus grain production. The principal grains are barley, milo maize, wheat, oats and corn. The latter two are grown in comparatively small quantities. The annual acreage planted to grain is not a uniform quantity from season to season. Prevailing market prices determine very largely the annual acreage which is devoted to the production of small grains. A great reduction in the quantity of wheat produced in 1917 was largely caused by the fact that most of the 1916 crop was sold by producers at $1.65 per 100 pounds, which made this crop comparatively unprofitable.

Yields vary with the season and with the individual. Barley will average about 1,800 pounds to the acre, and wheat about 1,500 pounds. More than 90 per cent of the wheat is Early Baart, a semi-hard wheat which does well in this section. A small quantity of California Club wheat is also produced. Little effort has been made to encourage the production of well matured, clean grain. One weakness in the present system of marketing is the fact that the farmer whose grain is dirty receives practically the same price as the farmer who has been careful to produce a high class, marketable product. This has practically placed a premium on slack methods of harvesting and has not encour-

* U. S. Department of Agriculture, Bulletin No. 541, Co-operative Organization By-laws, by C. E. Bassett and O. B. Jeeness, 1918.

aged the production of good grain. Individual grain acreages are comparatively small. Material assembled by the Arizona State Council of Defense and the County Agricultural Agent in 1917, covering 476 typical grain fields with a total acreage of 21,420 acres, shows that 458 of these fields, comprising 16,880 acres, were each 120 acres or less in extent.

Most of the grain is sold by the farmers at harvest time to local buyers. Millers, wholesale grain dealers and seed merchants buy over 90 per cent of the commercial output. Warehouse space can, of course, be secured for commercial storage, but, as a rule, most of the grain stored in these warehouses has already been purchased by the warehouse owner. Buyers owned about 80 per cent of the grain stored in 1916. It is significant, however, that in 1917 approximately one-half of the grain in storage on September 1 was owned by farmers. The following table shows the quantity of wheat, milo maize, barley and flour shipped into the Salt River Valley in 1916 and 1917 from points outside of the State:

TABLE I GRAIN AND FLOUR SHIPPED INTO THE SALT RIVER VALLEY

Commodity	*Carloads, 1916*	*Carloads, 1917 (To October)*
Wheat	4	7
Barley	30	25
Milo Maize	18	13
Flour	101	91

It will be noted that the quantity of wheat imported is negligible, while fair quantities of milo maize and barley are brought in from California. On the other hand, practically no grain or flour is shipped from Valley points to points outside of the State. It will be seen that the local markets of the Valley and State consume much more grain and flour than is produced in the Salt River Valley. The two principal problems for the Valley grain producer are those relating to seed and prices. No systematic attempt has been made to provide seed to grain growers at reasonable prices. Some seed is brought in from California, Kansas and the Northwest, and still larger quantities are supplied from local sources. Many grain growers dispose of practically their entire crop at harvest time and then re-buy at advanced prices for the next season's planting.

Strange as it may seem, a reasonable price basis for grain has never been established between the producer and the buyer. The customary condition of the local wheat market emphasizes this lack. Every year millers and grain wholesalers base local prices on the price for wheat at terminal market points. The growers have always taken the stand that inasmuch as the Salt River Valley is not a district of surplus production, and practically no grain or flour goes outside the State, the local market prices should be the prices at terminal market, plus the freight necessary to bring grain into the Valley. There has been no attempt on the part of the two factions to compromise on this matter and neither side has cared to make a clean-cut statement of the issues at stake. It will be noted that while comparatively little wheat is annually imported, there are considerable quantities of flour shipped into the Valley, largely from Kansas points. The contention of the farmers is that if the Kansas miller can afford to buy wheat at terminal market prices, convert it into flour, pay the freight on this flour to Valley points, and sell this flour in competition with that manufactured locally, the local miller should be able to purchase wheat on the basis of terminal prices, plus the freight to Valley points and operate as profitably as the Kansas miller. The growers, however, fail to recognize the fact that most of the flour so imported is hard wheat flour, while much of that manufactured from Valley wheat is milled from semi-hard wheat. There is an active demand for both classes of flour in Arizona, but there is a price differential of 40 cents to 50 cents per 100 pounds in favor of the hard wheat product. The local miller thus has an argument which is more or less sound. It would appear from a careful investigation of the entire situation that the proper price for local wheat should lie somewhere between the two price extremes mentioned. A fair scale of prices would encourage grain production in the Salt River Valley greatly and by increasing the volume of their business should enable grain handlers to operate with no reduction of annual profit, but on a slightly smaller margin of profit per 100 pounds of grain handled. As matters now stand, it is annually an open question as to what will be the price basis for Valley grain.

Four flour mills were in active operation in the Salt River Valley in 1917. The daily flour output of each of these mills approximated 50 to 60 barrels per 11 hour run. The two Phoenix mills consolidated near the close of the 1917 season. Another Valley mill was destroyed by fire and will be rebuilt on a modern scale in time to care for the 1918 crop. Hence, there will be three large flour mills in operation during the 1918 season. Less than one-half of the flour milled in the

Valley is sold at points within the Valley proper. The remainder is shipped largely to mining towns throughout Arizona.

Over 90 per cent of the grain is handled in sacks. The labor cost of sacking this grain, the cost of the sack itself, and unnecessary labor charges for extra handling are of course reflected in the price received by producers. One of the Valley mills now has an elevator arrangement for handling bulk grain, while another mill is building a large modern elevator and will encourage its patrons to furnish bulk grain. The handling of grain in sacks is such an expensive operation that there is little excuse for its continuance in this district.

It does not seem practicable or feasible to urge the formation of a co-operative grain marketing organization. The chief drawback is that individual acreages vary greatly and the membership of a grain marketing association would change so appreciably from season to season that it would not be possible to introduce the necessary flexibility into the plan of organization. There should be concerted action, however, by grain growers looking toward better grading of their product for market, more economical methods of handling the grain and better understanding with the buyers as to prices.

ALFALFA In common with other irrigated sections of the West, the Salt River Valley produces large quantities of alfalfa. Prior to 1917 approximately 50 per cent of the irrigable territory in the Valley was devoted to alfalfa. In general, this alfalfa acreage is utilized by producers for pasture, for commercial hay production and for seed. It is difficult to estimate the total acreage used annually for pasturing livestock. Many fields are devoted very largely to this purpose. A still larger area is pastured occasionally between cuttings. When it is remembered that the Valley is a very important dairying district and that fattening range stock for market is also an important phase of agriculture, it is possible to appreciate the value of alfalfa pasture to Valley farmers.

This district has been for a good many years a region of surplus hay production. Certain districts, notably near Gilbert, Peoria and Chandler, produce large quantities of hay for commercial shipment. This hay is field-baled and usually moves to market shortly after harvest. The following table shows the number of cars of hay shipped by stations from the principal Valley points in 1916 and 1917:

TABLE II CARLOADS OF HAY FORWARDED IN 1916-1917

Station	Carloads 1916	Carloads 1917 (To October)
Peoria	661	597
Glendale	475	503
Phoenix	457	632
Tempe	262	290
Mesa and Gilbert	1781	1877
Chandler	563	565
Total	4199	4464

It will be noted that there is a heavy movement of hay from certain sections of the Valley. Yields vary with soil and cultural conditions, but average 5 tons per acre. Little or no attempt has been made to grade alfalfa hay. The careless producer secures nearly as good prices as the farmer who has gone to some trouble to put up a superior product. Johnson grass is a troublesome pest in some sections of the Valley and where it has taken hold it constitutes the chief foreign element in the hay. Weed seeds carried by the wind and irrigation water have caused the hay in certain fields to be of inferior grade. Climatic conditions are such that hay of an excellent color can be put up if care is exercised.

Large quantities are shipped to the mining centers in Arizona and New Mexico. Jerome, Globe, Douglas, Bisbee, Nogales, Naco, Fort Huachuca and Prescott, in Arizona, and Hachita, Deming, Lordsburg and Gallup, in New Mexico, use large quantities of Salt River Valley hay. Much of the hay billed to Naco, Douglas and Nogales finds its way into the mining districts of Northern Mexico. During the past two years there has also been a considerable movement of hay from Valley points to El Paso for diversion to points across the border into Mexico or to smaller towns in Western Texas. In 1917, owing to the drought which prevailed in Western Texas, hay from the Salt River Valley was shipped as far East as Houston and San Antonio. As a matter of fact, Western Texas is usually an excellent market for considerable quantities of alfalfa hay from the Salt River Valley and other irrigated valleys in the West.

Hay prices to producers have varied greatly in past years. Data compiled by the United States Reclamation Service indicates that prices have ranged as low as $6 per ton at the farm. The average price paid the farmer for hay in 1916 ranged from $12 to $15 per ton. Prior to the first cutting in 1917, some growers were contracting with buyers for hay delivery at about $12 per ton. With an extraordinary demand becoming manifest early in the season, the price rose rapidly,

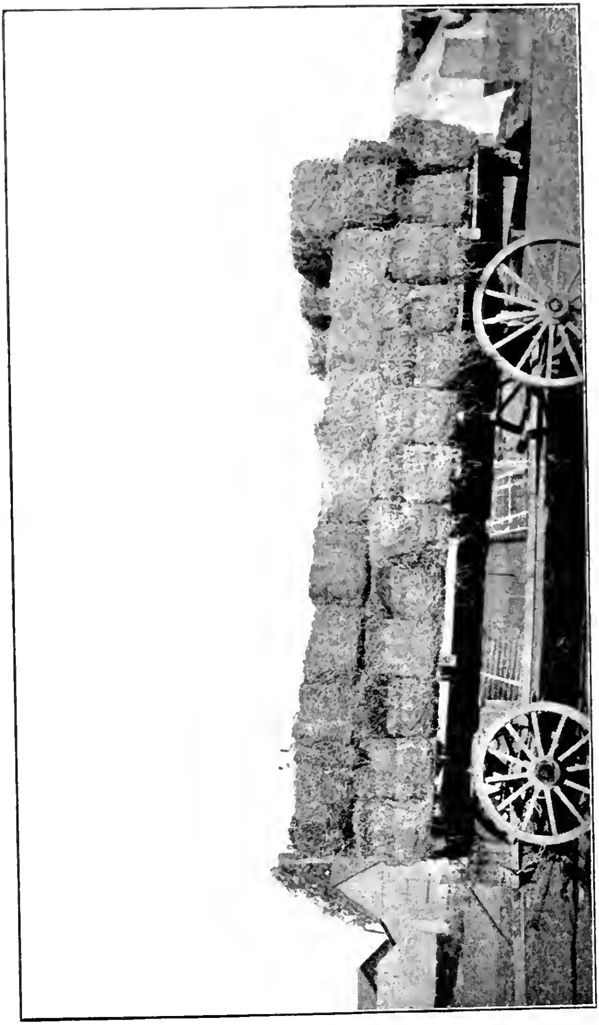

Fig. 2—Poorly graded alfalfa hay.

averaging about $18 in the middle of the season and closing in December at approximately $30 for good baled hay delivered to the loading platforms.

Practically all the hay sold from the farm is purchased by local buyers who in turn re-sell to their customers in other parts of the Southwest. About five local firms ship approximately four-fifths of all hay which goes out of the Valley. Only in exceptional cases is there direct sale from producer to consumer. With the local market largely controlled by a very few firms, the hay producers of the Valley have in many cases doubted whether or not a real competitive market existed. On several occasions large hay producers in the Valley have attempted to negotiate directly with buyers in nearby mining towns for direct sale. Usually they have found themselves unable to make such sale because they were unable to guarantee the grade of hay which would be delivered. The buyer in practically all cases preferred to deal with local dealers with whom he had established business relations and upon whose representations he could rely. The farmer has had no means of assuring buyers that he could deliver hay which was up to specifications. The complete lack of any system of local inspection has therefore entirely precluded the possibility of direct selling. A system of local hay inspection, whereby the producer could utilize the services of a competent hay inspector at a nominal fee would enable the farmer to place his hay on the market on equal terms with the large hay shipper and thus save for himself the speculative profits which are absorbed by local hay handlers.

Very few farms have hay sheds which are sufficiently large to care for any considerable quantities of baled hay. It usually is necessary for the farmer either to stack his hay in the field or to bale it and sell at once. Farm storage for baled hay is necessary if producers are to get the benefit of seasonal price changes in the hay market.

Very small quantities of alfalfa seed are produced in the main body of irrigated land in the Valley. Most of the alfalfa seed which is produced in this territory comes from the Buckeye Valley. Even in this district alfalfa seed production is usually incidental to hay production. If seasonal and price conditions are satisfactory, growers in this district allow one cutting of alfalfa to go to seed, harvest the crop and then again resume hay production. As might be expected, the annual production of seed varies greatly. During some seasons it is difficult to secure a good crop of alfalfa seed, while in other seasons the alfalfa seed crop is the most profitable one of the season. The alfalfa seed chalcis fly has been an important factor in reducing yields of seed in the Buckeye District in past years. During some seasons the damage is relatively small. In other years from one-third to one-half the crop has been destroyed. The seed is of fair quality and is usually clean. Practically all of the crop is sold to a few local buyers who re-sell the seed in other parts of the Valley and also do some shipping to outside points. The high prices paid for alfalfa hay in 1917 resulted in a relatively small quantity of seed being produced, but should conditions be reversed another season, seed would doubtless again become an important feature of alfalfa production in the Buckeye Valley. Most of the alfalfa seed is sold immediately after harvesting. It has been found that at this time there is little active competition from other districts and prices have usually been more satisfactory than those prevailing a few months later. There is no adequate provision for the storage of alfalfa seed. Some seed doubtless could be stored on the farm, but few farms have proper storages for this commodity. It does not appear, however, that this is a serious problem, because the producers are anxious to sell their seed immediately.

Dairy Products The dairy industry is one of the most important forms of specialized agriculture in the Salt River Valley. The natural adaptation of the Valley to the production of alfalfa, the large grain yields which can be secured and the possibility of growing large quantities of practically all desirable dairy feeds, coupled with mild winters prevailing in this section, make the Salt River Valley an excellent district for dairying. The national census for 1910 credited Maricopa County with 12,660 dairy cows out of a total of 28,862 in the entire State of Arizona. The same authority states that in 1909 2,357,753 gallons of milk, 22,004 gallons of cream, 626,583 pounds butterfat were sold. The annual report of the United States Reclamation Service states that in 1916 there were 48,628 dairy cattle on the Salt River Project alone, while the same authority states that in 1917 this total had risen to 50,975 head. In addition to stock on the Project proper, there is probably one-half as much again in other parts of the Valley. It should be understood, however, that not all of these were milking cows at the time the report was issued. The approximate number of milking cows in the entire Valley in 1917 was probably about 50,000.

Most of the dairy herds of the Valley are of Holstein-Friesian stock. Practically all other standard breeds of dairy cows are represented, however. The 1917 project report of the Reclamation Service indicates that 21,460 cows whose owners report complete returns brought in an average of $173,375 per month. This shows an average of $8.07 per cow per month and probably is a representative figure for the entire Valley. As might be expected in a district where extensive development of the dairy industry has been fairly recent, there is a considerable amount of inferior stock. At the same time, there are some very fine individual herds and the general character of dairy stock is improving each year. A comparatively sudden interest in silo building was manifested in 1917, and has had a most beneficial effect on the entire dairy industry in the Valley. About 17 silos were in existence in the Valley early in 1917. By midsummer this number had increased to about 40 and in November 45 silos were in use and 3 or 4 were in process of construction.

The dairy industry in the Valley has built itself largely around the problem of supplying milk and butterfat to creameries and evaporating plants. Considerable quantities of milk and cream are also retailed in Phoenix, Mesa and Tempe. There are in existence at the present time three creameries, all located in Phoenix, one evaporating plant located in Tempe and another evaporating plant in process of construction at Glendale. During 1916 and for the first seven months of 1917, there was another creamery in operation at Glendale. These plants care for most of the dairy products originating in the Valley. No stringent requirements are laid by the creameries upon their patrons. Practically all milk or cream which is in even a reasonably satisfactory condition is accepted and this has acted in some cases to encourage slack methods of handling milk and cream on the farm. In 1916 about 4,001,900 pounds of butterfat were collectively handled by the commercial plants in the Valley, while about 3,501,000 pounds were handled by the same firms during the first nine months of 1917.

These figures indicate more graphically than words the volume of the commercial dairy business in the Salt River Valley. Prices paid for dairy products during the past two years have varied from 31 cents for butterfat in cheese milk in September, 1916, to 55 cents for butterfat in the same form in October, 1917. The following table represents an average of prices paid by all creameries and evaporating plants during certain months of 1917 and shows the very rapid increase in price which became manifest during the later months of 1917:

TABLE III AVERAGE PRICES PAID FOR BUTTERFAT IN 1917

Month	*In Churn Cream*	*In Sweet Cream*	*In Cheese Milk*	*In Whole Milk*
February	42c	45.0c	47.5c	47.5c
April	40c	42.0c	46.0c	48.5c
July	41c	47.0c	47.0c	52.5c
September	45c	48.0c	50.0c	56.0c
October	47c	51.5c	53.0c	59.0c

The prices paid for butterfat in various forms have been fairly well in line with prices for dairy products in other sections, when overhead charges and costs of operation are taken into consideration. Evaporated milk, butter and cheese are the chief products turned out by the manufacturing plants. Data collected from the creameries indicate that the overrun in these plants varies from about 21 to 24½ per cent. The quantity of cheese produced per 100 pounds of milk ranges from about 7½ to 9½ pounds. In 1916 about 2,750,000 pounds of butter and 1,100,000 pounds of cheese were collectively produced by the creameries in the Valley. This does not include the butter and cheese manufactured on the farm, but represents only that which was produced by commercial plants specializing in the production of these commodities. During the first nine months of 1917 about 1,850,000 pounds of butter and 1,250,000 pounds of cheese were produced by the same concerns. Only one grade of butter is turned out by each plant. This butter is packed in one-pound cartons of the flat type customary in the West. Full cream and half-skim cheese have been produced at various times, although at the present time some of the creameries are producing full cream cheese only. By far the greater part of the butter and cheese produced in the Salt River Valley finds a market in the Valley itself or in other parts of Arizona. Some butter goes to points in New Mexico, to El Paso, Texas, and even as far as San Antonio and Houston. Occasionally carloads of cheese have been placed in Los Angeles, while in 1917 two carloads of cheese went as far East as Philadelphia. The principal market, however, for butter and cheese is within the State borders of Arizona, and of that sold within State borders about two-thirds of the butter and one-half of the cheese is sold outside the Salt River Valley in the mining centers of the State.

One of the heaviest charges which the dairymen in the Valley have to pay is that for the collection of butterfat. More than half of the milk and cream which is handled by the creameries and evaporating plants is gathered on motor trucks operated by these plants. As might be expected, with plants doing a competitive business, the various col-

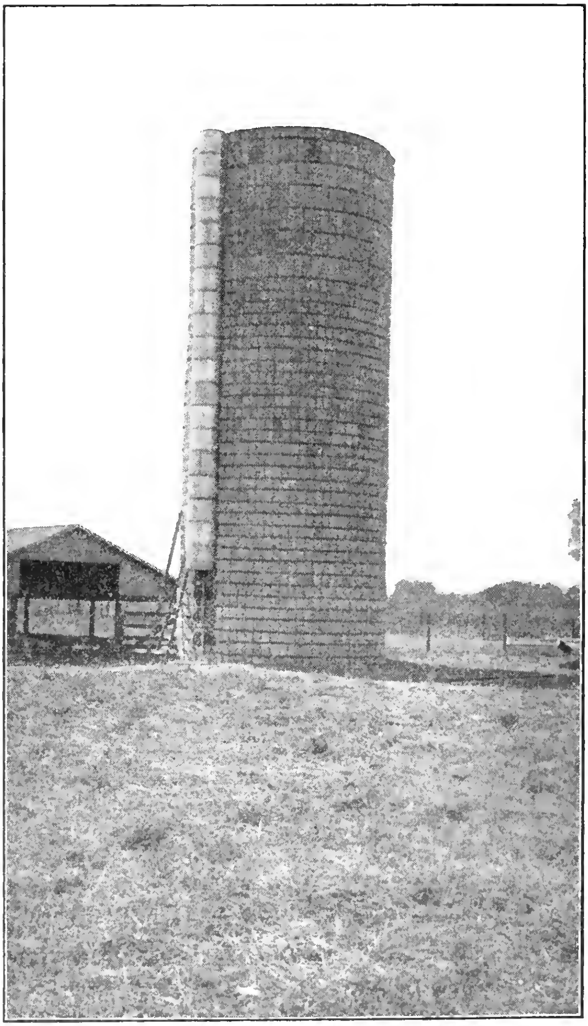

Fig. 3—A substantial factor in the newer dairy industry.

lecting routes are duplicated many times in the regular course of business and this in turn makes the cost of collection per pound of butter fat relatively heavy. Investigations show that the cost of collecting butterfat ranges from about 2 cents per pound to as high as 6½ cents per pound. This wide range is traceable to the fact that it is more economical to collect butterfat in cream than in whole milk and also it is relatively expensive to haul either cream or milk from more distant points in the Valley. As a matter of fact, motor trucks operated by creameries haul milk and cream for distances as great as 50 miles. The average length of haul, however, is much less than this, and probably does not exceed from 7 to 9 miles. Some important economies could be effected by arranging a division of territory for gathering purposes. It is altogether possible to add from 2 to 4 cents per pound to prices paid for butterfat if waste energy be eliminated in gathering milk and cream. The 35 trucks now devoted to the collection of milk and cream in the Valley probably could be replaced by 20 to 25 trucks if the average territory covered by each truck were enlarged by eliminating duplication of routes.

COTTON In 1917 the production of long staple cotton ceased to be a side line in general agriculture and became one of the leading industries in the Valley. For a number of years prior to 1917, cotton was produced on a fairly extensive scale, the acreage ranging from 1,500 acres to 9,000 or 10,000 acres. The development of superior types of cotton, the sudden realization on the part of growers that Arizona is climatically suitable for the production of Egyptian long staple cotton, and the prevailing high prices paid for cotton ginned in 1916, all combined to create a sudden flurry in the cotton industry of the Valley. Several years ago it was established experimentally that long staple cotton could be produced in the Valley. This information, however, was not utilized immediately by farmers in the Valley, who took merely a passive interest in cotton growing. When prices for long staple cotton passed the 50 cent mark, however, a large number of producers began to take more than a passing interest in the possibilities of cotton culture. The following table shows the approximate long staple cotton acreage for a period of years, together with the number of bales ginned each year:

TABLE IV ACREAGE AND YIELDS OF LONG STAPLE COTTON

Year	Acreage	Bales Ginned
1913	5,000	2,030
1914	11,500	6,060
1915	3,300	1,145
1916	7,300	3,260
1917	32,000	*13,500

*Approximately.

It will be noted that average yields are not extremely high. On the other hand, it must be remembered that long staple cotton production in this section of the country is still in an experimental stage with respect to individual experience. This was especially true in 1917, when an unusual acreage was planted. A large part of this cotton was cultivated by growers who had had little or no experience in cotton culture. A few cotton growers had produced short staple cotton in the Southern States, but even this did not materially assist them in handling the problems of long staple production. The cotton producers have not yet found themselves and it will doubtless take a number of years' practical experience on a large scale before they will be able to make the most of natural advantages. All things considered, however, they have produced an excellent crop in spite of their inexperience.

For several years prior to 1917 there had been a steadily decreasing acreage of short staple cotton. In 1917, however, the danger of attempting simultaneous production of both long and short staple cottons was thoroughly brought home to the growers and no short staple cotton was planted at any point in the Valley. Two varieties of long staple cotton were grown in 1917. Of the total acreage of about 32,000 acres, approximately 6,700 were of the Pima type, while the remainder was of the Yuma type. Both of these cottons had been grown in previous years in the Valley. Practically all of the long staple cotton produced prior to 1917 was of the Yuma type, while Pima cotton had been produced only in a small way. Both of these cottons have been developed through the efforts of plant breeding experts of the United States Department of Agriculture. The acreage of Pima cotton in 1917 represented the first widespread production of this variety. Pima cotton was developed at the Government plant breeding station at Sacaton just south of the Salt River Valley and was experimentally produced for several years prior to 1917. In the latter year a sufficient quantity of pure bred Pima seed was available to plant approximately 6,700 acres. The control of this seed rested largely with the United States Department of Agriculture, whose experts were anxious to preserve a pure strain of this desirable type. In order that there might be no admixture of the Pima and Yuma strains, it was determined to restrict the planting of Pima seed to a definite territory within the Valley, to have this cotton ginned separately from Yuma cotton, and to prevent the planting of any of this seed within any territory which was contiguous to plantings of Yuma cotton. The Tempe Cotton Exchange administered the distribution of Pima seed to growers in a limited district south of Tempe. No Pima seed was planted outside of this district and no Yuma cotton was produced within the arbitrary boundaries of this restricted area. In order that there might be no misunderstanding as to the purposes and provisions of this plan, every cotton grower who secured Pima seed through the Tempe Cotton Exchange executed a contract which was designed to continue the control of Pima seed by the Tempe Cotton Exchange. A copy of this contract follows:

TEMPE COTTON EXCHANGE

PIMA COTTON GROWERS' CONTRACT

THIS AGREEMENT MADE BETWEEN.. a resident of the County of Maricopa, and State of Arizona, hereinafter called the Grower, and the Tempe Cotton Exchange, a corporation, having its place of business at Tempe, in said County and State, hereinafter called the Exchange, WITNESSETH:

That the Grower as..is now and will at all times prior to the first day of March, 1918, continue to be in sole control of..acres of land hereinafter particularly described, on which he proposes to grow and harvest a crop of PIMA cotton during the season of 1917, which said land is situate near Tempe, in the County of Maricopa, State of Arizona, as particularly described as follows, to-wit:

....

....

....

....

in Township........................., Range.........................of the Gila and Salt River Base and Meridian, containing...................................acres.

That the Grower is desirous of securing from the Exchange a sufficient quantity of Pima cotton seed to plant said land during the season of 1917, and has applied to said Exchange for said seed;

That the Grower, in consideration of the Exchange furnishing said PIMA cotton seed to him, and of the benefits and privileges to be received by him from the Exchange under this contract for himself. his executors, administrators and assigns, hereby covenants and agrees with the Exchange, its successors and assigns, as follows:

1. To plant the seed furnished him under this contract only upon such part of the land above described as may be selected and approved by the duly authorized representative of the Exchange, and under no circumstances will any of said seed be planted on any other land, or used or disposed of for any purpose whatsoever than the planting of all or such part of the above described premises as may be selected and approved by said representative of the Exchange, and should any seed furnished under this contract be not planted on said land prior to the first day of May, 1917, then the Grower shall return all unplanted seed to the exchange not later than the tenth day of May, 1917.

2. That none of said seed will be planted within a distance of less than one-quarter of one mile of any land on which cotton of any variety other than PIMA is then being or is to be planted during the season of 1917, or upon any land which shall have been planted to cotton of any variety, other than PIMA, during the season of 1916; PROVIDED that the Exchange may, in writing endorsed on this contract, waive the foregoing requirements of this clause "2".

3. That the Grower shall deliver to the Exchange, for the purpose of ginning, and baling, all of the seed cotton that may be produced or grown from the seed furnished under this contract, and the Exchange, its successors or assigns, shall have the sole right and privilege of ginning and baling all the products of the cotton crop produced from the seed that may be so furnished.

4. That the representatives of the United States Department of Agriculture and the representatives of the Exchange, or either of them, shall at all times have the right to go upon the above described premises of the Grower for the purpose of seeing the said land is properly suited for the growing of Pima cotton; that said land is properly prepared for planting; that the seed furnished under this contract is properly planted; that the Grower at all times after the seed is planted, properly thins, cultivates, irrigates and otherwise handles and cares for the crop grown from the seed so furnished.

5. That the representatives of said Department or the Exchange, or either or both, may go upon said premises at any and all times and "rogue" all of such portion of the cotton plants produced from said seed as said representative or any of them may deem best, and that said representatives, either of the Department or of the Exchange, may at any time destroy any of such plants or portions of said crop as they may deem best with a view of maintaining the purity of said PIMA variety of cotton, and should such representatives or any thereof so require, this applicant will, at his own expense, destroy any

such plants or parts of said crop as said representatives or any of them may direct.

6. That the Exchange, its agents or assigns, shall at all times during the period in which said crop is being planted, grown, matured and harvested, have the right to enter upon said premises, and inspect said crop or any and all work done or being done in connection therewith and take any and all such measures as it may deem necessary or proper to protect such crop and thereafter handle and manage the same, for such period as the Exchange may deem best, and from time to time, as the crop or any part thereof produced from said seed shall have been harvested and delivered to the gin of the Exchange, and at all times thereafter, the Exchange, its successors and assigns, shall be deemed the sole and unconditional owner thereof, for the purpose of insuring and otherwise protecting the same, and shall have the exclusive right of possession and control thereof for the purpose of ginning the same and baling the lint cotton and recovering the seed therefrom, and the collection and disbursement of all proceeds from the sale of said lint cotton.

7. The Grower will receive and in good faith comply with all suggestions and directions relative to the preparation of the land therefor, and the planting, thinning, cultivating, irrigating, harvesting and delivering of the crop grown from said seed as may be given from time to time by the representatives of the United States Department of Agriculture or of the Exchange or both.

8. That all seed produced from the PIMA seed furnished under this contract shall at all times not only after the same is harvested, and ginned, but at all times while the same is being grown, matured and harvested, be and remain the sole property of the Exchange, it being understood, however, that the Exchange will pay the Grower for the merchantable cotton seed so grown and delivered to it pursuant to this contract, at local oil mill prices as the same may exist on the respective dates when the cotton from said crop may be ginned.

9. The Grower hereby promises to pay to the Exchange on demand for all seed that may be furnished to him under this contract prior to April 1, 1917, at the rate of $60 per ton, and for all seed that may be furnished to him under this contract after April 1, 1917, at the rate of $65 per ton, and further promises to pay to the Exchange on demand all other indebtedness of every kind and nature which may become due and owing by him to the Exchange on account of or in any wise connected with or incident to this contract or the production of the crop to be grown from the seed furnished under this contract, whether said indebtedness be for services rendered, materials furnished, money advanced, accounts or obligations guaranteed or assumed or otherwise, and for the purpose of securing and guaranteeing the payment of any and all sums of money and indebtedness as above provided, the Exchange shall at all times have a first lien and claim not only against the seed that may be furnished under this con-

tract, but also against all crops and products of every kind produced from said seed, as well as the proceeds from the sale of any and all such crops and products, which said lien shall attach and at all times remain against said seed and the crops and products produced therefrom, not only prior to the time when such seed may be planted, but also at all times while such crops and products are being grown, matured, harvested, ginned, baled and marketed. For the purpose of effectively securing the payment to the Exchange of all such sums of money and indebtedness as above provided, the Exchange shall have the sole and exclusive right and the Grower does hereby irrevocably appoint the Exchange as his agent to collect, receive, receipt for and disburse all proceeds that may be received from the sale of any and all crops and products grown from any and all seed furnished under this contract.

The Exchange in consideration of the faithful performance by the Grower of each and all his foregoing covenants, agreements and promises, hereby agrees with the Grower as follows:

1. That during the period of growing, maturing, harvesting, ginning and baling of the crop produced from the seed furnished the Grower under this contract, it will assist the Grower in any reasonable way that it may be able to so do, to obtain any necessary financial aid which the Grower may require to enable the Grower to properly grow, mature, harvest, gin, bale and market the lint cotton produced from the seed furnished under this contract.

2. That it will receive from the Grower at its gin in Tempe, Arizona, or at such other place as it may select, all merchantable seed cotton produced from the seed furnished under this contract and in the due operation of its gin during the ginning season of 1917, gin and bale such cotton and charge the Grower for such ginning and baling at a rate not exceeding three (3) cents per pound of the gross weight of each bale of lint cotton ginned from said crop.

3. That it will pay the Grower for all merchantable cotton seed grown from the seed furnished the Grower under this contract and delivered to it pursuant to the terms of this contract at local oil mill prices as the same may exist on the respective dates when the seed cotton grown from the seed furnished under this contract may be ginned during the season hereinbefore mentioned.

4. That in addition to the ginning charges above mentioned, it will charge the Grower on the lint cotton ginned and baled at the rate of one-half cent per pound on the gross weight of each bale of lint cotton ginned from said crop to cover the expenses of insuring, protecting, storing and handling the products produced from the seed furnished under this contract.

It is hereby MUTUALLY AGREED between Grower and Exchange that from time to time as the lint cotton produced from the seed furnished under this contract shall be sold and the proceeds thereof received by the Exchange, also as the seed from the crop produced from the seed furnished under this contract shall be ginned as hereinbefore provided and the value thereof credited by the Exchange to the Grower, the Exchange will first deduct from any such proceeds and credits all or such part of any sums of money or indebtedness as it may deem best then owing by the Grower to the Exchange, and will then pay any balance of such proceeds and credits, if any, to the Grower, or to his successors or assigns.

The several covenants and agreements of the respective parties hereto shall extend and be binding upon their respective heirs, executors, administrators, successors or assigns.

IN WITNESS WHEREOF, the Grower has hereunto set his hand and the Exchange has caused this agreement to be executed by its President, attested by its Secretary, and its corporate seal to be hereto affixed this ....day of ...., 1917.

....
Grower

TEMPE COTTON EXCHANGE

By..
President

ATTEST:

....
Secretary

This interesting contract was sufficiently explicit to provide for the perpetuation of a pure strain of Pima seed. An expert cotton classer connected with the Bureau of Markets of the United States Department of Agriculture, who spent several months in the Salt River Valley in 1917, directed the classing of more than 1,000 bales of cotton prior to December 1. His investigations showed that the Pima staple ranged in length from 1⅝ inches to 1¾ inches, averaging 1 11-16 inches. Yuma staple averaged ⅛ inch shorter than Pima. The greater length of the Pima staple doubtless will be a deciding factor in future plantings. Buyers in 1917 had little to guide them in differentiating between varying lengths of staple. In general, however, Yuma cotton sold for from 2 to 6 cents per pound less than Pima cotton of the same grade.

The problem of securing labor for picking the 1917 crop was a very serious one. The Salt River Valley Cotton Growers' Association, an organization of cotton producers, designed largely to care for labor problems, undertook to solve the difficulty by bringing laborers into the Valley from the southern states and from Mexico. A fund was raised by subscription among cotton growers and dealers in the Valley and this money was used for labor importation. Railroad fare was advanced to prospective laborers and they were required to repay this advance from the first wages secured in the cotton fields. Growers who desired to secure cotton pickers applied at the central employment office of the association and were assigned a share of the laborers who were brought into the Valley. The prices paid for cotton picking ranged from \$2.50 to \$4.00 per 100 pounds of seed cotton. Prevailing high prices for other forms of farm labor took many pickers from the cotton fields and the crop was not harvested as rapidly as was desired by the growers. In all likelihood the labor problem will remain one of the serious problems connected with cotton culture in the Salt River Valley.

There are at present in the Valley eight cotton gins, located at Glendale, Phoenix, Tolleson, Tempe, Mesa and Chandler. There are no cotton compresses in the Valley and the bales are shipped as they are turned out from the gin. Prices received for long staple cotton have varied greatly in past years. In 1914, owing to the demoralized condition of the general cotton market, prices to the grower ranged as low as 14½ cents per pound of lint. In 1916 the price started at 30 cents a pound, rose with rapidity to 47 cents a pound and in November had reached 53 cents. Forty-four bales of Pima cotton of the 1916 crop, which were held until early in the Spring of 1917, sold for 58.6 cents per pound. A considerable portion of the 1917 crop was sold under contract prior to harvest. These contracts, some of which were executed in the early Spring before cotton was planted, and others as the season progressed, called for delivery at picking time at prices ranging from 30 cents a pound to more than 50 cents a pound. The cotton which was unsold at picking time opened at about 53 cents, rose rapidly to 58 cents, then to 75 cents, and by December 1 a few sales of Pima cotton had been made at the unprecedented figure of 80 cents per pound.

It appears that Arizona long staple cotton is especially suited to the manufacture of high class automobile tire fabric and a considerable proportion of this cotton is being so utilized. Its tensile strength also makes it desirable for the manufacture of the fabric used for aeroplane wings. A considerable part of the Yuma cotton produced in 1917 was grown by or sold under contract to automobile tire companies. Several thousand acres, however, of this type, together with most of the Pima cotton was open for competitive bids at the beginning of the picking season.

Cotton marketing is largely an individual proposition and there are no farmers' co-operative associations designed entirely for the marketing of cotton. In 1917 representatives of thread companies, together with buyers representing important cotton factors in the East, offered an outlet for that cotton which was not sold for tire fabric. The commercial center of the cotton industry in the Salt River Valley is at Tempe. At this point there is the only large open cotton market in the Valley and competitive buying is conducted on a more extensive scale than at any other point.

A serious difficulty in 1917 was the lack of authentic information on the part of the growers concerning prices for Sakellardies and other Egyptian cottons. This, together with the confusion of ideas concerning the relative commercial values of Arizona long staple cotton and the imported product from Egypt provoked an unsettled market. The question of relative values was settled largely by preliminary reports made by the cotton expert of the United States Department of Agriculture. These reports, coupled with authentic price quotations on Egyptian cottons, determined primary prices paid to producers and offered the first satisfactory price basis established in the Valley. With preliminary prices established at a fair figure, the bulk of the sales was made at prices which reflected true values under conditions prevailing on the long staple cotton market. It is desirable that authentic price quotations for Egyptian and Sea Island cottons be published in local papers periodically throughout the season in order that growers may be informed as to general long staple cotton conditions. It is also desirable that an open competitive market be maintained in the Valley in order that producers may benefit by general market changes. It may prove necessary for growers to consign some of their product to storage in New England if prices in the local market are not satisfactory. Cotton stored at some convenient point in New England would be readily salable as spot cotton to spinners who might not otherwise manifest an interest in Arizona cotton. Action of this sort would presuppose some form of co-operation among the growers. As a matter of fact, it probably will be necessary for the growers to consider at an early date the question of uniting for co-operative marketing.

CANTALOUPES The cantaloupe crop is the most important of what might be termed the "speculative" crops of the Salt River Valley. Practically all of the crop is produced in fairly restricted areas around Glendale, Mesa, Phoenix and Chandler. The industry started in a small way in 1908 and has maintained a fairly steady growth to the present time, although there have been some intervening years when the acreage was small. In 1916 the total commercial acreage was about 2,000 acres. In 1917 about 3,100 to 3,200 acres were planted to cantaloupes, but the area from which marketable melons were actually harvested did not exceed about 2,800 acres. Cantaloupe growing in this Valley, as in all similar districts of the West, is a very specialized form of agriculture. Practically all of the crop is grown under contracts executed between growers and eastern commission houses. About 6 or 8 cars were handled independently by local firms in the Salt River Valley, while an inconsiderable acreage furnished melons for local consumption. One or two inexperienced growers attempted independent growing of cantaloupes in 1917 and having neglected to provide marketing facilities, found themselves unable to sell their melons for prices which would pay for the expenses of harvesting. The contract referred to is essentially the same as that in vogue in other cantaloupe districts in the West. The provisions of these contracts have already been discussed in considerable detail in publications of the United States Department of Agriculture.[1]

They provide for the furnishing of seed and crate material by the distributor at specified prices to the grower, for cash advances to the grower through the growing season and at harvest time, and stipulate that for service rendered the distributor shall receive a commission of 15 per cent of the gross sales. The practice of making liberal cash advances to growers throughout the growing season is gradually being eliminated. Some of the distributors each year have been lowering the usual cash advances, while in 1917 one of the large distributors made no cash advances whatever, although customary advances of seed and crate material were made as formerly.

All melons are packed on the farm in field packing sheds. The standard crate, containing 45 melons, the pony crate, containing 54 melons, the standard flat crate, containing 12 or 15 melons, and the jumbo flat crate, designed to care for larger melons, are the chief

[1] See Schleussner, O. W., and Kitchen, C. W., Marketing and Distribution of Western Muskmelons in 1915. U. S. Department of Agriculture Bulletin 401

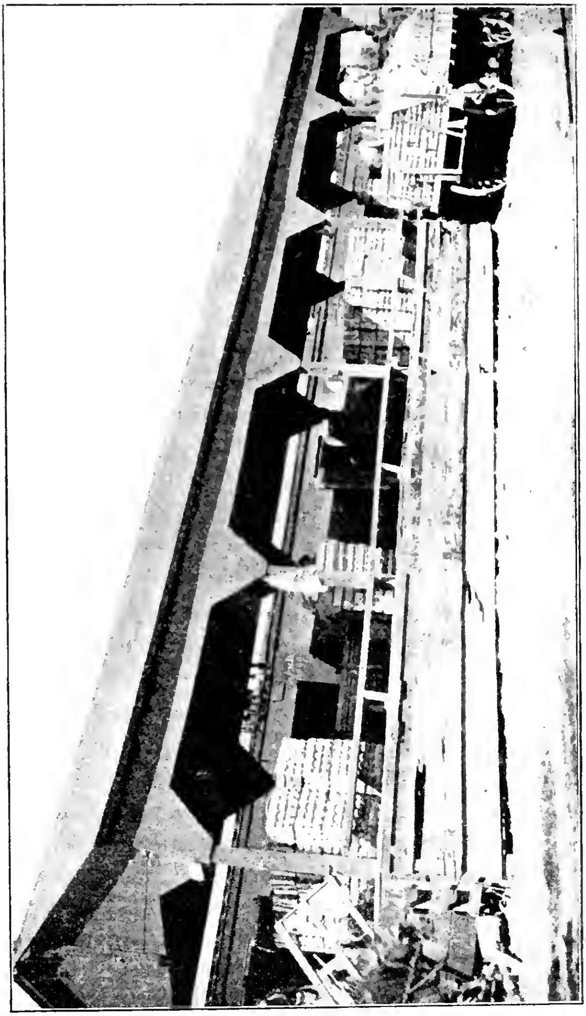

Fig. 4—Loading cantaloupes at Glendale.

containers in use. Small quantities were shipped in 1917 in special containers, such as the pony flat crate and the special flat crate for pink meat melons.

Inspection is accomplished at the loading platform when melons are delivered by the grower for shipment. Field inspectors for the distributing concerns attempt to visit as many field packing sheds as practicable each day in order to advise with growers as to methods of picking and packing. Most of the cantaloupes, however, are produced on small individual acreages and it is manifestly impossible for a limited inspection force to give adequate inspection at packing sheds. Hence, the real inspection is that given at the loading platform. Many of the cantaloupes are grown by Japanese growers. In 1917 more than one-half of the commercial acreage was controlled by the Japanese. This was particularly true in the Glendale-Phoenix district, where the Japanese cantaloupe growers were greatly in the majority. In past seasons most of the pink meated melons were grown in the Glendale district, while the production of this type on the south side around Mesa was merely incidental. A noticeable feature of production in 1917 however, was the small acreage in Burrell Gems. Only about 300 acres or approximately 10 per cent of the total acreage were pink meat melons and most of these were produced around Mesa. This was largely due to the fact that Glendale growers received unsatisfactory returns in 1916 on their pink meats and in 1917 abandoned this type. The growers of Burrell Gems in the vicinity of Mesa, however, received very satisfactory returns in 1917 and it is likely that the 1918 season will see an increased acreage of pink meat melons produced in the Valley. About 60 acres of the white rind melons, known to the trade as the "Honey-Dew" melon, were grown in 1917. Most of these were produced on the north side near Glendale. Owing to the comparatively limited demand for this type of melon, it does not seem likely that there will be any material increase in the 1918 acreage. The following table gives the shipments of cantaloupes by stations in 1916 and 1917:

TABLE V SHIPMENTS OF CANTALOUPES, 1916-1917

Stations	*Shipments by carloads*	
	1916	*1917*
Glendale	362	536
Mesa	388	433
Phoenix	103	68
Chandler	12	18
Fair Grounds	......	258
Total	865	1314

Picking starts during the last week in June and extends through July and into the first week of August. Melons from this district reach practically every large market in the United States from Boston to Denver and so compete with late offerings from Imperial Valley, early shipments from the Turlock district and cantaloupes from Georgia and other eastern producing districts. A cold backward Spring in 1917 was doubtless responsible for the poor flavor and carrying quality of the crop. Most of the cantaloupes were distinguished by relatively large seed cavities and a low sugar content. Owing to the unusual moisture content and the large seed cavity, many of the melons arrived at market in a greatly deteriorated condition and in spite of an active demand, the prices which were received reflected something of the true value of the melons. Ordinarily, however, cantaloupes from the Salt River Valley are of good quality and are well and favorably known on practically every large market in the country. Prices in 1917 were satisfactory. The delivered value of the melons ranged from $2.25 to $3.25 per standard crate. Customary yields of from 150 to 160 standard crates to the acre were materially reduced in 1917. The average delivered value of the 1917 crop was about $2.40 to $2.50 per standard crate, which was equivalent to from $1.25 to $1.40 f. o. b. Valley points. Returns to growers ranged from $0.75 to $2.00 per standard crate and averaged about $1.10 per standard crate.

The marketing problem for the cantaloupe producer is ordinarily not an acute one, although the speculative nature of the crop sometimes causes some fairly heavy losses for the growers in a bad season. About 10 car lot shippers or distributors operated in the Valley in 1917. More than three-fourths of the crop, however, was moved by five or six of these shippers. On the whole, this system of marketing has been satisfactory, and it is doubtful whether a farmers' co-operative marketing association could secure a more widespread distribution of melons than was effected by the combined efforts of the distributing concerns who handled the crop in 1917. The season, however, was marred by the operations of one or two irresponsible concerns who took advantage of the small grower's inability to care for his business interests and failed to make complete returns on all shipments. The Market News Service, conducted by the Bureau of Markets of the United States Department of Agriculture, supplied necessary information to the growers concerning prices and market conditions. There is need, however, for some agency to act as advisor to the small grower who intends to enter into a contract with a distributor. Most of the concerns operating in the Salt River Valley are reliable, but experience in 1917 indicated the need for looking into the credentials and past history of some operators who have been guilty of rather sharp practices.

HONEY Honey usually is produced in the Salt River Valley as a side line on the farm. The total annual production of this commodity, however, makes it a fairly important one. The report of the State Apiary Inspector in 1915 indicated that in Maricopa County there were 52 beekeepers owning about 24,440 colonies of bees. Recent estimates indicate that in 1917 the total number of colonies had been reduced by from 5 per cent to 10 per cent. More than 95 per cent of the honey is extracted and placed in 5-gallon cans. Two of these cans constitute a case, which is the unit for marketing. The average annual yield per colony ranges from 50 to 70 pounds, the average in 1917 being about 65 pounds. The small portion of the crop which is sold as comb honey is disposed of locally. The commercial output of extracted honey is divided into four grades, known as water white, light amber, amber and dark amber. The various amber honeys are produced from alfalfa bloom and constitute more than 90 per cent of the commercial output. A small quantity of mesquite honey is classed as water white and sold accordingly. A native desert plant known locally as Cat's Claw furnishes nectar for a white honey which could almost be classed as water white. A mixture of Cat's Claw and alfalfa honey makes an excellent type of light amber honey.

Of the total quantity of honey produced in the Valley, about one-third is used locally and two-thirds finds its way to outside markets. Records indicate that in 1916 about 26 carloads of honey were forwarded from various points in the Valley. There is an association of honey producers in the Valley known as the Arizona Honey Exchange, which handles more than one-half of the product which goes to market. The balance is handled by a local independent buyer who represents several larger honey buyers.

The plan of selling honey through the Exchange is simplicity itself. The extracted honey is delivered to the Association Secretary, who negotiates with wholesale buyers in various parts of the country and places the honey with the concerns offering the highest bid. For his services the Secretary receives a small commission. There are no closely drawn contracts connected with the association business. It largerly rests on a general understanding between the various members and the association. Very little honey is sold by the producer to large outside buyers. Most of the extracted honey shipped from the Salt River Valley ultimately passes into the hands of wholesale biscuit manufacturers, wholesale drug manufacturers, tobacco manufacturers and confectioners.

Prices for amber honey have ranged from $4.50 per case in 1916 to $12.40 per case in 1917. Prices for amber honey during the latter part of 1916 ranged from $5.40 to $6.00 per case of 120 pounds, while prices early in 1917 averaged about $8.40 per case. This price rapidly rose as the 1917 season progressed to 11 cents, then to 12.2 cents and closed at about 12.4 cents. Small quantities of mesquite honey in 1917 brought $13.00 per case. These prices were fairly well in line with prevailing market quotations. There is at present no general dissatisfaction with the local honey markets. It is likely that better marketing arrangements could be made if all the honey producers of the Valley were organized into one association to care for the selling interests in a businesslike way. As long as prices received, however, are fairly well in line with wholesale market quotations, it does not seem likely that the beekeepers of the Valley will organize more extensively. On the whole, there is no serious problem in connection with the market for Salt River Valley honey and there seems to be no need to recommend any changes at this time.

FRUIT The production of fresh fruit for market is not one of the leading industries in the Valley. This phase of agriculture, however, is not limited to any considerable extent by climatic or soil conditions and could easily be made one of the most important agricultural activities in this section of the Southwest. There are in general two types of fruit produced. The output of deciduous fruits consists very largely of peaches and apricots, while oranges and grapefruit constitute the chief offerings of citrus fruit. A few plums and figs produced in a very small way complete the list of tree fruits produced in the Salt River Valley.

The output of deciduous fruits is rather evenly divided, about one-half being peaches and one-half apricots. The apricots are largely Newcastles, Royals, Blenheims and Moorparks. Almost every variety of peach which can be grown in this climate is produced and the variety list ranges from Elbertas to Salways. Most of the peaches are Elbertas however. The wide range of varieties noted above has re-

Fig. 5—A typical new citrus development on the north side of the Salt River Project.

sulted in a fairly long producing season and to this extent has prevented local market gluts to a considerable extent. About 2,100 acres in the Salt River Valley are now devoted to the production of deciduous fruits. The individual acreages, however, are small and a comparatively large number of growers are interested. Individual acreages range from 3 acres to 160 acres. Most of the plantings, however, range from 5 to 10 acres. Few of the orchards are handled by experienced fruit growers and this has tended to demoralize partially the commercial production of this class of fruit.

The season of 1917 was fairly typical of conditions as they now exist and may be reviewed profitably. The crop was fairly large, although a few individual orchards had a small yield. Most of the trees, especially the apricot trees, bore too large a crop of fruit. Because of poor market prospects, few of the growers considered it necessary to thin their fruit properly early in the season and, as a result, a large part of the crop was of excellent quality, but was small and unattractive for market purposes. With but few exceptions no arrangements were made for marketing the crop prior to harvest. The first fruit ripening in the trees found the growers with no ideas as to its disposition. The local market was soon glutted and low prices offered locally caused several of the growers to make no attempt to harvest their fruit. As a result there was a considerable loss of fruit which, while not first class marketable stock, could nevertheless have been handled at a profit if more favorable circumstances had prevailed. Prices for local sales averaged to the grower about 1 cent per pound for apricots on the trees and from 2 to 3 cents per pound picked into lug boxes. Larger quantities than usual were dried and canned, but in spite of this effort at conservation, there was a relatively heavy loss of good fruit. Despite the local situation, there was a reasonably active demand for peaches and apricots in the mining towns of Arizona and New Mexico, while the larger cities in Kansas, Texas and Oklahoma were offering about $2.50 per 25-pound box. A few shippers in the Valley eased the local market by moving fruit to outside points. Early in the season, before the California apricot crop began to mature, 3 or 4 cars of Newcastles went forward to Los Angeles. This fruit met with a satisfactory sale, but shipment in this direction was soon curtailed because local shipments from California drove the Arizona product from coast markets. One growers' association at Glendale as a side line shipped considerable quantities of peaches and apricots in small express lots to mining towns in Arizona. Returns on these shipments were also satisfactory. One large shipper, who purchased the entire output of several orchards on the trees, placed a number of express shipments of apricots on the Texas markets and realized from $1.35 to $1.75 per 25-pound box f. o. b. Phoenix. In general, sales outside of the Valley were very satisfactory, returning from 3 cents to 7 cents per pound to Valley growers, as against the local market of 1 cent to 2 cents. However, practically all of the fruit shipped from the Valley was selected and graded stock and hence possessed a greater intrinsic value than the large quantity of mediocre fruit which was sold locally for prices which hardly paid expenses.

Total shipments of peaches and apricots by freight and express in 1917 were equivalent to approximately 12 carloads. While only a relatively small part of the fruit crop of 1917 was good marketable stock, nevertheless at least twice as much could have been sold outside of the Valley had the growers been in a position to consolidate their output and assure prospective customers of a reasonably dependable supply. With but few exceptions the growers do not know how to grade and pack their fruit for market. This indictment is not intended to be a sweeping one, as there are several growers who have in the past shipped some excellent fruit. These exceptions, however, merely indicate the possibilities open to the fruit growers of this section and emphasize the lack of knowledge which prevails among the growers in general. At the present time there are no grades and standards which apply to deciduous fruits in the Valley.

Peaches and apricots are merely shipped as such and the buyer has not even a tentative grading system to safeguard him on his purchases. In general, two types of package are used for shipment outside of the Valley. The ordinary lug box common to all fruit districts in the West is used extensively for shipment to mining towns and even as far as El Paso. Careful hand packing is unnecessary when these boxes are used if reasonable care is used in the selection of the fruit which goes into them. They constitute a cheap and satisfactory package for shipments which do not have to go more than 500 or 600 miles. Large southwestern cities, such as Dallas, New Orleans, San Antonio and Houston, prefer the western fruit box with the fruit packed in splint baskets and arranged in tiers. It is more expensive to put up a pack of this nature, but if the fruit is of good carrying quality and reasonably free from defects, it will find a ready and profitable sale. Los Angeles and other Pacific coast cities are reasonably good markets for early offerings of apricots. It is necessary to utilize these markets with discretion, however, and to cease shipping when the California crop begins to mature. The mining towns of Arizona and New Mexico always will utilize large quantities of fruit in lug boxes and are not quite so particular as the larger cities with respect to grading and packing. These mining town markets have never been thoroughly utilized by Valley fruit growers because they have not been able to guarantee the buyers in these towns a dependable supply of saleable fruit. As a result buyers have learned to look to other districts for their fruit supply. It probably will be better for the peach growers to confine their shipments rather largely to the mining districts. The large peach crop from the southern states moves to market at about the same time as does that from the Salt River Valley and growers in the latter district will hardly be able to compete with Texas, Oklahoma and Arkansas.

Briefly stated, the commercial problem of the deciduous fruit grower in the Salt River Valley will be first and foremost to secure a better understanding as to what constitutes good marketable fruit. It goes without saying that fruit growers will find it necessary to inform themselves more thoroughly with respect to early thinning of their fruit and proper methods of grading and packing. There should unquestionably be some method of consolidating the output of deciduous fruit for carload shipping and to insure a dependable supply to customers. Provision also must be made for adequate inspection of all fruit. This inspection cannot rest with the individual grower, who has small knowledge of market values. The entire problem is one of co-operative effort and a fruit shippers' association is needed to insure a dependable supply of well graded, well packed and carefully inspected fruit. The fruit acreage in the Valley is hardly large enough to warrant the creation of a complete co-operative marketing association designed to care for all the commercial interests of the growers. An association, however, for the purpose of co-operative shipping and designed to promote better inspection and better grading methods is entirely feasible and will in a large measure answer the present question of the grower who is blindly looking for a market.

There are at present about 2,300 acres planted to citrus fruits in the Valley. Individual groves range in size from 5 acres to 75 acres, but, as with the deciduous fruit industry, the individual acreage is relatively small. Oranges are the principal citrus offering, but the success of earlier grapefruit plantings has stimulated later plantings. Most of the oranges are Navels, Jaffas and Valencias. There are, however, small plantings of Mediterranean Sweets, Blood Oranges, and various seedlings. Because of climatic conditions, the oranges of the Salt River Valley have established an enviable reputation at market. The fruit is highly colored, sweet and juicy, with a thin, tender skin. The citrus industry is in a much more satisfactory condition than is the deciduous fruit business.

The greater part of the citrus output of the Valley is shipped through the Arizona Orange Association, an incorporated stock company composed of growers who have organized for marketing. Holdings of stock in this association vary with individual acreages and every share of stock carries with it one vote. The association maintains a packing house in Phoenix, where the fruit is assorted, graded and packed for market. Methods of selling the crop through the association have varied considerably in past years. In 1914 and 1915 the oranges were sold through a general selling agency, which operated branch offices in most of the principal markets of the country. In 1916 it was decided that the association should undertake to sell direct to the wholesale trade, and a sales manager, who was also a member of the association, was charged with the duty of handling the deal. Shortly after the season opened, it was necessary for the sales manager to resign from his position and another member was chosen to carry on the work. This unexpected change in plans at the last moment handicapped the association and, while the returns were fairly satisfactory, it was not possible for the association to handle the crop as efficiently as had been planned. The 1917 crop is being handled again by the association, which has entered into agreements with members of the trade in many of the principal markets. It remains to be seen whether this procedure will prove satisfactory.

In 1916, 71 cars of oranges were shipped. Most of the citrus output finds a market in the large cities of the East. The Arizona orange ripens in time to meet the heavy demand during the holiday season. This district is one of the very few orange producing districts in the country which can place fruit on the market in time for the Thanksgiving trade, while the Christmas holidays find a considerable portion of the crop at market or in transit. It will be seen that marketing conditions are especially favorable for citrus fruit from this district, which enjoys a near-monopoly during a season of the year when the demand for citrus fruit is at its height. This earliness of maturity, coupled with excellent quality, causes the orange from the Salt River Valley to command a decided premium over such other citrus offerings as are marketed at the same time with the Arizona product. This premium averages from 50 cents to $1.00 per box.

The citrus marketing problem at present is not to find a market for the fruit, but to insure the growers a price which will reflect accurately the true commercial value of the citrus crop in this district. It would appear desirable for the Arizona Orange Association to establish a permanent marketing policy instead of changing general plans season by season. Affiliation with the California citrus growers for marketing the entire citrus crop of the Southwest is a matter which should be given serious and earnest attention by the orange and grapefruit growers in the Salt River Valley. It is possible that a satisfactory plan of co-operation could be worked out between California and Arizona growers which would be mutually beneficial. It might also be well for the Arizona Orange Association to consider whether or not the organization would be strengthened by giving each member of the association one vote, instead of voting according to stock holdings. As matters stand at present, two or three growers can control the policy of the association completely and even the possibilities of such action on their part will always have a tendency to make smaller stockholders suspicious of the larger growers.

The principal limitation to the citrus industry in this Valley is a climatic one. The area which is sufficiently free from frost to offer chances of success is very limited and even groves most advantageously situated are sometimes visited by frost. In the past this has acted to influence greatly citrus shipments from year to year. Most of the growers are converted to the principle of orchard heating, but even with this safeguard, there is a certain risk attached to the industry. The relatively high prices received for fruit, however, and the ready market which is always available, has caused the citrus industry to assume a healthy growth which would easily become an outright boom if frost limitations did not interfere.

Livestock Fattening livestock for market is an important industry in the Valley. Because of the large quantities of alfalfa and grain which have been produced, the livestock industry always has been a very important one in this section of the country. Each year finds a large number of cattle and sheep from the outlying range districts brought into the Valley for fattening. In 1916 about 920 carloads of livestock were shipped from Valley points to outside markets. Shipments in 1917 approximated 1,000 cars. Most of this stock moved to

Los Angeles, although Kansas City ranked a fairly close second. A noticeable feature of the livestock industry in 1916-1917 was the great decline in the number of hogs held on farms in the Valley. This decline was very largely due to the prevailing high prices for feed, which made the hog business unprofitable for the time being.

Small producers who annually turn out from 3 to 8 head of stock find it necessary to dispose of their animals to local buyers. This stock is either killed locally or consolidated by these buyers into carlots for shipment to terminal markets. Large livestock shippers sell at prevailing wholesale prices, while prices received by small producers are not so well established. The small farmer is entirely dependent upon the local buyer and prices paid by these buyers have varied greatly in the past. Where producers are fairly well informed as to market conditions, the local buyer often has been forced to pay a price which would approximate true values. In other cases, the buyer has taken advantage of the small producer and prices have ranged from 4 cents to 8 cents below prevailing market prices. As matters now stand the small producer has no alternative. He has not sufficient quantity of stock to ship to market and so finds it necessary to accept the best bid he can secure from the local speculators.

It will be seen that the real livestock problem in the Salt River Valley is that of the small producer who cannot ship to market direct. There is an evident remedy for this condition of affairs. The farmers' co-operative livestock shipping association is the most elementary form of co-operative agricultural effort. There are a sufficient number of small livestock producers in certain restricted areas in the Salt River Valley to make it feasible to organize community livestock shipping associations in a few districts where there is a sufficient quantity of stock to warrant the formation of such organizations. It is suggested that community associations might be organized at Scottsdale, Glendale, Fowler, and at some point centrally located on the South side, possibly Gilbert or Chandler. These associations require no elaborate financial arrangements and can readily be conducted by producers who wish to secure true market values. There is nothing in the livestock industry of the Valley which would make it necessary for these shippers to modify materially the general plan of operation under which such livestock shipping associations have been organized in the Middle West.[1] These associations have been very successful in the latter ter-

1. U. S. Department of Agriculture, Farmers' Bulletin 718, Co-operative Livestock Shipping Associations, by S. W. Doty and L. D. Hall, 1916.

ritory and should be equally successful in the Salt River Valley, where marketing conditions are not essentially different.

POTATOES The production of potatoes for market is not an important activity in this district. Most of the crop is produced in the sandy loam soils near the Agua Fria River, west of Glendale. The crop is marketed during the month of June as a rule. In 1917 the commercial movement started during the first week in June and ended about the middle of July. Most of the crop moved during the last two weeks in June. Yields vary with seasonal conditions and in the past have ranged from 30 to 100 bushels per acre. In 1917 the yield was reasonably good and averaged from 80 to 100 bushels per acre. The usual field is about 25 acres in extent, although fields in 1917 ranged from 10 acres to 160 acres each. About 90 per cent of the crop is grown by a dozen growers in the territory mentioned above. The potatoes are loaded in sacks holding from 95 to 110 pounds each and shipped to market in decked cars. Practically all shipments from this section are decked, except local shipments to mining towns within the State, where the average time in transit is from 24 to 48 hours. Refrigerator cars are used for shipping purposes. In 1916 38 cars of potatoes were shipped from Valley points, while in 1917 the commercial movement was 115 cars.

Marketing conditions in 1917 were fairly characteristic of average conditions and may well be discussed at some length. The writer secured a complete financial statement covering the commercial handling of 83 cars out of the total of 115 cars shipped in 1917. The first car rolled on June 9, while the last car went forward on July 12. No preliminary arrangements were made by the growers for disposition of their crop and at the last moment the producers, in lieu of a better arrangement, collectively entered into a joint contract with two local commission houses, who agreed to handle the growers' potatoes on joint account. The contract was a very loosely-worded agreement which laid no specific obligations on either party. It was, in fact, a rather indefinite Memorandum of Agreement rather than a bona fide contract. According to its provisions the potatoes were to be handled by the two local firms on a commission basis. It was understood that these firms were to attempt to secure prices for Valley potatoes which would be equivalent to those secured by California growers who were shipping at the same time. The selling agencies were not obligated to secure such returns, however, but merely agreed to use their best business judgment in disposing of the crop. Their remuneration was to be 7 per cent of gross sales.

Notices and quotations were sent by mail or telegraph to prospective buyers in Arizona, New Mexico, Texas, Colorado, Oklahoma and Kansas. A large number of replies were received and the preliminary outlook was very favorable. The first cars were sold on order f. o. b. Glendale, subject to inspection by the purchaser on arrival. These first cars were billed out at from \$3.50 to \$3.75 per 100 pounds f. o. b. Glendale. It soon became necessary to revise this selling plan and so arrangements were made between the two local firms and brokers in Denver and El Paso. At this point, it may be stated, that aside from 12 to 15 cars sold to buyers in mining towns in Arizona, all of the potatoes from the Salt River Valley were sold in El Paso or Denver, the shipments being rather evenly divided between these two points.

Shortly after the first cars were received complaints began to arrive, accompanied by claims for allowances. No inspection whatever was made at loading stations or in the field and so there was doubtless room for complaint by the buyers in many cases. There seems to have been no reason, however, for some of the excessive claims which were made later in the season other than that market conditions were weaker and buyers found losses staring them in the face. Practically all claims were allowed by the local firms who represented the growers. It was very difficult for these firms, operating as they were, to verify reports given by buyers, and in order to maintain an even demand all of these claims were allowed. Allowances made for various causes ranged from \$20.57 per car to \$613.75 per car. The total allowances made by selling agencies to all buyers for all purposes amounted to \$14,046.12 on the 83 cars.

Final records showed that the 83 cars nominally billed out at \$71,249.47 f. o. b. Valley points, after commissions, brokers' fees and decking costs had been deducted, actually returned \$51,534.00 to growers, equivalent to about \$2.15 per 100 pounds. This heavy loss was chiefly due to lack of inspection when the cars were loaded. A second important factor was the inadequate protection afforded the growers against unjust claims for damages. Some loss was also caused the growers because rates on potatoes from the Salt River Valley to El Paso were higher than rates from Southern California to the same point. The freight differential in favor of Southern California shipments amounted to 12½c per 100 pounds and in order to compete actively in El Paso with Southern California offerings, it was necessary for the Salt River Valley growers to allow 12½c per 100 pounds on sales made in that city to cover freight differences. It estimated that had there been adequate inspection before shipment, and had the growers been afforded proper protection against unjust claims for damages, fully $12.000 could have been saved to the shippers on these 83 cars alone.

Experiences in 1917 and during previous years have indicated that individual action by the growers is usually disastrous. Since practically all of the potatoes are produced by about a dozen growers in a very limited district it would seem feasible to organize a small potato shipping association, organized for the purpose of consolidating the output and handling the crop as a unit. It does not appear expedient to recommend that the growers attempt their own selling. A potato shipping association, however, would have a sufficient quantity of marketable potatoes to enable it to contract for the marketing of the entire crop with some reliable potato-selling agency, who could and should enter into individual contracts with the members of the association to handle all potatoes on a commission basis This contract should obligate the sales agency to furnish complete inspection services at loading platforms and this agency should also undertake a certain amount of educational work among producers during the digging season in order to insure the harvesting of good commercial stock. By the terms of this contract, the potato growers should be obligated to dispose of all their potatoes for the season through the agency with whom the contract is executed and should also be required to accept the judgment of the agency's inspector at the loading platform. Because hot weather usually prevails at harvest time it is very desirable that Salt River Valley potatoes be dug as early as possible, be carefully sacked, and rolled to market as rapidly as possible. If these conditions are fulfilled, and an adequate inspection service is offered, there is no reason why the potato crop from this section should not be permanently profitable.

Lettuce The lettuce crop ranks next in value to cantaloupes as a speculative crop. The acreage has varied greatly from year to year in response to the stimulus of changing prices. Practically all of the crop is produced in the vicinity of Glendale and shipped from that point. In 1917 about 225 acres were grown. Most of this acreage was seeded to the New York Head variety, although some of the Boston Head variety was grown in a relatively small way. Individual acreages varied from 2 acres to 20 acres. In 1917 about 100 carloads were shipped. Less than 10 per cent of the total crop is marketed within the boundaries of the State of Arizona. The great bulk of the movement is to the large markets East of Denver, notably Kansas City, Chicago, Cleveland, Pittsburgh and New York.

The lettuce growers afford the best example of co-operative effort in the Salt River Valley. Until late years the lettuce industry has been on a very unsatisfactory basis and attempts to market the crop independently have been almost uniformly unsuccessful. The crop in 1917 was handled in a way which was distinctly creditable to the growers who had organized for marketing. The United Produce Growers' Association of Arizona handled all of the lettuce from the Valley, with the exception of 5 or 6 cars assembled by local commission houses.

This association is a regularly equipped stock corporation with an authorized capitalization of $50,000, divided into 5,000 shares of preferred stock and 5,000 shares of common stock, all of which has a par value of $5 per share. The purpose of the common stock was to raise a fund of $25,000 from outside sources, mainly from business men and others interested in the development of the trucking industry. This stock is a non-voting stock and also a non-dividend-earning stock. After the association was fairly started and a number of shares of common stock had been sold, it was decided to withdraw this class of stock from the market, as it was felt unnecessary to have such a large capital available. The preferred stock is offered to growers only and constitutes the voting stock of the corporation. Sales are limited to one share to each grower and in turn each grower who intends to utilize the services of the association for marketing must be a shareholder. The funds resulting from the sale of this stock constitute the capital which at present is required to transact business.

It was the intention of the organizers to divide this association into distinct sections, each administering its own functions and duties and nominally connected with the central association known as the United Produce Growers' Association of Arizona. The lettuce section, however, is at present the really active section, although about 80 or 90 cars of cantaloupes were handled by the association in 1917. Some deciduous fruit was also shipped by this association in 1917, although the cantaloupe and deciduous fruit sections were not organized on exactly the same basis as was the lettuce section. As a matter of fact, the association operated as one association in 1917 for the conduct of all its business, and, strictly speaking, the plan of dividing the association into sections was not in effect in 1917.

The business operations of the association are conducted through a Secretary-Treasurer, an executive committee of five members, an acreage committee, a crate committee and a seed committee. In the past the Secretary-Treasurer has been the chief business officer of the association. The acreage committee inspects land which it is proposed to plant and is expected to act in an advisory capacity toward the growers. The crate committee is charged with the duty of arranging for containers for shipment of the crop. The seed committee confines its attention to arranging for a suitable supply of seed and the executive committee, of which the Secretary-Treasurer is a member, maintains a general oversight of the business and during the shipping season allots consignments to the various produce houses with whom connections have been established. The Secretary-Treasurer is the only salaried member connected with the association. In 1917 an inspector was employed by the association to supervise harvesting, packing and loading.

The small quantity of lettuce sold in Arizona and New Mexico is shipped in express lots and sold f. o. b. Glendale. Practically all of the lettuce shipped locally is sold on standing order and statements are made on a weekly or monthly basis, according to preliminary arrangements. The great bulk of the crop moves to the Eastern markets in carloads and is handled entirely on a consignment basis. Reliable commission firms are selected in several of the principal markets. The regular commission of 10 per cent is paid to these representatives. In 1917 the association was represented by firms in Kansas City, Cleveland, Indianapolis, Chicago, Pittsburgh and New York. The association has definitely decided that it will not sell on an f. o. b. basis subject to inspection on arrival at destination. Careful inspection, both in field and at the loading platforms, was in practice in 1917, and no lettuce was shipped which was not of superior quality, and well graded and packed.

A two-tier ventilated crate peculiar to this district has been used with considerable success. This crate is paper-lined and contains from 24 to 40 heads. Early shipments in 1917 were pre-cooled in a small pre-cooling plant and were then loaded into iced cars and rolled to market at once. With the advent of warm weather during the middle and latter part of the season, however, it was found desirable to pack the lettuce with cracked ice between the two layers in each crate. In addition the refrigerator cars were iced well in advance of loading and the thoroughly chilled lettuce was shipped at once. The results of this careful attention were accurately reflected in the returns which the growers in this district secured in competition with lettuce growers in other districts.

Up to and including April 17, 1917, 61 carloads had been shipped to eastern markets and 3,233 crates equivalent to about 8 carloads had been sold locally in Arizona and New Mexico. The first 61 cars were distributed to Kansas City, Cleveland, Pittsburgh, Philadelphia, New York, Chicago and Denver, more than one-half of this number going to Kansas City, Chicago and Pittsburgh. From April 17 to the close of the season about 39 additional cars were shipped, in addition to moderate express shipments to the mining towns of Arizona. Marketing conditions during the early part of the season were very favorable and because of their excellent pack and grade the growers secured some attractive returns. The first 21 cars which rolled to market returned to the growers a total of $14,732.99, or an average f. o. b. return per crate of $1.57. Returns for the next 40 cars were not so high, ranging around $1.00 per crate, but still netting a fair margin of profit. Near the close of the season, however, there was a decided slump in market prices, caused by heavy offerings from other sections. The unexpected drop in market prices found the association with more than 20 cars in transit and some unfortunate losses were sustained, which partially offset the large profits made earlier in the season.

In addition to offering a sales service the association furnished to growers during the season more than $8,000 worth of supplies. These supplies were secured in large lots and re-sold to growers at prices below those which they would have had to pay on independent purchases. Considering the volume of their business and the speculative nature of their product, it is doubtful whether it will be possible for the lettuce growers greatly to improve their system of marketing. It is impossible to remove entirely the hazards connected with the marketing of a perishable crop like lettuce. On the whole, however, these growers have worked out for themselves an excellent and efficient system of marketing when it is considered that their output is limited and their association a small one. The success of this association has been an encouragement to those who believe that co-operative effort will solve the marketing problems of the Salt River Valley.

MISCELLANEOUS About 56 cars of watermelons were shipped in 1916 and 78 cars in 1917. This crop is produced in the vicinity of

Phoenix and is handled through the Union Melon Growers' Association. This organization has headquarters at Phoenix and while not in the strictest sense of the word a farmers' co-operative marketing association, is nevertheless an organization for the purpose of consolidating watermelon shipments. The marketing of this crop is purely a local problem and, as the following table will show, practically all of these melons were sold in Arizona and New Mexico:

TABLE VI DESTINATIONS OF WATERMELON SHIPMENTS IN 1917

Destination	*Number of Cars*	*Destination*	*Number of Cars*
Gallup, N. M.	22	Globe, Ariz.	4
Albuquerque, N. M.	7	Bisbee, Ariz.	4
Douglas, Ariz.	5	Other Arizona Points	22
Prescott, Ariz.	5	Other N. M. points	5
Flagstaff, Ariz.	4		

Except for supplying Arizona and New Mexico, it is doubtful whether watermelons ever will be produced in surplus quantities in the Salt River Valley. This crop differs materially from the cantaloupe crop in this respect, since the latter is a fairly important factor on the large markets of the United States.

Less than 100 acres of grapes are grown in the Salt River Valley. Most of these are of the Thompson Seedless variety and are ready for market in advance of the offerings of California table grapes. The commercial acreage is in the vicinity of Mesa, from which point about 9 cars were shipped in 1917. Some of these grapes are sold locally in the Valley, but many of them move to large Eastern markets, notably Chicago. The marketing is largely on a consignment basis.

Dates are perhaps the most interesting of the special crops in the Valley. The principal orchard is near Tempe and is controlled by the University of Arizona. In addition, there are small quantities of edible dates produced incidentally on many of the farms in the Valley. It is difficult to ascertain the total acreage in dates outside of the Tempe orchard, which is the only important commercial orchard in the Valley. The latter contains about 10 acres of bearing palms and produces a wide range of desirable varieties. The Hayani and Rhar are among the more important of the so-called soft varieties, while the Deglet Noor is an interesting example of the harder date, which matures later in the season.

Dates from palms owned by farmers over the Valley are all sold locally in the towns in the Valley. Most of the output of the Tempe

Fig. 6—Bearing date palms in the Tempe orchard.

orchard is also sold in the Valley, although considerable quantities were shipped in small express lots of from 2 to 15 pounds to eastern markets in 1917. Many of those shipped out of the State, however, were sold on orders placed in the Valley. The 1917 crop was packed in ordinary berry cups holding one pound each. After being hand picked, the fruit was pasteurized for a short period and then packed in layers into square berry cups which were lined with paper, topped with an attractive, colored lithograph and tied with colored fiber ribbon. These small baskets were then placed in crates holding from 2 to 15 pounds and were ready for shipment. Practically all of the crop in 1917 was sold at a uniform price of 20 cents per pound packed at the orchard. The dates retailed on the local markets in Phoenix, Tempe and Mesa at from 30c to 35c per pound. No attempt was made by the management of the orchard to secure higher prices, since this orchard is maintained for experimental purposes. The demand far exceeded the supply in 1917 and the same condition has prevailed in previous years. The date crop in the Valley is normally an excellent one, while the market is always active. The only real limitation to the expansion of this industry is the difficulty of securing a suitable number of offshoots of desirable varieties. It requires some care and experience to get a young grove started, but having once become thoroughly established the date palm is easy to care for. Should it be possible in the future to import any real quantities of desirable offshoots from the Orient, it is probable that there will be a decided expansion of date growing in the Valley.

In 1917 about 475 acres were devoted to olives, while a number of young groves have been set since the beginning of the season. The olive does well in the Salt River Valley, but the production of this commodity is relatively small. Practically all of the crop is sold locally to pickling factories, which normally put up considerable quantities of this product. Most of the crop is pickled in a ripe or semi-ripe condition.

THE MARKETING PROBLEM AS A WHOLE

Present and Future Outlets Agriculture in the Salt River Valley has not been built around a national market and producers have not learned to consider the distant market as a logical outlet for any great quantity of their produce. In this respect this district is more or less unique among the important irrigated districts in the far West.

While it is not entirely accurate to state that the local or State market is the principal one for products from this area, it is true nevertheless that the local market plays a much more important part than in many other irrigated districts.

Of late years, however, there have been certain exceptions to these generalizations. During the past two years approximately 20 per cent of the commercial hay crop of the Valley, which was marketed in carlots, moved to points in Texas and over the international border into Mexico. The growth of the cotton industry has caused a corresponding decrease in the production of crops which normally are marketed in Arizona and New Mexico. The cantaloupe crop also furnishes relatively large quantities of a product more than 85 per cent of which is marketed at points from 1,500 to 3,000 miles from origin. Probably 75 per cent of the lettuce and potato crops annually find a market beyond State borders. In the future there doubtless will be a reasonable expansion of trade with markets more distant than those to which Valley farmers have become accustomed. The increase in the cotton industry, exemplified by the large acreage planted in 1917, will doubtless be responsible for an important increase in the value of products which move to distant markets.

The local and State markets for products from the Salt River Valley never have been fully appreciated by producers. These markets are at present among the most important outlets for Valley products and in future years will continue to be profitable consuming centers of an increasing quantity of farm products from the irrigated districts of the State. These markets at present use all of the grain products produced in the Salt River Valley and in addition import large quantities of feed and mill products from points outside the State. Most of the hay crop in the Valley which is baled for market is sold in mining towns throughout the State. Similar towns in New Mexico offer the next best outlet for hay. More than 90 per cent of the dairy products in the Valley are consumed within the States of Arizona and New Mexico, the mining towns of Arizona taking the greater portion of the surplus from the Valley. While the deciduous fruit output is very limited most of the commercial crop which is not used within the Valley itself is shipped in express lots to the mining towns of the State, where in the past it has been disposed of at prices satisfactory to the growers. Large quantities of meat products are also consumed by these towns. In contrast to the cantaloupe crop, practically all of the watermelons produced in the Valley are sold either in Arizona or New Mexico. Large quantities of miscellaneous farm products are produced in a small way in the Valley which have a considerable aggregate value and which are sold within the State. The very fact that these products are produced in small individual lots makes it imperative that the local market be utilized as extensively as possible.

The advantages of the local markets of the State should be obvious to the small producer in particular. As a rule, these markets desire good commercial packs and grades, but are not so insistent on fancy packs and careful grading as are the larger markets further East. The comparatively short haul necessary to place products in these markets, coupled with the correspondingly small express rates, have made these markets seem attractive to the small shipper. As a matter of fact, the mining towns, while consuming large quantities annually, prefer to have their products in relatively small quantities at regular intervals. Except for a few of the staple products they are important as l. c. l. markets and are so used by producers.

It is doubtful if many of the shippers who use these markets realize the total quantities which they ordinarily consume. In 1916 10 small mining towns, selected at random along one railroad north of the Valley, used a total of 251 cars of flour and feed. During the same year four of these same towns used a total of 60 cars of fruits and vegetables, in addition to the large quantities of these products received in less than carload lots. Again referring to 1916 figures, it is found that 10 of these towns used 445 cars of hay, while during the same year 18 towns along this line used a total of 161 cars of grain. All of these towns have relatively small populations and are not among the important mining centers in the State, which use still larger quantities of all classes of farm products. The volume of business handled in some of the larger towns may be inferred from the statement that in 1916 about 222 carloads of fruits and vegetables were unloaded in Bisbee alone, exclusive of the large quantity which came to this city in small lots. Records show that the mining district around Ray received 30 cars of fruits and vegetables from Phoenix during the first nine months of 1917. The above figures have been selected more or less at random in order to emphasize the fact that the importance of the mining towns in Arizona as markets should not be underestimated by the producers in any part of the State. As a matter of fact, these towns secure only a small fraction of their products from the Salt River Valley. Most of the fruit and vegetable supply of these towns comes from California and other surrounding states, while considerable quantities of flour, feed and other staples also come from points outside the State. This condition has been brought about because buyers in these towns have learned that they cannot rely upon the Salt River Valley for a dependable supply from season to season. Negotiations in the past with Arizona producers and shippers have been rather unsatisfactory and buyers have learned to look elsewhere for their supplies.

Enough has been said to indicate the possibilities which are open to the producers of the Salt River Valley through the expansion of what might be termed the local market. It is probable that double the present quantity of Valley fruits and vegetables would be used in the mining towns of the State if the producer were able to guarantee a reasonably dependable supply and could offer a product which would compare favorably with the output from California and other western districts. At the present time there is a very active market in these mining towns for grain, hay, flour and other staple products of the Valley and it hardly seems probable that this phase of the business is susceptible of as great expansion as is the traffic in more perishable commodities.

GENERAL PROBLEMS AND DIFFICULTIES Strictly speaking, the Salt River Valley is unorganized for agricultural marketing purposes. Development along these lines has been natural and gradual and not the result of any clear, well formulated plans. As a result, the present agricultural marketing plan of the Valley, if we may so dignify unorganized effort, is simply the result of individual enterprise working along strictly individual lines.

One of the most striking features of agricultural enterprise in the Valley is the wide range of production. Natural causes have contributed toward diversification. The results are exactly what might be expected. There has been little or no community of interest between producers from the very fact that crop and marketing plans have almost invariably been individual plans and resulting problems have been individual problems. This, of course, has militated against community effort and has caused postponement of co-operative action. The producers in this section are just beginning to realize clearly that there must be community action of some sort if commercial success is to be obtained. For example, while the total acreage in truck crops and deciduous fruits is fairly large, the crop scheme is so arranged that growers are not reaping the benefit of large-scale production. The total acreage in these crops is composed of a large number of small units, and is not as well centralized geographically as would be desirable for concerted action. There are, of course, certain well defined areas devoted to these crops, but in general we find small individual acreages scattered over almost the entire Valley. The individual grower finds that he does not produce enough to warrant carlot shipping and does not feel that returns from outside markets offer him a sufficient margin of safety. As a result the local Valley markets are usually oversupplied for short periods, while excellent outside markets are untouched because the individual cannot obtain the carlot rate on his small output.

Another factor which has greatly hindered efficient marketing is the seasonal change in the acreage of each crop. It is nearly impossible for growers to organize for marketing when the man who grows 20 acres of wheat this year will produce no wheat next year and his neighbor, who may have grown no grain for 2 or 3 years, suddenly enters the field for one year as a producer of, let us say, 40 acres. Thus, it happens that one man is actively interested in a certain crop this year and his interest next year in the same crop may be passive because he has reduced or entirely eliminated his own acreage. This condition of affairs may not at first appear to be productive of serious results, but, as a matter of fact, it exemplifies one of the most difficult problems in the Valley.

If individual production were fairly stable or well standardized it would be possible to assemble the producers of certain communities for definite, concerted action. As conditions are at present, however, the membership of any association organized for the purpose of caring for specific crops, of necessity would change its membership to a considerable degree each season. The acreage in certain crops, notably alfalfa and fruit is a fairly constant quantity from year to year. The individual acreage in almost all other crops, however, is dictated largely by individual fancy or preference and up to the present time this individual preference has borne no relation to prospective community action for the purpose of marketing. In other words, it does not occur to the farmer who contemplates planting 10 acres of potatoes next year or who may contemplate reducing his potato acreage to that figure, that this decision has any relation to beneficial co-operative effort on the part of his neighbors. The following table compiled by the United States Reclamation Service and applying to the Salt River Project, which in turn comprises about three-fourths of the irrigated territory of the Salt River Valley, shows the seasonal changes in total acreages for different crops, but does not show the decided changes in individual acreages for the same crops.

TABLE VII ACREAGES OF PRINCIPAL CROPS ON SALT RIVER PROJECT

Crop	*1913*	*1914*	*1915*	*1916*	*1917*
Alfalfa	86,930	86,733	83,006	84.355	67,964
Barley	24,946	17,066	16,459	13,295	9,309
Beans	1,623	567	1,111	710	1,425
Cotton	4,545	11,501	2,160	6,033	23,444
Corn	1,889	2,315	1,193	984	1,851
Cantaloupe	981	1,846	1,604	1,584	2,096
Fruit, citrus	707	707	1,054	1,259	967
Fruit, deciduous	1,436	1,246	1,944	1,248	1,250
Milo maize, etc.	22,572	12,651	26,260	28,589	25,471
Oats	2,399	1,930	3,374	1,433	900
Olives	133	133	135	487	500
Potatoes	478	232	267	381	373
Wheat	9,493	9,744	11,230	10,081	3,794
Watermelons	350	826	462	262	426

It will be noted that there has been a fairly pronounced variation so far as total acreages are concerned. This is important as indicating the variable quantities of farm products which must find a market each year. The totals indicate, to a certain degree, the problem which outside buyers must face when entering the Valley as commercial factors. One of the most important considerations to the prospective buyer is the possibility of securing a uniform quantity season by season. Where both individual and total acreages vary to as pronounced an extent as they do in the Salt River Valley, the outside buyer finds it difficult, if not impossible, to adjust his business to care for fluctuating supply. He prefers to turn elsewhere to districts which will furnish a dependable annual supply. This one fact alone probably has operated to a considerable extent to keep Salt River Valley products from the local mining town markets of the State.

The size of the average farm in the Salt River Valley bears a certain relation to the commercial problem. This territory has never been one of bonanza farming. There has been in the past a number of large holdings, aggregating several thousand acres each. The individual holdings, as a rule, have been comparable to those throughout the more intensively farmed sections of the Middle West. According to the provisions of the Reclamation Act, which apply to all lands within the boundaries of the Salt River Project, the individual holdings must be reduced to a maximum of 160 acres for each owner. This tact has served in itself to break up the larger farming units into farms which could be handled by resident owners. Some large individual acreages have been developed in the outlying districts, where water rights are independent of the restrictions laid down by the Reclamation Act. Records of the Salt River Valley Water Users' Association show that on an ownership basis the average individual holding on the Salt River Project approximates 58 acres. Many tracts are subdivided among several tenants, who in turn operate these subdivisions as separate units. Data compiled by the United States Reclamation Service in 1917 indicate that 4,342 farmers (both owners and tenants) operated 196,586 acres on the Project, or an average of 45 acres to the individual.

Thus it will be noted that individual holdings, while not extremely large, are sufficient to permit general farming. Until the average holdings fall below 40 acres, it will not be necessary to resort to specialized forms of agriculture in order to provide an adequate labor return.

Tenant farming also had a decided influence on commercial prospects. Referring to records compiled by the United States Reclamation Service, we find that, according to the 1917 report, 41 per cent of the farmers on the Salt River Project are tenants. The form of tenantry varies. Some of the tenants operate on a share basis, while a large number operate on a cash rental basis. The latter form was particularly prevalent in 1917 among the newer cotton growers and, because of the prospects of large financial returns, good cotton land rented in 1917 at from $15 to $25 per acre, the average rental being $20. Tenant farming has made it difficult to organize for commercial purposes on a permanent basis. The tenant farmer who has no sure tenure naturally does not manifest the requisite interest in building up a permanent producers' organization when his membership in such an organization may be short lived. Proper financing of such an organization is more difficult with the tenant farmer than with the permanent land owner.

The human factor presents one of the most difficult problems in connection with the betterment of market conditions in the Salt River Valley. This problem is a more or less intangible one and is not subject to a careful statistical analysis. At the present time individualism is still the key note of communal conditions in the Valley. Many of the present producers have come from other districts into the midst of conditions that are more or less strange to them. As might be expected, this fact has reacted adversely on any tendency toward co-operative action. The primary weakness of widespread individual action in a district where conditions demand community action is strikingly in evidence. It appeared from observation in 1917 that the individual idea is being replaced gradually and it is altogether possible that co-operative action in the near future will be as important a feature of commercial agriculture in the Salt River Valley as it has been in most other western irrigated districts.

The distance of the Salt River Valley from metropolitan distributing centers in some cases has given pause to prospective investors. The following table shows the approximate distance from Phoenix to the principal outside markets:

Table VIII Distance from Phoenix to Certain Markets

City	*Distance By Rail*	*City*	*Distance By Rail*
Los Angeles	499 miles	New Orleans	1,624 miles
El Paso	433 miles	Kansas City	1,487 miles
San Antonio	1,052 miles	Chicago	1,938 miles

It will be noted that the average distance from market is rather great and, at first glance, this problem would appear to be a most serious one. Its importance, however, is minimized when it is remembered that relatively small quantities of farm products are shipped to distant markets. The local and State markets have in the past contributed largely to the support of agriculture in the Salt River Valley, and as time goes on it is more than likely that these markets will increase in importance to the farmers in this territory and offer an outlet for still greater quantities of surplus products.

General Remedial Measures Previous discussions have indicated that the producers of the Salt River Valley are not facing a single problem, but are confronted with a series of problems which can be co-ordinated only with difficulty. It hardly seems desirable or feasible to advocate the formation of a series of farmers' co-operative associations for the purpose of marketing the many diverse crops in the Valley and having no general affiliations with each other or with a stronger central agency. In the first place, it would appear that these associations would lack the financial strength which is so desirable in an organization of this character. The overhead and operating expenses of the small association are also relatively heavy and probably a large number of producers would not be inclined to view with favor the prospect of sharing the expenses of such an organization. It also would seem that there does not exist the requisite commercial leadership for each set of producers unless general costs of operation are increased by the employment of skilled marketing assistance.

While the arguments against the formation of a large number of small organizations are difficult to overcome, it is at the same time desirable that some action be taken looking toward the consolidation of the output of certain commodities so that producers may benefit by marketing in relatively larger quantities than they do at present. For example, if the deciduous fruit growers in the Valley are to establish a reasonably satisfactory market for themselves, it will be necessary for their product to be assembled for market in larger quantities and that it be carefully inspected prior to shipment. The small livestock producer in order to benefit by prevailing market conditions must arrange for co-operative shipping with his neighbors. Marketing conditions among the potato growers in the past have been relatively unsatisfactory, but no permanent remedial measures can be adopted by these producers until their output is handled as a unit, so that systematic marketing plans can be adopted. But even the elementary co-operative action just indicated would need some stronger agency to advise and direct a movement of producers.

The rather sweeping statement already has been made that there is at present in the Salt River Valley no large and influential farmers' co-operative organization. This statement had reference to organizations for marketing purposes. Co-operative action along another line, however, has met with considerable measure of success. The Salt River Valley Water Users' Association is one of the most substantial farmers' organizations in the United States. This association was organized for the purpose of co-operating with the Government in securing a permanent water supply for the land in the Salt River Valley through the provisions of the Reclamation Act. The association has a present membership of about 3,500 and represents a total of 205,000 irrigated acres. It is a stock corporation regularly incorporated under the laws of the State of Arizona, with a capital stock of $18,000,000, divided into 300,000 shares of the par value and denomination of $60 each. The ownership of stock is confined to land owners and the division of stock is proportionate to the acreage owned. The association is permanent in nature, owns an office building in the City of Phoenix, and is amply financed, the charter providing for the maintenance of a treasury fund not exceeding $100,000, with which to care for emergencies. The membership of this organization includes the majority of farm operators in Maricopa County and so the association constitutes a very substantial nucleus from which to operate.

Investigation indicates that the participation of the Salt River Valley Water Users' Association in the marketing problem is eminently desirable from the point of view of the producer. The organization as already in existence, is capably managed and directed, and is financed more completely and thoroughly than any farmers' co-operative marketing association could hope to be. It would be possible for the association to provide a division designed to offer to the farmers of the Valley competent marketing advice. A marketing specialist might be retained and his duties outlined substantially as follows:

1. To advise with growers and growers' associations as to markets.

2. To negotiate for the sale of farm products on request of growers.

3. To investigate on request of growers any malpractices or dishonesty on the part of outside sales agencies with whom the growers may deal.

4. To advise with growers as to the provisions of any contracts which they may enter into with commission houses or other sales agencies.

5. To handle claims of growers against railroads for damage to goods or loss in transit.

6. To represent actively the combined growers of the Valley in securing fair and equitable freight rates on Valley products.

7. To assist actively in developing and establishing grades and standards for Salt River Valley products.

8. To publish a market review for distribution to producers, summarizing all market information of value to local producers.

It will be noted that the activities of such a division would cover a very wide range, while at the same time no obligations would be assumed by the growers except such as might be entered into temporarily for the purpose of arranging sales through the general division. The cost of such activities would be inconsiderable when benefits are considered, and the financing of this work could be handled in the same manner as is the financing of other special lines of work in connection with the irrigation system. The simplicity of such a plan is its strongest point and the fact that such an arrangement could be consummated through the association with no reorganization whatever should make the idea appeal to those who believe that marketing conditions in the Salt River Valley should receive the scrutiny and attention of someone competent to care for such matters.

CONCLUSIONS The commercial problem is one of the most important and is economically of such nature that it can be solved by the producers themselves. Briefly summarized, the principal problems are (1) the present inability of growers to supply dependable quantities to buyers who desire to negotiate for such products year after year; (2) the lack of grading and standardization which now prevails throughout the entire district and applies to practically all farm products; (3) the serious lack of consolidation of the annual output to enable growers to place surplus products in outside markets. The solution of the first problem will come with the stabilizing of cropping plans. It is an illuminating fact that the agriculture of the Valley is now actively in process of being standardized and within a comparatively short time it is altogether probable that a more or less permanent cropping system will be in effect throughout the Valley, because general conditions are making it necessary for producers to unify their plans. The question of better grades and standards, and plans for the consolidation of products for large lot shipping, will result from more complete co-operative action on the part of the farmers in the Valley, who will not be long in realizing that the individual can stand alone no more advantageously in the Salt River Valley than in any other district as distant from large markets.

The University of Arizona

College of Agriculture

Agricultural Experiment Station

Bulletin No. 86

Irrigation pipe with tongue and groove joint.

Machine-Made Cement Pipe for Irrigation Systems and Other Purposes

By G. E. P. Smith

Tucson, Arizona, October 30, 1918

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The Experiment Station offices and laboratories are an integral part of the University at Tucson. The Salt River Valley Experiment Station Farm is situated one mile west of Mesa, Arizona. The date palm orchards are three miles south of Tempe (co-operative U. S. D. A.) and one mile southwest of Yuma, Arizona, respectively. The experimental dry-farms are near Cochise and Prescott, Arizona.

Visitors are cordially invited, and correspondence receives careful attention.

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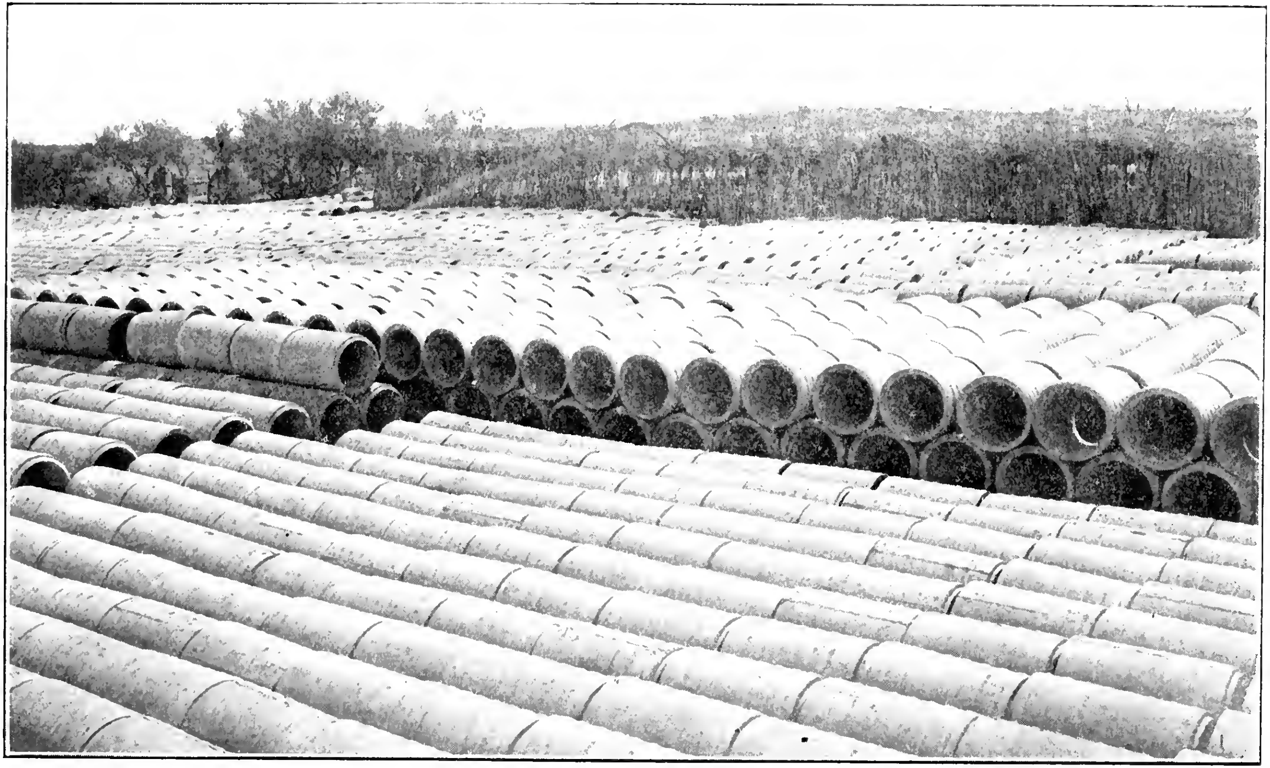

Stackyard at Continental, Arizona, showing also the "ramada" of brush, in which the pipe was cured for 36 hours.
Photo by W. C. Axelton.

MACHINE-MADE CEMENT PIPE

FOR

IRRIGATION SYSTEMS AND OTHER PURPOSES

By G. E. P. Smith

INTRODUCTION

Eleven years ago this Station published a bulletin on hand-tamped cement pipe.* At that time cement pipe was unknown in Arizona, while in southern California it was in disrepute owing to the many failures of pipe lines which had been laid about a decade before. The failures were due in some cases to unsound cement, and in other cases to insufficient cement or poor methods of mixing, tamping, or curing. Several machines which made and laid the pipe continuously in the trench had been tried unsuccessfully, and finally abandoned. However, a few pipe lines which had been well constructed of hand-tamped pipe, especially those built by Mr. Arthur S. Bent of Los Angeles, demonstrated the great possibilities of cement pipe for irrigation distributing systems. In preparation for the bulletin above referred to, the writer made considerable 15-inch pipe, using various mixtures, and studied the water-tightness and other characteristics, and as a result the bulletin strongly recommended the use of cement pipe for irrigation lines, sewers, culverts, ditch gates, drain tile, and underflow collecting systems.

Since 1907 a great deal of hand-tamped cement pipe has been laid in Arizona. At the present time several companies in the State are devoted to this work exclusively, and many farmers have purchased forms and made their own pipe. Arizona cities, however, continue to use clay sewer tile, although it is more expensive and is in some other respects inferior to cement pipe. In California the use of hand-tamped cement pipe has increased greatly, and it is estimated that over 5000 miles of such pipe have been constructed, effecting an enormous saving of water from evaporation and seepage losses in open ditches.

Meanwhile, there have been developed in the Middle West, notably in Iowa, some excellent machines for manufacturing cement

*Bull. 55, Arizona Agricultural Experiment Station, 1907.

tile and jointed pipe with great rapidity and at a low cost. These machines have been used chiefly for drainage tile, for which there is a great demand in Iowa and neighboring states, but at the present time they are coming into use for sewer pipe also. In the South-

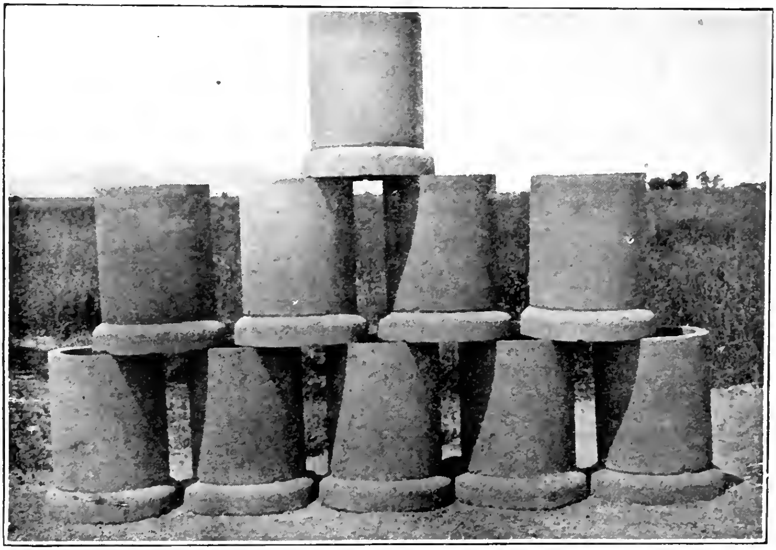

Fig. 2.—Stack of 15-inch cement pipe made by the irrigation department, University of Arizona, in 1907. (From Bulletin 55.)

west the need is for irrigation pipe and to a much less extent for drainage tile, sewer pipe and culverts. It now appears strange that this section has been so slow to adopt this valuable type of machinery.

In August, 1916, the owners of the Continental Ranch near Tucson decided to use cement pipe lines throughout the ranch for the distribution of irrigating water. The required sizes varied from 8 inches to 20 inches in diameter, and about 10 miles of pipe line were needed the first year. After a careful investigation of pipe machines by the writer and with the assurance of securing highly-trained expert operators, the machine-made pipe was adopted and a contract was let to a representative of the Sioux City Engine and Machinery Co., the manufacturers of the McCracken cement pipe machines. This gentleman had operated the McCracken machines for many years, and brought with him from Iowa two other experienced men; and, inasmuch as both cement and sand of excellent quality were available and were to be furnished at the machine by the owners of the ranch, it was believed that no risk was being taken.

Difficulty arose, however, in obtaining the necessary equipment, owing to pressure of business in the foundries of the Middle West, and work was not commenced until December 14, 1916. In the meantime, since it was necessary to have three miles of pipe line laid by February 1, 1917, a portion of the contract was taken away and re-let to a company making hand-tamped pipe. This company began work about November 28, and finished pipe-making January 9.

The conditions, therefore, were ideal for obtaining a comparison between machine-made and hand-tamped pipe. Both parties were experienced, both were using the same sand and cement, and both were curing their pipe under absolutely the same climatic conditions. The two methods could be compared as to speed and cost, and the pipe made could be compared as to strength, perviousness, and frictional resistance to flowing water. The tests were planned and partly carried out, but, unfortunately, an insufficient number of the hand-made pipe were held out at the time of laying. Some tests, therefore, were made only on the machine-made pipe. All tests made are reported later on in this bulletin.

In the fall of 1917 the town of Glendale, Arizona, voted bonds for a main sewer line and outfall sewer to New River. Bids were received under the specifications for both clay and cement pipe sewers. Although the specifications were more severe for the cement pipe, the bids on it were lower than for the clay pipe. The contract was awarded to the lowest bidder, who proposed to furnish pipe made on a Thomas-Hammond pipe machine. The machine was brought to Glendale from Los Angeles in October and was engaged in pipe-making for about four months. The laying was completed in May, 1918. Altogether the following list of pipe was delivered laid in the trench:

4,050	ft.	of	14-inch	pipe	
25,425	"	"	15-	"	"
3,450	"	"	18-	"	"

The great advantage of the use of cement pipe for irrigation conduits lies in the fact that the seepage and evaporation losses from open ditches are prevented. These losses are appalling. Dr. Samuel Fortier, Chief of Irrigation Investigations, U. S. Department of Agriculture, states that "a large percentage of the water, estimated at 40 percent of the amount taken in at the heads of the main canals, is lost by absorption and percolation along the routes."* These

*Bull. 126, U. S. Dept. Agr., 1914, p. 1.

losses in the Salt River Valley were reported in 1915 by the Reclamation Service as 45 percent, and in 1917 as 32 percent. For small canals these losses are often over 5 percent per mile in adobe soil and 15 to 20 percent per mile in porous soil. An extreme case is shown in Fig. 3. Here the entire flow is lost. The ditch has a valuable water supply at its head and the vain effort is made to hurry the water over the sand on a steep grade. When the photograph was taken, the last drop of water was sinking away near the willow tree shown by the arrow, while three miles away alfalfa and other crops dependent on this stream were drying up and dying.

In southern California there are extensive distribution systems

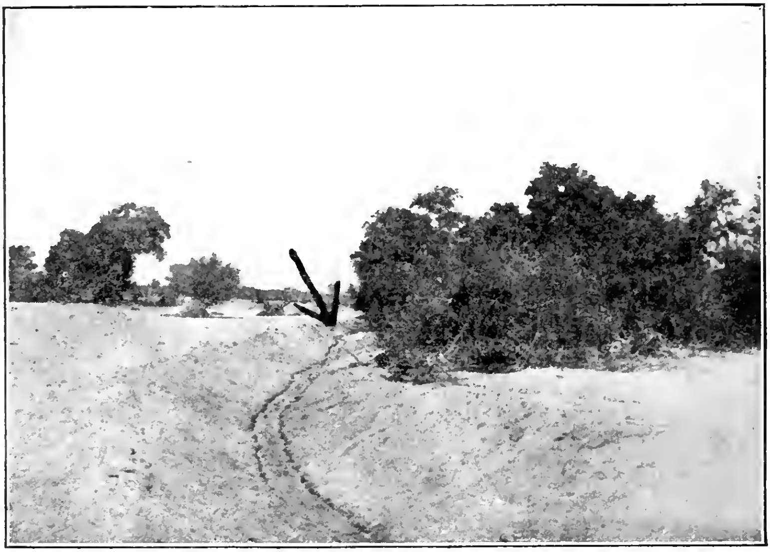

Fig. 3.—Small irrigation ditch near Tucson, showing loss of entire flow by seepage. (From Bulletin 55.)

that are piped throughout so that the loss of water in distribution is practically nothing. As a result of this and other economies the duty of the water is nearly nine acres per (Arizona) miner's inch of flow. The average duty of water in southern Arizona can be increased greatly by the use of cement pipe for small ditches and concrete linings for larger ditches and canals.

There are additional reasons for the use of cement pipe for irrigation ditches. The maintenance of open ditches is difficult. Under the subtropical skies of Arizona, weeds and algae grow rankly and occupy the whole cross-section of the ditch. Bermuda and Johnson grass thrive along the banks. Unless this vegetation is removed at frequent intervals, it obstructs and diminishes the flow. Ditch cleaning is very expensive. The small Flowing Wells ditch near Tucson, before it was lined, cost \$80 per mile annually for cleaning alone. In the Yuma Valley the cost of cleaning lateral canals by hand is about \$550 per mile. Furthermore, gophers perforate open ditch banks and cause the waste of rivulets for days or even weeks before the holes are repaired. Sometimes the holes enlarge, and the ditch bank breaks, with consequent loss of the entire stream. A break on the Turlock canal of California, in 1910, thought to have been due to a gopher hole, caused 1000 feet of the canal on a steep hillside to be washed out, and the canal was out of service for six weeks of the period of maximum need for water; the actual cost of repairs was \$20,000, but the damage to crops was estimated at \$1,000,000. The maintenance of cement pipe lines is so small as to be negligible.

Another reason for using cement pipe is that the distribution lines can be run through low places and over ridges; it is not necessary to follow grade lines, for the water can be carried under pressure through the low portions of the line. This makes it possible to square up the fields much better and to reduce the cost of grading. Less labor is required, also, to irrigate from pipe lines than from open ditches.

Again, there is a great saving of land. Open ditches occupy about one percent of the land, but the necessity for turning teams on each side makes the loss three or four percent. An open ditch is a great obstruction and interferes with farm operations. With cement pipe the loss of land is practically nothing.

Special effort has been made to investigate and report on the various causes of failures of pipe lines. As these causes become fully understood, designers and pipe men will so adjust their practices that the danger of failures will quite disappear.

Acknowledgment is hereby made to Messrs. A. L. Enger, F. C. Kelton, H. C. Schwalen, and F. W. Sharman for assistance in conducting the various tests of cement pipe, and to Mr. W. E. Code and Miss Hester Hunter for their services in proof-reading.

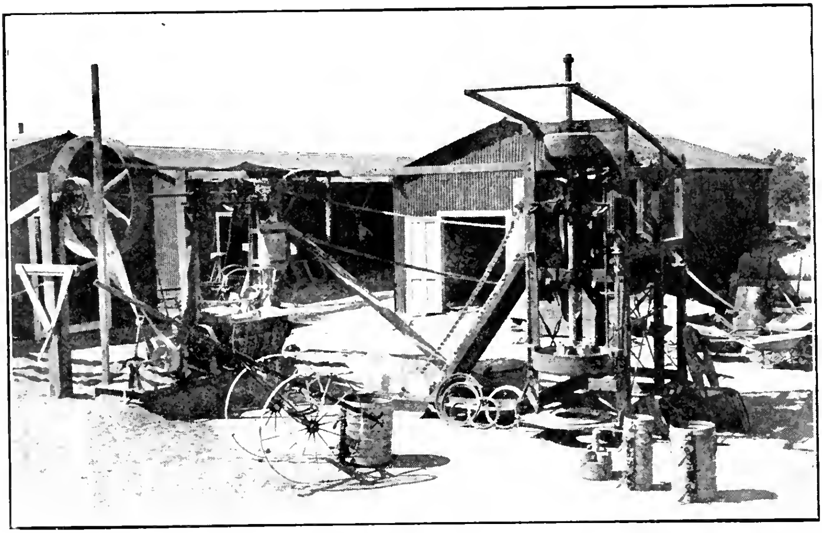

Fig. 4.—Cement pipe plant at Continental, Arizona, showing the McCracken No. 2 pipe machine and accessories, the mixer, the jack shaft, and the cement house. The ramada is located at the right.

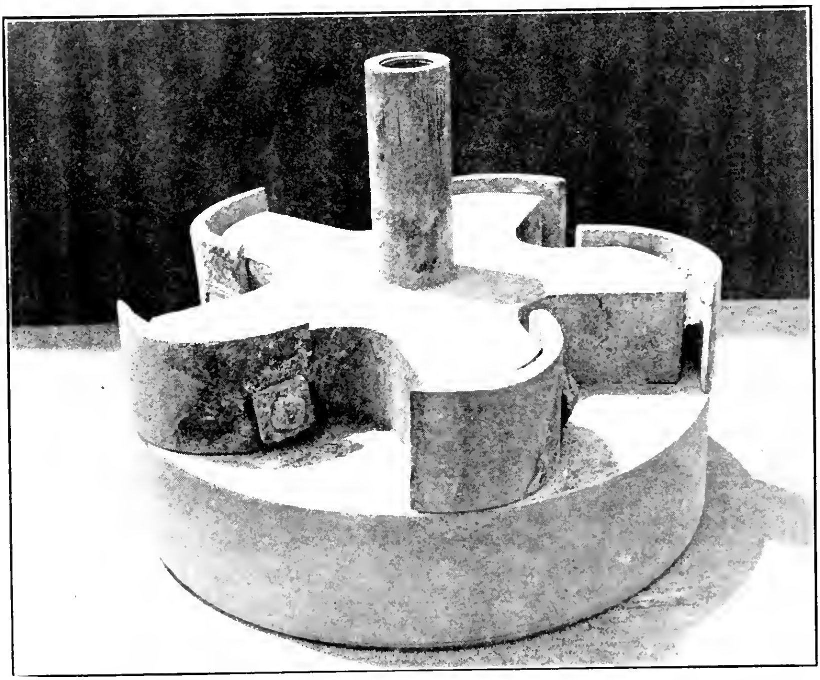

Fig. 5.—McCracken packer-head for 20-inch cement pipe. The five vanes are followed by the cylindrical trowel.

MANUFACTURE OF CEMENT PIPE

THE McCRACKEN PIPE MACHINE

The pipe machine at the Continental Ranch is known as the McCracken machine, after the designer. It is made at Sioux City, Iowa. A view of the machine and equipment is given in Fig. 4. A cut showing all features of the McCracken mechanism is shown in Fig. 6. The main frame is built of angle iron and is strongly braced. The frame of the No. 2 machine at Continental is 7 feet 6 inches long by 3 feet 8 inches wide by 10 feet high. The pulley shown at the extreme right is the main pulley, driven by belt, at a speed of about 225 R.P.M. The heavy vertical shaft at the front of the machine is called the packer shaft. It rotates at 330 R.P.M., meanwhile rising and descending through the pulley at the top. The vertical motion is given to the packer shaft by a powerful lever, hinged at the back and operated by a slow-moving crank on the large gear wheel. The outside form, or jacket, rests on a table, which is revolving for all sizes up to 14 inches, and is stationary for larger sizes. The cement mortar, after being transferred from a concrete mixer, is fed into the hopper seen at the extreme left. The mortar is carried up by the link bucket elevator and discharged through a chute into the pipe mold. The size and number of buckets is determined by the size of the pipe. The operation of the machine is controlled by a clutch on the main pulley.

On the lower end of the packer shaft is the packer-head, shown separately in Fig. 5. It consists of a cylinder made of the hardest grade of white iron surmounted by backward-curved vanes, either two, four, or five, depending on the size of pipe being made. The vanes (often called wings) catch the mortar as it falls into the form and plaster it rigidly against the form. The rotating cylinder, called the trowel, follows, and increases the density, and, at the same time, gives the interior of the tile or pipe a smooth uniform glazed surface. The packer rod makes 50 revolutions during each ascent. At least two sets of forms are used, so that while one is being used at the machine, the other can be taken to the curing shed, where it is "stripped" off from the tile and returned to the machine. Two-wheeled carriers with long handles are used for moving the tile, since even a 12-inch tile and mold are heavy, weighing about 150 pounds, and a 16-inch green tile and mold weigh about 240 pounds.

The operation, then, is to set a form, or jacket, on the table, rotate the table so that the jacket comes beneath the packer-head, and

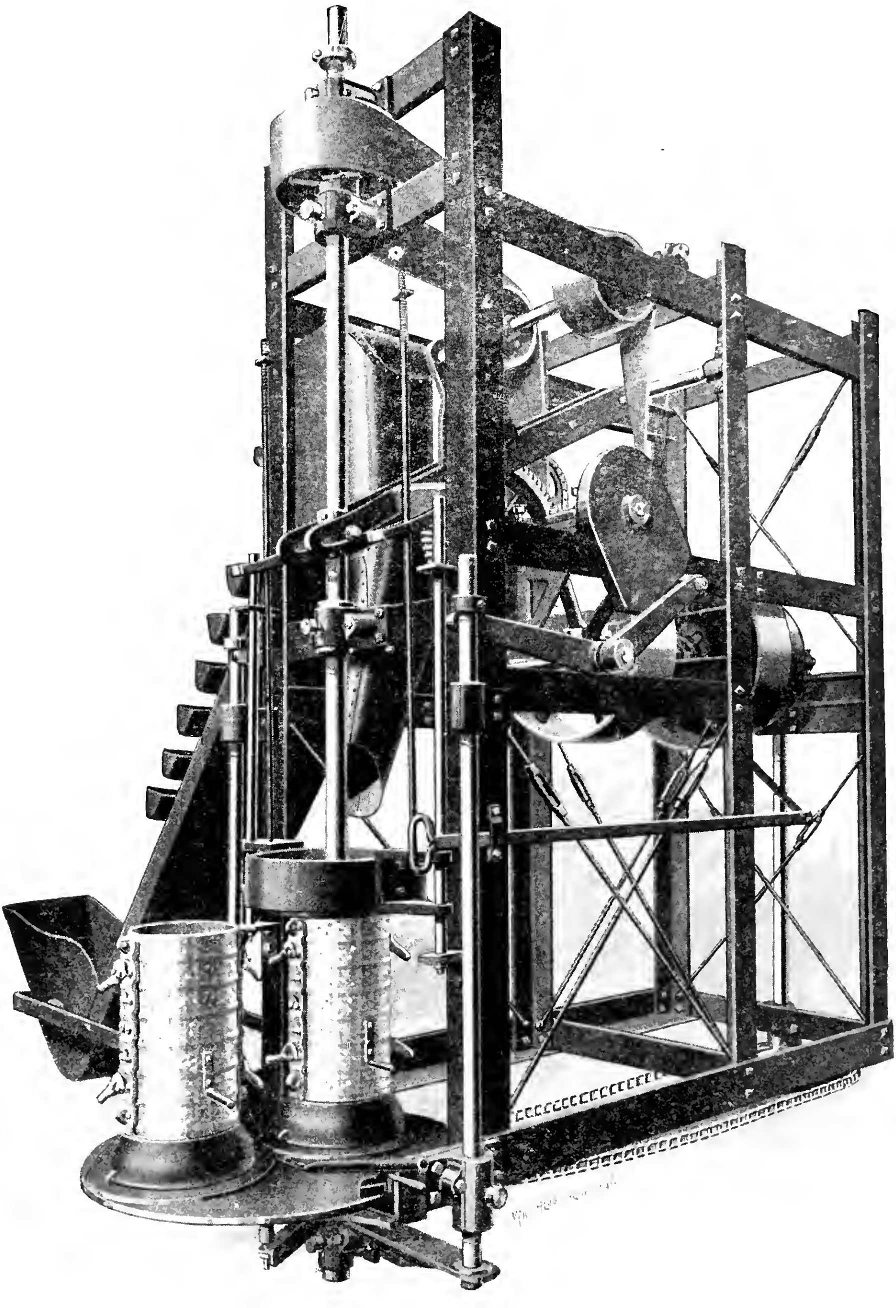

Fig. 6.—McCracken No. 3 pipe machine with equipment for bell-end sewer pipe.

start the machine, whereupon the packer descends to the table and then begins to rise again. Mortar is discharged automatically into the jacket, and the packer-head, beginning at the bottom, revolving and gradually rising, forms the mortar into a tile. In case a perfect tile is not formed, as happens occasionally, then it is "stripped" immediately and the mortar is shovelled back into the hopper again. Experience in handling the machine is of much importance; the selection and screening of the sand and the degree of wetness of the mortar are of even greater importance.

Fig. 6 shows the largest size sewer pipe machine, in which the table is turned, and a special bell packer at the bottom is operated automatically. The bell and spigot joint is shown in Fig. 7. In California and the Southwest, however, the bell and spigot joint is not much used, the tongue and groove joint being preferred. This joint is illustrated in the cover cut. The groove is made at the bottom by means of a small iron ring or pallet placed in the form, and the tongue at the top by an equivalent ring on the under side of the guide hopper. A great advantage of the tongue and groove joint is that the pipe can be laid in the trench much faster than bell-ended pipe. Also, there is less breakage in handling the tongue and groove pipe. There is no valid reason why this joint should not be used for sewer pipe as well as for irrigation pipe; indeed, it should be preferred in the interest of economy.

Fig. 7.—McCracken sewer pipe with bell and spigot joint.

Since the forms are corrugated, the outer surface of the pipe is corrugated. This probably adds to the strength somewhat, but the more immediate purpose of the corrugations is to prevent the tile from slipping from the mold while being carried to the curing floor. Corrugations on the inside, however, would be very objectionable, since they would reduce the capacity of a pipe line greatly.

The bottom pallets must be left under the pipe until the mortar is set sufficiently to permit turning the pipe over. If the pipe are cured in the open air, this requires from 24 to 48 hours, depending upon the season of the year. The pallets are released by a gentle tap of the hammer. Many pipe manufacturers in the Middle West cure the pipe in steam chambers, which accelerates the hardening process.

The thickness of the pipe recommended is given in Table I. The thickness of the drain tile is about one-twelfth of the diameter of the pipe, of the sewer pipe one-tenth of the diameter, and the thickness of the irrigation pipe is intermediate between the other two. If the irrigation pipe is to be subjected to considerable heads, it should be "one-tenth pipe."

TABLE I. THICKNESS AND WEIGHT PER FOOT OF MACHINE-MADE PIPE

Inside diameter	Drainage tile*		Irrigation pipe (for low heads)		Sewer pipe	
Inches	*Inches*	*Pounds*	*Inches*	*Pounds*	*Inches*	*Pounds*
4	...	...	...	...	...	...
6	...	...	...	...	...	...
8	¾	...	⅞	...	⅞	...
10	⅞	...	1	...	1	...
12	1	42	1⅛	47	1¼	52
14	1⅛	55	1¼	61	1⅜	67
16	1⅜	75	1½	82	1⅝	89
18	1½	92	1⅝	100	1¾	108
20	1¾	112	1⅞	120	2	128
22	2	141	2	141	2¼	159
24	2	153	2⅛	163	2⅜	185

The capacity of the McCracken machine per hour for irrigation pipe is about 300 feet of 6-inch pipe, 200 feet of 12-inch pipe, 120 feet of 16-inch pipe, and 80 feet of 24-inch pipe. Straight tile are turned out somewhat faster. The older machines make pipe of 24 inches length, but the most recent models make the tile or pipe 30 inches in length. The range of sizes for the No. 2 machine is from 4 inches to 24 inches in diameter.

A complete outfit consists of the machine, an engine or motor of 25 horsepower, a concrete mixer, and two-wheeled carriers; jackets, pallets, and packer-heads for each size of pipe which it is desired to make; and two sizes of elevator buckets.

The proportions for the mortar should be 1 cement to 3 sand, except for city sewer pipe and irrigation pipe under high head, for which the proportions may be 1 to 2¾ or 1 to 2½. In many cases pipe have been made of leaner mixtures, 1 : 4 or 1 : 5, but failures have resulted sometimes, and the leaner mixtures require better conditions of curing.

The force of men required to make pipe, as exemplified at Continental, is as follows: At first there were three skilled laborers,— the foreman, the machine operator, and the stripper; and five un-

*For very deep trenches, heavier pipe should be used.

skilled laborers,—the mortar maker, the mortar feeder, two carriers, and one man to sprinkle the pipe in the curing and stack yard. After all the laborers had become accustomed to their work, the foreman was dispensed with. While making 18 and 20-inch pipe two extra laborers were required.

To protect the freshly-made pipe from sun and rain, a shelter was built just to one side of the pipe machine. It was constructed of poles, branches, and river brush and is called, locally, a ramada. It is 65 feet by 75 feet in size. The frontispiece is a view of the pipe yard in August, 1917. It shows the ramada in the background.

OTHER PIPE MACHINES

The date of the first manufacture of cement pipe by machine is uncertain. Cement pipe was being used largely for sewers in Maine about 1870. An advertisement in an old directory of Maine of 1868 contains the commendation of a prominent architect who states that he had known of the use of cement pipe in Boston for 30 years. The pipe made by the advertiser, in the city of Portland, was of various sizes up to 18 inches in diameter, both circular and egg-shaped in section. It is claimed that this man had a machine for making pipe and that the principle of packing was similar to that of the Sanders machine described on page 86. At that time natural cement was used exclusively for the pipe, Portland cement being too costly, and probably the pipe was of very inferior quality.

THE SHERMAN

About 1885 the Sherman patent sewer pipe machine was designed and built at Omaha, Neb. It was moved from there to Brooklyn, where for twenty years it supplied that city with cement sewer pipe in great quantities. The machine employed the tamping principle, and was the prototype of the Thomas-Hammond machine described on page 84. The Sherman machine had eight metal tampers and an inside core which was pulled upward when the forms were filled. The outside form rotated with the table on which it stood. The smaller sizes of pipe, of 6, 9, and 12-inch diameters, were circular in section, and the larger sizes, 15, 18, and 24-inches in diameter, were of egg-shaped section, which is the ideal section for important sewers. All sizes had flat bases. The wall thicknesses were 1 inch for the 9-inch pipe, 1⅜ inches for the 15-inch pipe, and 1¾ inches for the 24-inch pipe. They were made of cement, sand, and broken trap rock in proportions 1 : 1½ : 2½. Much of the pipe was "carbonized" in kilns with coke gas and steam and it is said that three days in the kiln were equal to two weeks of curing in air. Prior to the advent of the Sherman machine, all the sewer pipe used in Brooklyn was made by hand tamping, using natural, or "Rosendale," cement.

THE SCHENK

A pipe machine which has been used extensively in Iowa and neighboring states is the Schenk, made at Waterloo, Iowa. This was the pioneer tile machine, the first one having been built in 1906. It was the first centrifugal packer, and, as might be expected, was troublesome to operate at first, but many improvements have been introduced and the Schenk has become entirely reliable.

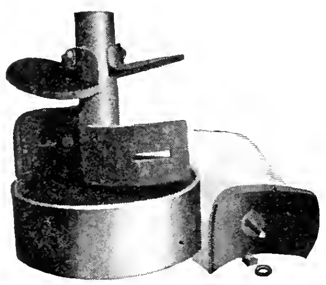

Fig. 8.—The Schenck packer-head, showing trowel and wings.

The principles of the Schenk machine are very similar to those of the McCracken, the differences being in the mechanical details. The packer shaft is rotated by gearing and is elevated by a lever the rear end of which is controlled by a heart-shaped cam wheel, which in turn is operated by worm drive from the main shaft. The original Schenk packer-head was shaped like an ordinary earthen jug, but the one now in use has vanes and a cylindrical trowel exactly like the McCracken.

The range of sizes possible with the regular No. 2 Schenk machine is from 4 inches to 18 inches, with lengths of either 12 or 18 inches. There is also a Schenk sewer pipe machine with range of sizes from 4 to 30 inches, and in length either 24 or 30 inches. The Schenk is said to be a very fast machine for the smaller sizes of tile. The manufacturers guarantee that it will make 3000 feet of 6-inch straight tile per day with six men. It is not known that they have yet furnished pallets for tongue and groove pipe, but doubtless would do so if the demand warranted it.

THE NATIONAL

A pipe machine, called the National, made at Boone, Iowa, differs from the two preceding in that both outside and inside forms are used and the mortar is tamped in place. It is adapted to making large pipe, particularly from 20-inch to 45-inch, though the range of sizes in the regular equipment is from 14 inches to 36 inches diameter. The lengths used are 24, 30, and 36 inches.

A view of the National pipe machine is shown in Fig. 9. The heavy steel frame is seen to carry a short main shaft (8) driven by pulley, and a long countershaft (6) at the top driven by chain. The countershaft operates two vertical tampers (4), which play up and down like trip hammers, alternately striking tamping blows, 350 per

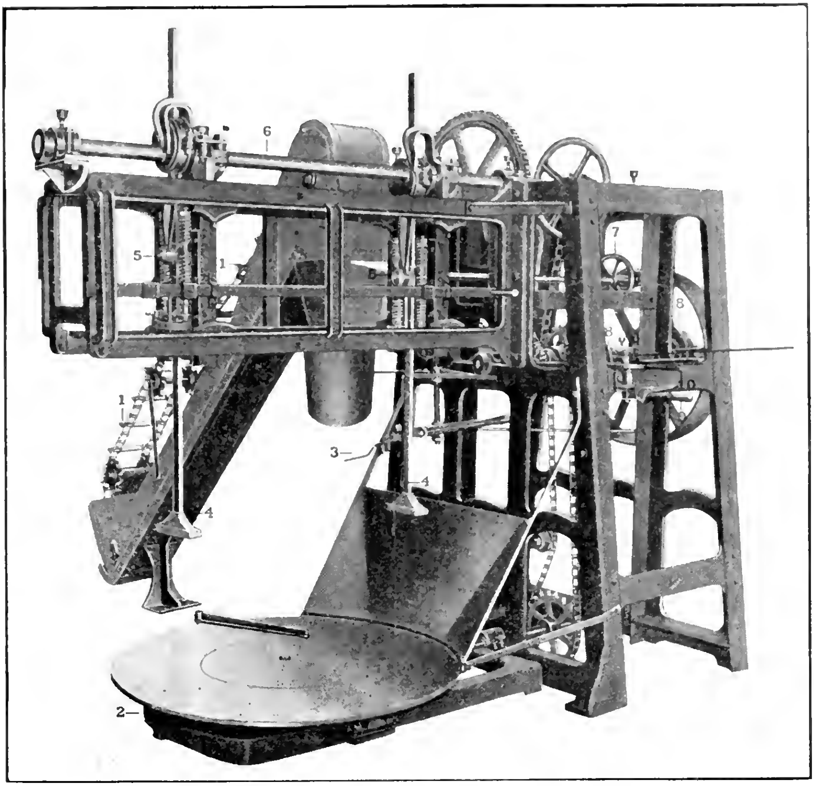

Fig. 9.—The National pipe machine.

minute each, with a force of 75 pounds. The tampers begin at the bottom and work up with the concrete. The table (2) on which the forms are set is rotated, bringing all parts of the tile under the tampers. The mortar or concrete is elevated (1) and dropped into the mold as in the other machines. Five horsepower is said to be required on the belt and a 10-horsepower gasoline engine is advisable.

The rate of output claimed for the National machine is 700 feet of 14-inch tile per day, 600 feet of 18-inch, 550 feet of 24-inch, and 350 feet of 30-inch. Eight men are needed for sizes up to the 20-inch and eleven men for larger sizes. The wall thicknesses of the pipe are the same or a little greater than those given in Table I. The mortar is mixed drier than for the McCracken, as otherwise the tampers work through it instead of on it.

One form of made-up reinforcement that has been used with the National machine consists of two rings of heavy wire, one close to the inside of the pipe and the other near the outside, the two rings being connected at intervals by wire spacers, all electrically welded. It is called double hoop reinforcement.

THE MONARCH

The manufacturers of the National also make the Monarch, which is similar in principle to the McCracken and Schenk machines. It has a solid heavy cast frame, surmounted at the top by a sort of walking beam which raises and lowers the packer shaft. The beam is attached to the shaft through a ball thrust bearing. The Monarch is designed for making drain tile from 5 to 20 inches in diameter. The table on which the smaller sizes are made has six stands for the jackets, so that the operation of the machine is very rapid. Two lengths of tile can be made, 12 and 18 inches.

THE THOMAS-HAMMOND

All of the preceding machines except the Sherman are made in Iowa. Another machine, the Thomas-Hammond, originated in Tacoma, Washington, in 1908. The product of the Thomas-Hammond machines is called "glazed cement pipe," and is accepted by leading cities on the Pacific coast for sanitary sewers.

Several changes have been made in the original design of the machine so that it is now much more compact, accessible, and portable. The newest model is now called the Hammond, and about a score of them are now in service. This machine uses the tamping principle, but, while the outside form and tile revolve under the tamper, the inside form stands still and serves to give the tile a smooth or glazed interior surface. The concrete is fed into the mold in a uniform stream and in layers about 1¼ inches deep. The tamper strikes 400 blows per minute, each blow being from 300 to 500 pounds, depending on size of pipe. The revolving table is so timed that the blows overlap. The tamper is of oak or hickory and rises automatically, due to the compacting of the concrete. When the forms are filled, the inner form is withdrawn and the outside form with the tile is taken away on a wheeled carrier. On the older machines the inner form was withdrawn downward, but in the latest models it is pulled upward. The older models have two tampers; the later models, one. The range of pipe sizes is from 4 inches to 30 inches in diameter on the largest of the three sizes of machines.

The pipe machine used at Glendale recently is a Hammond. Its construction is shown in Fig. 10. A vertical shaft is concealed in the heavy cast iron standard. This shaft operates the tamper which is carried on a swinging arm. At the bottom is a horizontal shaft which drives the vertical shaft and rotates the table on which the pipe is made. This shaft carries a winding drum, also, by means of which the inside form is withdrawn upward. The horizontal shaft is driven by a quarter-turn belt from a jack shaft above, and the jackshaft is driven from the main shaft which also drives the two-sack batch mixer and the endless belt elevator. A 20-horse-power electric motor furnished the power at Glendale.

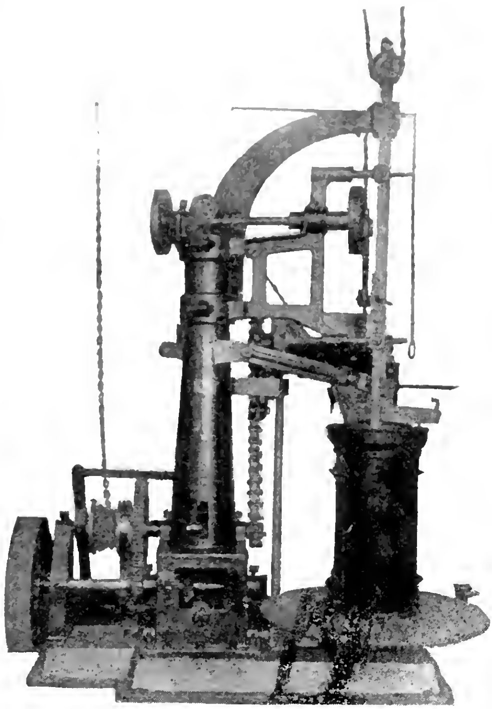

Fig. 10.—The Thomas-Hammond pipe machine.

The outside forms are of heavy steel, in halves, held with screw clamps. The inside form is a long cylinder with surface well polished by the rubbing to which it is subjected when a tile is being made. The Thomas-Hammond machine has been used mostly for bell-ended pipe and the Glendale specifications required bell and spigot joints. When the body of the pipe has been tamped full, a special form to make the bell is put in place, and the tamping is then continued. The pipe rests on a cast iron ring with three blunt feet. When a fresh pipe is wheeled to the curing space the bell form is first removed, then the outside forms, and a light galvanized ring is slipped onto the top edge of the bell, as otherwise its weight might cause the bell to slump off. The pipe is then left standing on its bottom ring for at least a day.

The pipe making crew at Glendale was composed of eight men. Only one man, the foreman, came with the machine, and great difficulty was had in breaking in green men, especially since the force kept changing. The best day's record of pipe making was 722 feet of 15-inch pipe, and the average day's run was from 575 to 600 feet. The pipe was cured in an open yard and was kept wet for seven days. It was hauled over rough roads to the line of trench but there was practically no breakage. Tests were made on about 100 specimens in a frame quite similar to that shown in Fig. 24. With the full pressure from the city main, about 30 pounds, none of the pipe broke and none of them showed any seepage, save a few small spots that became moist. The pipe were inspected carefully. A few, perhaps one percent, were rejected on account of burnt interior surfaces, short bells, or cracks, most of the cracks being at the spigot end.

THE ALLEN

The Allen machine has a revolving table and a tamper. Both inside and outside forms rotate with the table. The machine is designed for sizes from 3 inches to 24 inches in diameter. About six of these machines have been built, two of which have been in use at Phoenix for several years. It is understood that no more of these machines are being built.

THE SANDERS

More recently two more pipe machines have been put on the market in southern California. One is the Sanders, built by the Pomona Manufacturing Company and the other is built by Kellar-Thomason Company of Los Angeles.

The Sanders pipe machine has a steel frame work, the base of which is only 4 feet by 8 feet. This frame is mounted on four small wheels, so that the machine can be shifted around in the pipe yard or can be moved readily from one job to another. A 6 horsepower distillate engine is mounted on the back end of the frame and is belted to the main shaft located at the top of the frame, directly above the front end. The vertical packer rod is driven from the main shaft by beveled gears. The weight of the machine is approximately 1800 pounds and a 6-horsepower engine weighs about 1000 pounds additional.

The ordinary forms, consisting of core, jacket, and tongue and groove rings, such as are used for hand-tamped pipe, are used with the Sanders machine. Thus, a contractor who has an equipment of forms for hand-made pipe need not buy a new equipment. The packer is a long revolving cylinder which is lowered into the space between the core and jacket. On the bottom of the packing cylinder and held by rivets, there are three or more chilled iron flat-bottomed "shoes" which are tilted at a small angle. When the

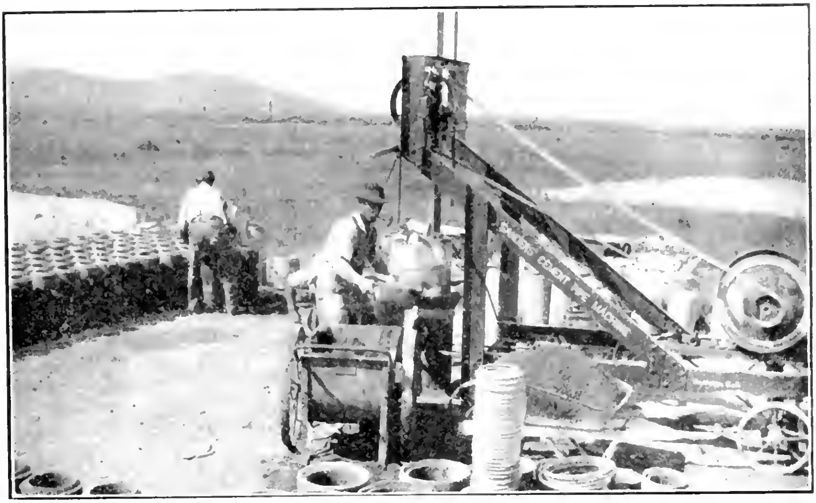

Fig. 11.—The Sanders (Pomona) pipe machine.

cylinder reaches the bottom, shovelers begin to throw mortar into the forms. The mortar accumulating and passing beneath the revolving shoes raises the cylinder and the mortar is packed into the form densely, the pressure being downward rather than outward as in the McCracken system. When the cylinder reaches the top it is held by a band brake while the table is rotated so as to bring another (empty) jacket under the packer, and the cylinder is then lowered again by partially releasing the brake. Meanwhile the top, or tongue, joint is made on the cement pipe by workmen, and the core is removed. The form containing the pipe is wheeled away to the curing floor, where the jacket is stripped off. The packing cylinder makes about 40 revolutions per pipe, the number depending upon how fast the mortar is fed, and about 30 seconds of time is required in this operation.

The table on which the forms rest has three grates for forms, so that while one pipe is being made, another is being removed and the forms for a third pipe are being made ready. The table has a socket bearing at the center, about 1½ inches diameter, resting on a spindle so that it turns easily when the operator raises the spindle by stepping on the end of a foot lever. About ten of these machines are now in use. The range of sizes is from 6 to 14 inches in diameter.

THE KELLAR-THOMASON

The Kellar-Thomason machine is larger and requires a 20-horse-power engine or motor. The machine is quite similar to the Mc-

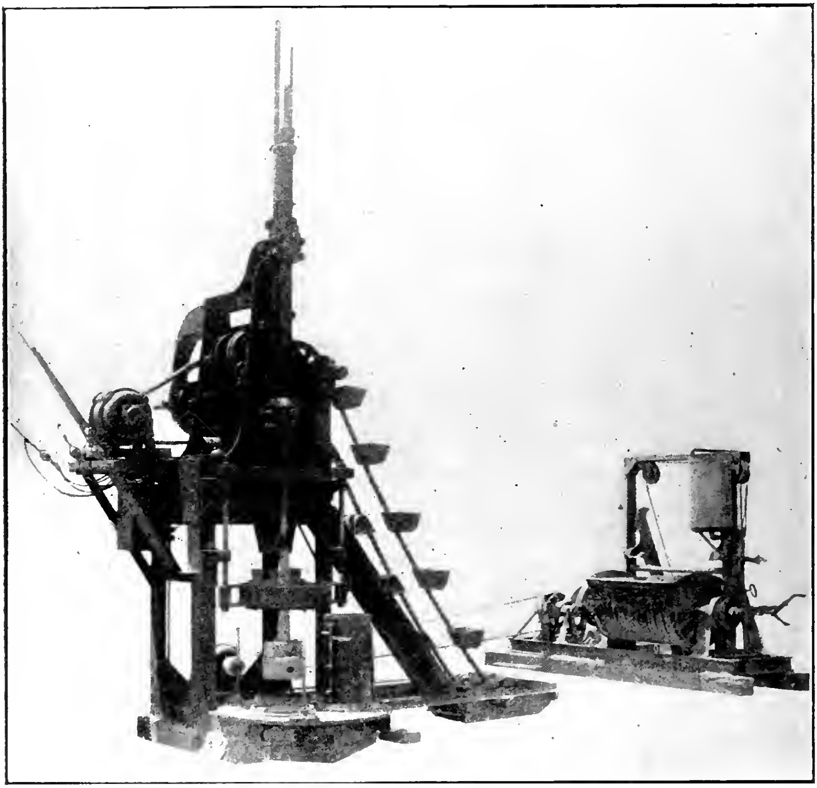

Fig. 12.—The Kellar-Thomason pipe machine.

Cracken and uses the trowelling process, but is more compact and of sturdy construction, as seen in Fig. 12.

The ordinary split jacket for hand-tamped pipe is used, but no core, and the mortar is packed securely against the jacket by the winged trowel. The usual crew is five men for small pipe and seven men for large pipe. The range of pipe sizes is from 4 to 20 inches and the capacity of the machine is from 1000 to 2000 feet per nine hours, according to the size.

The manufacturers state that they have made internal pressure tests on their machine-made pipe, and found 8-inch pipe to with-

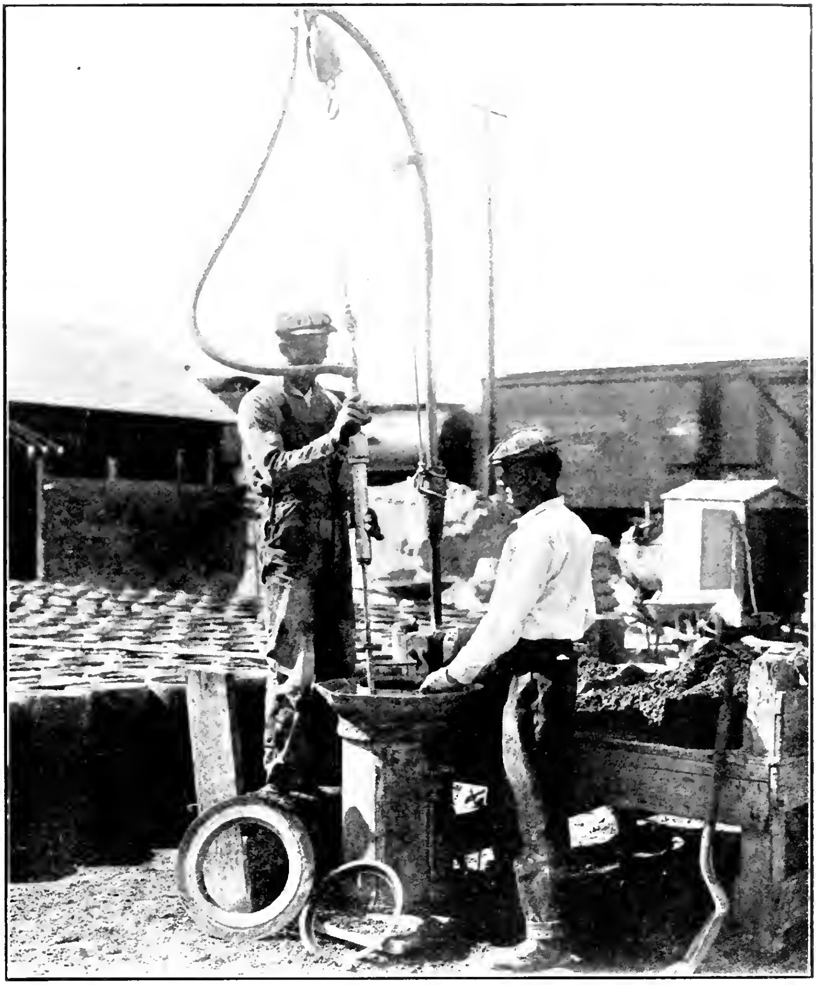

Fig. 13.—Filling the ordinary hand molds with a pneumatic tamper. There are six plants in California where these tampers are used successfully.

stand from 65 to 85 pounds per square inch, 10-inch pipe a maximum of 77 pounds, 16-inch pipe 65 pounds, the pipe being made of 1 : 3½ mixture. They state also that tests on 1 : 5½ pipe showed strength about 60 percent of the above figures.

The first of these machines was installed at Van Nuys, California, in March, 1916, and has been in successful operation since that time. Another machine is in service in Yuba City, California.

PNEUMATIC AIR TAMPERS

Several pipe contractors, who still use the ordinary hand molds, have installed air compressors in their yards, and use pneumatic tampers, which are similar to pneumatic hammers and drills. The Ingersoll tamper, which is preferred, weighs about 20 pounds and is suspended from a tripod with pulley and counterweight. It has a 5-inch stroke, and strikes 750 blows per minute. The head of the tamper is three-fourths of an inch thick and 6 inches long, in circular form to conform to the curve of the mold. The air pressure is 90 pounds per square inch. The compressed air is piped about the yards and several pipe crews can use it at once. A 7-inch by 6-inch compressor, displacing 75 cubic feet per minute, will supply two crews. About 10 percent more pipe can be made than by hand tamping, and the pipe is tamped more uniformly and more densely.

THE DURYEE-COLE

A continuous pipe machine, the Duryee-Cole, is in process of manufacture and will doubtless be tried out soon.

HAND-MADE CEMENT PIPE

Cement pipe made and tamped by hand has become very common throughout southern California and Arizona. The usual style of outfit is that shown in Fig. 14. It consists of outside and inside collapsible forms, a rimmer for forming the tongue on the top end of the pipe, enough bottom pallets for one or two days' run, hopper, tampers, scoop, and shovels. Bell-ended pipe is made by hand in the Middle West. An example of such pipe is shown in Fig. 2.

After the forms are placed in position and a batch of mortar is made ready, one man feeds the mortar into the forms while another tamps vigorously. Care must be taken not to feed the mortar faster on one side of the ring than on the other, nor faster than it can be thoroughly tamped. The mortar is made of a rather dry consistency; most pipe makers make it unnecessarily dry. When the forms are filled and the top joint (tongue) has been made, the forms are carried by hand to the curing floor, where the inside form, or core, is first removed from the tile and then the outside form, or jacket, is removed.

There are six cement pipe plants in California where pipe is made of very wet consistency, so wet that the jacket cannot be removed in the ordinary way lest the mortar slump to the ground. Instead of opening the jacket to remove it, the jacket is shaken off by quick jerking movements upward. When the jacket comes free, the tile settles over an inch in its length. The tile thus made becomes strong and is exceedingly impervious. More skill is required than in making dry or semi-wet pipe.

The hand-made pipe is thicker than machine-made pipe, except in the larger sizes. The usual thickness and weight for the common sizes is given in Table II. The large sizes should be made with thicker walls. It is seen from the table that the 12-inch pipe has wall thickness one-eighth of the pipe diameter, while the 36-inch pipe has wall only one-twelfth of the diameter. Most of the serious pipe failures have occurred on large pipe lines. This matter is discussed further on page 133.

TABLE II. THICKNESS AND WEIGHT PER FOOT OF HAND-MADE PIPE

Diameter	Thickness	Weight per foot
Inches	*Inches*	*Pounds*
4	1	...
6	1⅛	20
8	1¼	31
10	1⅜	44
12	1½	57
14	1⅝	68
16	1⅝	87
18	1¾	100
20	1⅞	114
22	2	141
24	2¼	163
30	2¾	...
36	3	...

Extra strong pipe can be made by using an oversize outside form. One contractor in this way makes 8-inch pipe of two strengths, one having the wall thickness one-eighth inch greater than the other. Sometimes a 14-inch jacket is used with a 12-inch core and the pipe is, therefore, 2⅝ inches thick. A contractor who makes very wet pipe in this manner states that he guarantees it under 100 feet pressure.

The working force at Continental for hand-tamped pipe consisted of two skilled men and four unskilled laborers, though the latter were not all employed to advantage. The tamper was unusually strong and active, and had had long experience in pipe making and laying. He was able to make from 270 to 300 feet of 16-inch pipe in a nine-hour day, which is an exceptional record. In May, 1916, near Tucson, two experienced pipe makers, working on a contract, made 200 to 220 feet of 12-inch pipe or 110 feet of 16-inch pipe per eight-hour day. Later, at the same place, one man with two inexperienced helpers made 12-inch pipe at the rate of 180 feet per day. About the same time and only a few miles away, another pipe crew brought from Los Angeles was making 1000 feet of 18-inch pipe. The making required ten days, partly on account of the ex-

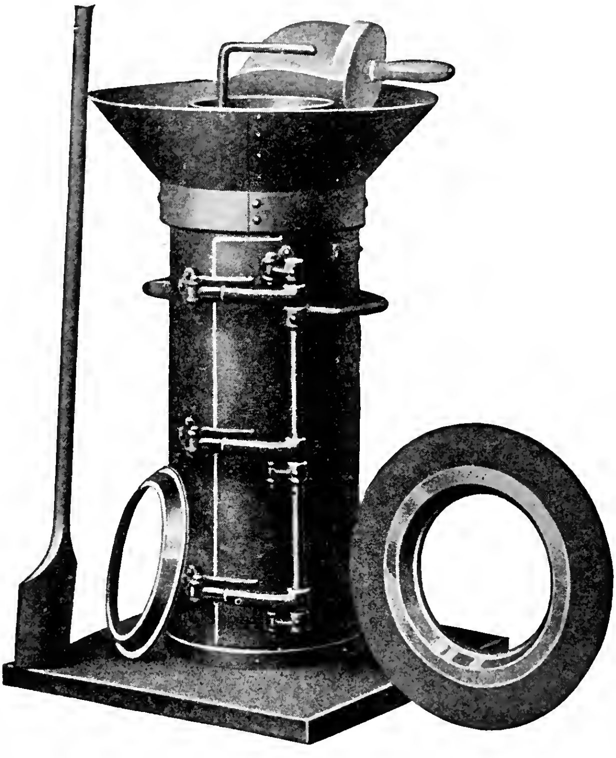

Fig. 14.—Pipe molds for hand-tamped cement pipe.

treme heat, though the foreman stated that, ordinarily, a crew should make 220 feet per day. On the University campus considerable 8-inch pipe is used from time to time. It is made by two workmen who turn out 100 to 120 feet per eight hours.

It is apparent, therefore, that no uniformity in the rate of pipe making by hand exists, and standards cannot be safely set. One pipe maker may accomplish twice as much as another. In case a farmer purchases forms and makes his own pipe, as sometimes occurs, he should not try for a record output until he first learns how to make pipe of high quality.

The proportions used with hand molds are 1 of cement to 3 or 4 of sand and gravel or broken stone, the richer mixture being used for pipe to be placed under some pressure or where sand alone is used for the aggregate. In one instance recently, near Tucson, a contractor made pipe with a 1:4½ mixture instead of 1:3 as had been directed. The pipe was weak and very porous. With hand molds much coarser aggregates are allowable than with the McCracken pipe machine, gravel even up to one-half the thickness of the pipe being permissible. Such particles do not interfere with hand tamping, but they do prevent the formation of the desirable "polished" surface with the revolving packer-head. The advantage of including small gravel is that the same strength can be obtained with a smaller proportion of cement.

The greatest advantage of the hand-made pipe is that it can always be made at or near the place where it is to be used. Usually sand of suitable quality can be found within a moderate distance and the wagon haul for sand and cement is not expensive. On the other hand, machine-made pipe presupposes a factory at some central location for supplying the demand for pipe in an irrigated or drainage district. Only on large contracts would it be profitable to move a large machine to the work. A portable Pomona machine obviates this difficulty to some extent. A freight charge on the pipe plus the cost of a long wagon haul might increase the cost of the pipe to a point where the superior qualities of the machine-made pipe would be more than offset by its greater cost. Therefore, there will always be a field, small jobs and in isolated locations, where the hand-made pipe will be employed.

WET-POURED CONCRETE PIPE

Wet-poured pipe, also, can be considered as hand-made, though it differs materially from that described above. The fact that the concrete is poured wet makes it necessary to leave the pipe in the molds until the concrete is thoroughly set. This requires many sets of forms and the investment in forms is so great that wet-poured pipe is used only for large sizes. Usually, too, wet-poured pipe is for pipe lines under considerable hydraulic pressure, and the pipe usually is reinforced.

Two large contracts for wet-poured pipe have been executed at Tucson, one for the water-supply main from the city's supply wells four miles south of Tucson to the main pumping plant on Osborne

Avenue, built in 1914, and the other the outfall sewer, built in 1917.

The same forms were used on both jobs. They are four feet long and the pipe is 30 inches inside diameter with a shell 3½ inches thick. The pipe for the water-supply line was made at a yard, in the center of which was a high derrick. The boom was long and reached over a wide area. Each pipe was moved from the pouring floor out into the yard just before removing the forms and the derrick was used again later to load the pipe for hauling to place along the trench. The concrete mixture was 1 of cement, 2 of sand, and 4 of broken stone or screened gravel. The reinforcement was of round iron wound spirally and was designed to withstand an internal pressure, varying from zero at the upper end to 30 pounds per square inch at the lower end of the line, with 15,000 pounds per square inch allowable working stress in the steel.

For the outfall sewer the pipe was made along the trench and the forms were moved along as the work progressed. This obviated the necessity of hauling the pipe long distances, but required much hauling while making and curing the pipe. The mixture was the same as for the water-supply line, but the reinforcement was uniform the whole length of the line and consisted of ½ inch round iron rings spaced 6 inches apart, and 4 rods of the same size running longitudinally through each joint from the end of the tongue to the end of the groove. The maximum difference in elevation in the sewer line is 73 feet.

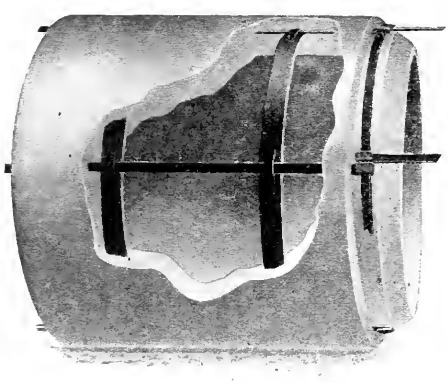

Fig. 15.—The Johnson reinforced pipe joint. (From Bulletin 55.)

The only criticism of the pipe just described is that the longitudinal reinforcement does not extend continuously across the joints. This continuity can be obtained in various ways, and some ingenious joints have been patented, notably the Johnson and the Meriwether, the former of which is shown in Fig. 15. The Johnson pipe uses special bar reinforcement, and the Meriwether uses "Triangle Mesh." Ordinarily longitudinal reinforcement is not needed. It is needed, however, if the bed of the trench is of uneven bearing power and settlement is liable to occur. An inverted siphon laid beneath a river should have heavy reinforcement longitudinally. A long section of the city supply pipe was unjoined when a river flood broke into the unfilled trench and floated the pipe line upward. Usually the longitudinal reinforcement is introduced merely for the purpose of holding the horizontal rings in place.

The circular reinforcement is designed usually to take all of the internal tension, allowing 16,000 pounds per square inch for the unit stress. If the tension is due to internal water pressure, the steel is placed near the outside of the pipe, but buried in the concrete about an inch to protect it from rust. If the reinforcement is to resist the weight of backfill, then the steel rings are made elliptical, so that they are near the inside of the pipe at top and bottom and near the outside on the two sides. For pipe over 24 inches in diameter it is practical to allow higher pressure heads, because the pipe layers can work inside of large pipe and can make better joints. Many concrete pipe lines with heads between 100 and 200 feet are in successful use.

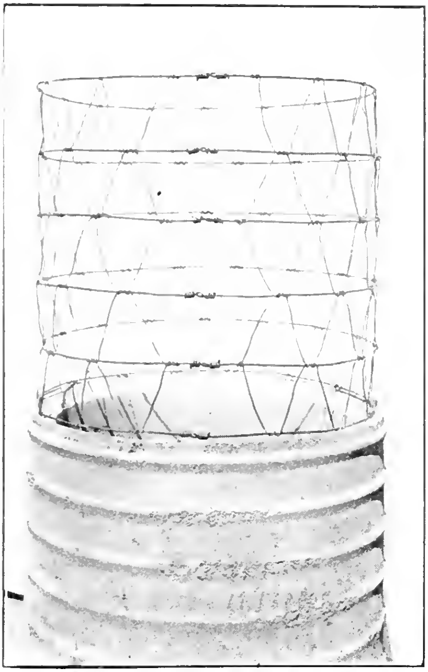

Fig. 16.—Cage of Triangle Mesh reinforcement with wires properly spliced.

The Massey Company make reinforced concrete culvert pipe for railways and highways. For small sized pipe they use steel mesh, with steel uprights and bell rings, while in the larger sizes they use a cage of ⅜-inch Havemeyer bar for vertical bars and all rings, all hand-tied with No. 14 annealed wire. The mix is 1:2:4.

Reinforced concrete pipe, wet-poured, is also constructed in place in many instances, a local example being the cross-cut collecting head of the Tucson Farms Company near the southwest corner of the city. The power conduit at the Roosevelt Reservoir has two inverted siphons constructed in this manner, one of them crossing Cottonwood Canyon at a depth of 75 feet below the grade line of the canal.

PIPE MAKING

THE MORTAR

The materials for making cement pipe must be of good quality. The cement must pass the standard specifications of the American Society for Testing Materials. A comparatively quick setting cement is desirable. Riverside (California) cement was used at Continental. Four carloads were sampled and tested for strength and fineness. The normal consistency was obtained with 25½ percent water in 1917 and 24 percent in 1918.

TABLE III. TENSILE STRENGTH OF RIVERSIDE CEMENT

Car No.	Date of sample	1-day test Neat	7-day test		28-day test		Tested by
			Neat	1:3	Neat	1:3	
		Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	
1	Oct., 1916	215	502	218	672	286	F. C. Kelton
2	" "	216	598	239	649	239	" " "
3	June, 1918	408	745	288	835	408	Smith, Emery & Co
4	" "	396	698	257	745	372	" " " "

TABLE IV. FINENESS OF RIVERSIDE CEMENT, OCTOBER 2, 1916

Car No.	Percent passing screen	
	100-mesh	200-mesh
	Percent	*Percent*
1	97.8	80.1
2	97.7	81.5
3	99.1	86.6
4	99.0	86.3

The percentage of magnesia (MgO) was 4.1, as determined in June, 1917, and again in June, 1918.

Users of cement should take samples occasionally and have standard tests made for soundness, strength, fineness, and percentage of magnesia. In every large city there are commercial testing engineers, and in Arizona the University offers to make these tests for a moderate charge to cover the cost.

The sand for cement pipe must be clean, and should be composed of sharp quartz particles. If it comes from gravel beds and is for use on a McCracken or other trowel machine, it should be screened through a half-inch mesh screen, for larger pieces are apt to roll under the action of the packer-head. For tamped pipe, whether made by hand or on one of the tamping machines, a considerable percentage of coarse gravel or broken stone is desirable, for the strength of the pipe is enhanced thereby. All the better class of pipe contractors who tamp are coming to use coarse aggregate with the sand. The usual ratio is 5 of sand to 3 of broken stone. A larger proportion of stone might be stronger but there would be some cavities, and more danger of seep spots. Broken stone gives greater strength than gravel. If pipe is broken up for examination, the pieces of broken stone are more often broken through, while the breaks run around the gravel. Stone that passes through a ¾-inch screen is suitable for 12-inch pipe, and stone from a 1-inch screen for 18-inch pipe. If it is possible to obtain broken stone that has passed through a 1½-inch screen, it could be used in a limited way in packer-head pipe.

For tamped pipe, therefore, the most favorable proportions are 1 of cement, 2½ of sand, and 1½ of ¼ inch to ¾ inch broken stone. If no stone is available, the mix should be 1 of cement to 3 of sand. For sewer pipe the proportions used in many cases are 1:2½, but so rich a mix is not necessary unless the sewer is laid very deep or is in soil containing a high percentage of white alkali, particularly sodium sulfate.

Two samples of the sand being used at Continental were taken on April 3, 1917, and two samples on June 26, 1918. They were subjected to mechanical analysis.

TABLE V. MECHANICAL ANALYSIS OF SCREENED SAND AT CONTINENTAL, ARIZONA

Screen	Separation size	Percent passing screen				Classification
		Sample No. 1	Sample No. 2	Sample No. 3	Sample No. 4	
Meshes per lin. in.	*Mm.*	%	%	%	%	
200	0.10	0.4	0.6	.33	.21	Very fine sand
150	0.135	0.7	1.1	.64	.44	Fine sand
100	0.20	1.7	2.6	1.25	.89	Fine sand
70	0.25	4.8	6.4	2.55	1.99	Fine sand
40	0.44	17.7	21.2	8.85	8.49	Medium sand
20	1.00	51.2	57.0	33.85	43.99	Coarse sand
10	2.07	79.1	82.3	59.85	75.29	Fine gravel
6	....	...	...	74.95	87.39	
4	....	...	...	84.35	92.99	

A cement mixer of the batch type, such as the Blystone, should be used at all cement pipe plants. The cement and sand should be mixed dry for about a minute before the water is let in from a measuring tank attached to a frame just over the mixer. Mixing is then continued for at least one minute more before the mixer is dumped. The mortar on the floor must be used up quickly and no dry or set mortar should be retempered and used.

At Continental 607 cubic inches, or 22 pounds, of water were used for a one sack batch. This is 23.4 percent of the weight of the cement. The mortar when dumped was just wet enough to retain its form when compressed in the hand. But when the outside jacket was stripped from the fresh tile, the tile quaked like stiff jelly, and small drops of water stood on the surface. When the mortar had set, the surface was covered with a fine water-web; this web may be accepted as the test for correct consistency. The strength and imperviousness of the pipe depend in large part upon the percentage of water used; in every case it must be carefully watched, for the amount of water needed varies with the brand of cement and with the fineness of the sand. If the mortar is mixed too dry the pipe may be pervious, and if too wet the strength is reduced.

The unit quantities of sand and cement per tile, or per 100 feet, is somewhat variable even on the same machine. The outside jackets, when old, become stretched, and the packer-heads become worn; both of these causes tend to increase the thickness and weight of the tile. The rate of feeding the elevator buckets and the speed of the machine tend to vary the density of the tile walls. An approximate estimate of the quantities required can be had from the following data obtained at Continental.

TABLE VI. QUANTITIES OF MATERIAL FOR MCCRACKEN CEMENT PIPE

Diameter of pipe	Thickness	Pipe per cubic yard of sand	Pipe per sack of cement
Inches	*Inches*	*Lineal feet*	*Lineal feet*
12	$1\frac{1}{4}$	69.0	7.0
14	$1\frac{3}{8}$	56.2	5.5
16	$1\frac{5}{8}$	40.2	3.9
18	$1\frac{3}{4}$	38.3	3.5
20	$1\frac{7}{8}$	30.7	3.1

The handling of the machine is an art and cannot be learned from a bulletin. The normal method of learning to run a machine is to serve an apprenticeship. The purchaser of a machine to be used in Arizona should include in the contract that the manufacturers send an experienced pipe maker to install the machine and to operate it for at least a month.

The operator stands with the right hand on the clutch lever, holding a large trowel in the left hand. With the trowel he can hold back the mortar in the chute or can help it along. Too much mortar chokes the packer-head and puts a heavy load on the engine.

To change the machine from one size of tile to another requires about an hour's time. This is done sometimes during the noon hour or after working hours in the afternoon.

The advantage derived from reinforcing machine-made pipe is not fully determined, but it seems probable that much reinforced pipe will be used in the future with the extension of the field for cement pipe. For machines of the National type, double hoop reinforcement is the best. For packer-head pipe machines some form of cage in which the circular rings are supported is preferable. At Continental electro-welded hoops of No. 7 wire were tried first. The rings were of a size to fit into the corrugations of the jacket, where they were securely held. Three rings per 2-foot pipe were used, and they were found to be firmly imbedded in the concrete. But there was difficulty in getting the rings properly welded in local machine shops, and on account of the surface position of the rings they could not be expected to resist corrosion. Cages made of hog wire were next tried with success, and later similar cages made of "Triangle Mesh." The last proved to be the best adapted to the purpose; it is rigid and stays in position in the jacket. The mesh comes in rolls of 150 feet, and in various widths, of which the 20-inch width was selected. The longitudinal wires in the mesh are 4 inches apart and are thoroughly braced by the cross wires which run diagonally.

When the reinforced pipe were tested in the internal-pressure machine, the results were disappointing. There was no increase in strength, and there was some leakage along the lines of the wires. This same type of reinforcement was tried in a tamping machine in California, and it was found that the steel weakened the pipe greatly. A correspondent who uses double-hoop reinforcement writes that the reinforcement is not considered to prevent the tile from cracking, but it does prevent the tile from collapsing in case cracks occur. Despite these discouraging reports, it is believed that a technique can be found for making reinforcement effective in packer-head pipe. The action of the trowel compacts the mortar to so great an extent that it appears to have the consistency of jelly, and this should be enough to create a bond between the cement and steel. It may be that the curing process in the open air permits the cement to break from the steel through shrinking. The author was able to make but a few tests, and believes that full investigation will reveal a method of successfully reinforcing McCracken and other similar pipe.

CURING

Curing the tile requires that it be kept wet until the mortar has not only set but has hardened. Seven to ten days is the usual time for curing but two weeks is preferable. A water supply under pressure is desirable, and several automatic sprinklers should be provided. It is awkward and difficult to keep the pipe wet with hand sprinklers or with water that has to be handled with a pail, as

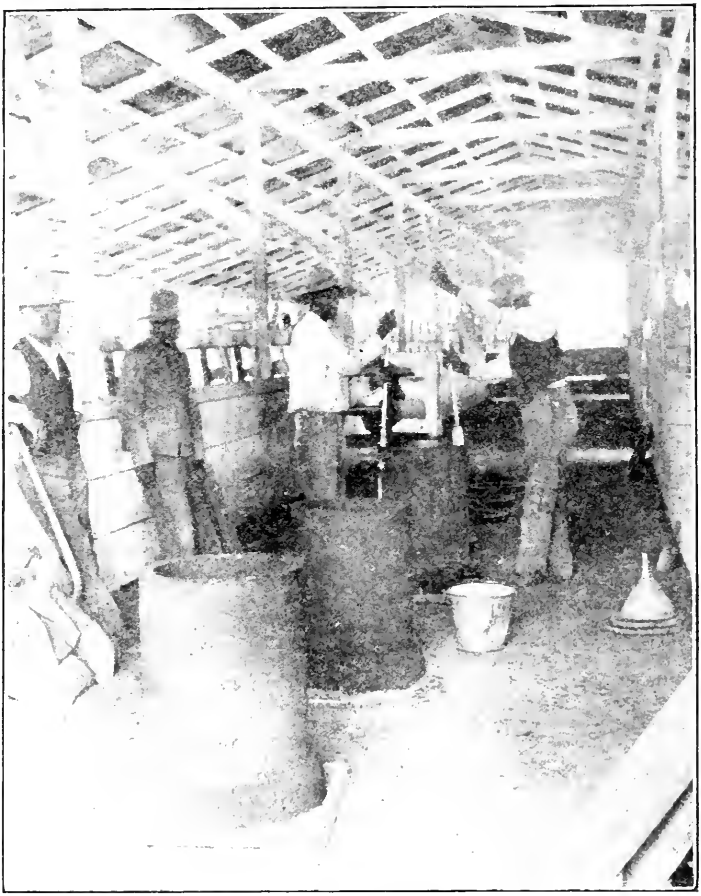

Fig. 17.—Yaqui Indians tamping 15-inch cement pipe at Flowing Wells ranch. (From Bulletin 55.)

from a ditch. An occasional wetting is not enough; the pipe must be kept wet.

For at least twenty-four hours and preferably forty-eight, the pipe should be protected from the sun. Any cheap shed covering is satisfactory; overlapped palm leaves are good. The shed should be close to the pipe machine and on level ground. In moving the pipe from the shed to the stackyard, each length is turned on its side and rolled, care being taken to avoid striking any hard object.

Nearly all hand-tamped pipe is made and cured in the open air. Here is opportunity for reform. In a humid climate it may be possible to cure pipe in the open, but in Arizona a covering is needed during most of the year.

In a few cases farmers have rolled their new-made pipe into the irrigation ditch or a creek when the pipe was about three days old. In each case unusually good pipe has resulted.

Steam curing, as practiced in the Middle West, is exceedingly effective. The green tile are placed on the platforms of low cars and run on tracks into tunnels. When a tunnel is full, the doors are closed tight and saturated steam from a boiler is admitted. The boiler pressure is kept at about 5 pounds. The hot, dripping atmosphere accelerates the setting and hardening, and makes the curing independent of unfavorable weather conditions, especially freezing temperatures. After 36 hours in a steam chamber the pipe can be loaded and shipped immediately.

In southern Arizona less difficulty is experienced from freezing than from the extreme heat and dryness of the summer months. One effect of the dry heat is to make some cements set before the mortar can be placed. During the construction of the Laguna dam, a shipment of California cement persisted in setting in one minute. It was necessary to dig the concrete out of the mixer with chisels and drills. Another California brand gave the same trouble in another locality. The author rejected two carloads of a Kansas cement in 1908, because the cement took its initial set in three minutes. In this case the author's tests were confirmed by a commercial testing firm in Philadelphia. This phenomenon of abrupt setting is not well understood, but it is a safe conclusion that the storage of cement in hot, dry places for long periods may be dangerous, and furthermore the cement pile and sand pile should be kept as cool as possible in midsummer, possibly by sprinkling the sand pile with water.

The importance of curing should be emphasized for it is the feature of pipe manufacture that is most apt to be neglected. Undoubtedly much cement pipe, both hand-made and machine-made, never attains the strength of which it is capable, because it is allowed to become dry before the hardening process has progressed to a proper point.

WATERPROOFING

Machine-made cement pipe is impervious at ordinary pressures; no waterproofing is necessary for it.

Hand-made pipe usually leaks when first put into use, but the leakage decreases gradually and finally ceases. The original leakage depends upon the proportions of the mortar, the consistency, and the thoroughness of mixing and tamping. It is customary to paint the inside of the pipe with a wash made of cement and water to reduce the seepage.

Hydrated lime is effective in waterproofing concrete but is seldom used in pipe manufacture. The Cement Pipe Company of Phoenix have used it in both machine and hand-made pipe. They use 10 pounds per sack of cement. In case the pipe will be under considerable pressure this amount should not be exceeded, and perhaps 8 pounds is a safer limit. In the tests of 1907 the author made pipe with mixtures in which a heavy percentage of lime was depended upon in part for the strength of the pipe. At present prices there is no economy, however, in the substitution of lime for cement. There is another advantage in the use of hydrated lime in hot weather, in that the mortar holds water better and the pipe is more readily cured. Tar compounds have not been used for waterproofing cement pipe.

PIPE LAYING AND PIPE LINE FAILURES

PIPE LAYING

The pipe should be laid in the trench in the same manner as sewer pipe is laid, with straight alignment and uniform grade. Many lines, where the pressure is light, are laid by the contractor without any preliminary surveying. It is better, however, in all cases to have the grades established and stakes set every 50 feet by a surveyor. A map and profile showing alignment, elevations, and gates and valves is worth the cost. An undulating grade involves many air pockets, which tend to induce water hammer and to decrease the flow.

THE TRENCH

The width of the trench should be 10 inches greater than the external diameter of the pipe. This allows room for the pipe layer and for the bander who must straddle the pipe.

The bed of the trench should be prepared with care. If the trench is cut too deep and refilled to grade, the refilling should be tamped. There is likely to be a very slight settlement of the entire pipe line, but if it is uniform throughout the length no injury will result. Unequal settlement, however, produces cracks.

At the University Farm a pipe line was carried across a ravine on an earth fill. In the center was a 5-foot culvert, the top of which was close to the invert of the pipe line. The earth fill settled while the culvert was unyielding, with the result that the pipe line cracked just over the culvert several times until, finally, the settlement ceased.

The manner of backfilling must depend upon the size of the pipe, the depth of earth to be supported by the pipe, and the nature of the soil. Many expensive failures of pipe lines, usually of large-sized pipe, have been due to insufficient backfilling beneath the invert. Soil which breaks up in chunks, such as clay, does not settle back beneath the pipe, while sandy soil or any soil that pulverizes is known to the pipe layer as "a good pipe soil." The best methods of filling the space beneath the pipe are by flooding a small depth of backfill and by tamping. In one district where clay soil predominates, it is customary to backfill only to the top of the pipe and then run a small stream of water down the line. This settles the heavy soil under the pipe, and this supporting soil is allowed to dry out before the trench is filled. Sometimes the flooding is repeated when two or three feet of earth have have been placed over the pipe. No extensive flooding should be done, however, without first filling the pipe line, as there is danger of floating an empty pipe line upward and breaking the joints. If the flooding is not feasible, the soil can be tamped in until the backfill is above the center of the pipe. One contractor has his backfiller straddle the pipe and as he pulls the soil in with a shovel he continually tramps upon it. In the drainage districts of the Middle West usually the bed of the trench is shaped semi-circular to fit the drain tile and it is considered poor practice to lay the tile on a flat bed. The soils are, of course, heavy and wet, and there are no convenient facilities for flooding as there are along an irrigation pipe line. A 2-inch layer of sand is sometimes spread on a clay trench bottom to serve as a bed for the pipe.

In case the pipe has lain in the pipe yard until it is thoroughly dry, it is a good precautionary measure to run water over a shallow backfill before or at the same time that the water is turned into the line, in order to guard against failures such as described on page 110.

METHODS OF LAYING

Cement pipe with tongue and groove joints are laid in the trench with great facility. The mortar used for this purpose should be rich. It is usually mixed with two parts of sand to one of cement. Hydrated lime adds to the smooth working qualities of the mortar, making the mortar "fat," but it is not essential. It was used at Continental for a time, then discontinued, and afterwards used again. Six or eight pounds per sack of cement is the proper amount to use.

The pipe are distributed along the trench by team, and are handed down and stood on the groove ends in the trench. A galvanized iron form about 12 inches long, called the laying core, is inserted in the groove end, projecting about three inches. The space between the form and the groove is then filled with mortar, and additional mortar is placed under the tongue in the trench. The joint of pipe is tipped over and jointed quickly. While a helper raises it slightly with a pair of pipe tongs, or a leather strap, the pipe layer stooping down gives the pipe a quick thrust which closes the groove tightly over the tongue. Small sizes are handled by the layer without a helper. The laying core is then drawn out through the end of the pipe and placed in the groove end of the next pipe. The pipe layer reaches in with a long-handled brush and smooths the joint. A third man, following along in the trench, spreads a band of mortar about three inches wide over the joint. This is called banding. It is omitted sometimes on pipe lines of small pipe that are to be

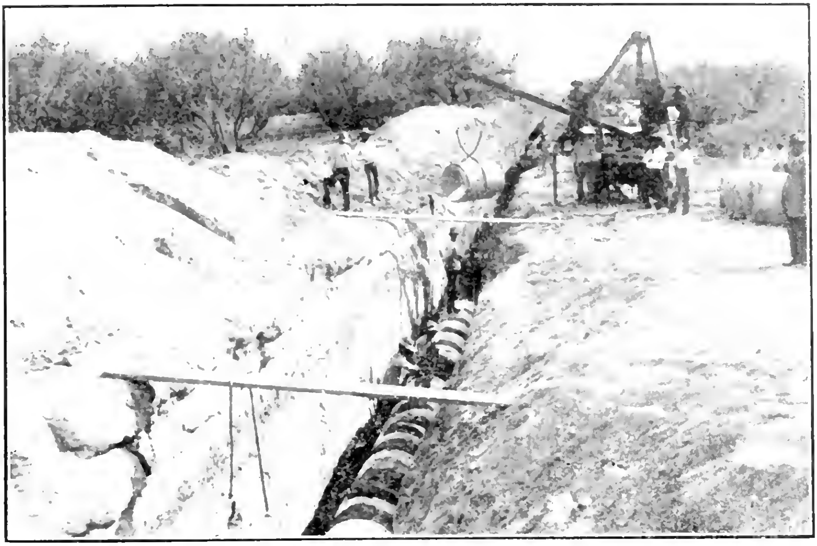

Fig. 18.—Laying the concrete pipe for water supply main for City of Tucson.

under slight pressure head. A fourth man prepares the mortar and brings it in pails to the trench, and one or two laborers, following

Fig. 19.—Laying 20-inch cement pipe in shallow ditch at Continental.

close back of the bander, backfill the trench enough to cover at least two inches over the pipe. In hot weather it should be backfilled at least 8 inches over the pipe. A water tank mounted on wagon trucks is moved forward with the mortar boxes several times a day. Large sizes of pipe are lowered by means of tripod or derrick with block and tackle.

The custom in other places is to use a smaller laying crew—only three or four men. The layer handles pipe up to 16 inches in diameter alone. The addition of a few more unskilled men does not add materially to the cost per day and it permits of much faster progress.

Sixty percent of the pipe layers, it is said, do not use a laying core. Over half of the pipe at Continental was laid without one. Pipe layers are much divided in opinion as to the usefulness of the core. Many layers make good water-tight joints, with smooth inside surfaces, without it. However, a man with limited experience or who is inclined to shirk his work is much surer to place a proper amount of mortar, and to secure it throughout the full circle of the joint, if he uses a core, and for that reason it is recommended that specifications require its use. The inside joint should always be brushed even when a core is used.

There is one pipe manufacturer in California who makes McCracken bell-end pipe for irrigation pipe lines. His method of laying is as follows. The layer faces the bell-end of the last pipe laid, and the helper straddles it. The helper washes the bell-end with water and places mortar in the lower half of the bell while the layer builds a fillet of mortar around a core projecting from the spigot end of the upright pipe. The pipe is shoved into the bell-end, and the helper fills the top of the bell with mortar. A bander finishes the joint, and a mixer and a back filler complete the laying crew. No excavation is made for the bells. The experience of this contractor does not reveal any superiority of the bell and spigot pipe over the tongue and groove pipe.

The specifications for laying the sewer line at Glendale were as follows. "Before a pipe is laid, the lower half of the hub of the preceding pipe shall be plastered on the inside with a stiff mortar mixed 1 : 1, and sufficient thickness to bring the inner bottoms of the abutting pipes flush and even. After the pipe is laid, the remainder of the hub shall be thoroughly filled with similar mortar and the joint wiped inside and finished to a smooth bevel outside."

A new feature introduced recently on the Thomas-Hammond machine is the self-centering joint. The lower part of the bell is beveled so that the spigot, when it is forced into the bell, becomes accurately centered. This tends to give maximum flow capacity to the pipe line. However, it was found at Glendale that the mortar on the bottom interfered with the centering by raising the spigot end and, therefore, much of the line was laid without first placing the mortar in the bottom of the bell. Without the bottom mortar it becomes difficult to fill the annular space beneath the pipe and this work is likely to be done carelessly. The annular space is only 3/8-inch, which is so narrow that no tool can work in it easily. Mr. F. N. Holmquist, the engineer, states that in his opinion there is considerable leakage through the joints at Glendale due to insufficient mortar in the joint. The leakage is probably greater in those portions of the line that were in caving ground, where trenching and placing could not be carried on ahead of the jointing.

The rate of speed in pipe laying is quite variable. Ordinarily about 700 feet of 12 or 14-inch pipe, or 500 feet of 16-inch pipe per day is considered good. One foreman reports 900 feet of 12-inch pipe, without the laying core, on straight work with no connections or short turns. At Continental one pipe laying gang with three skilled men and two laborers laid as high as 1075 feet of pipe, part 12-inch and part 14-inch, in eight hours. At a later date, a single skilled pipe layer, with six unskilled helpers, laid over 1000 feet of 12-inch pipe in nine hours. The highest rate reported for 16-inch pipe is 800 feet. In this case two experienced men alternated at jointing the pipe and banding. Experience at Continental indicates the following average rates:

TABLE VII. AVERAGE RATE OF SPEED IN PIPE LAYING

Diameter of pipe	No. of feet per 8-hour day
Inches	*Feet*
12	700
14	600
16	500
18	400
20	350

These rates do not include the installation of risers and valves. This work is usually included in the contract price, but sometimes it is done on force account.

There is great danger that a newly-laid pipe line may dry out before the joint mortar has properly set and hardened. Whenever laying ceases, as at noon, a plug of wood or sacks should be put in the end to prevent a draught of air from blowing through the line. As soon as possible after laying, a stream of water should be turned into the line to keep it thoroughly wet, certain valves, of course, being left open so that the line cannot be subjected to any pressure.

RISERS

The risers are made by cutting a hole in the side of a joint of pipe, and inserting another joint, the end of which is cut in the shape of a saddle. The two pieces are then cemented together. For machine-made pipe the cutting and shaping are done a few hours after the pipe is made, but hand-made pipe, being much less hard, can be cut in the field. Often the holes are cut after the pipe line is laid.

The making of Y's and T's and other fittings such as bends is an undeveloped business. The present method of making the pieces and cementing them together is unsatisfactory. It is slow and expensive and the joints when made look patchy. These specials should be cast in one piece in special molds, using rich mortar or thicker walls. The molds, especially in the large sizes, would be expensive, but contractors whose business is pipe making or laying can afford to have them.

The riser valves are usually cemented onto the risers in the field, though it is preferable to do this work in the pipe yard, if the lengths of the risers can be known in advance. Cement work of this nature can be cured more easily and better in the yard than in the field. Risers should be of smaller diameter than the pipe line. If they are of the same diameter, the line is unduly weakened at the point where the hole is cut for the connection.

EFFECT OF HIGH TEMPERATURES

On account of the high temperatures in midsummer in southern Arizona, pipe laying at that time is attended by some danger. The expansion and contraction of mortar and concrete with changes in temperature are high, and a freshly-laid pipe line has little resistance to breaking if contraction occurs at once, usually the first night. This was illustrated at the University Farm in June, 1916, when a new pipe line a quarter mile long broke at almost every joint. It became necessary to uncover the line and make the joints over again, and in some cases a third time. The work had been guaranteed and the loss fell on the pipe contractor. Another instance occurred the previous summer in the Antelope Valley, at the head of the hot Mojave desert, where every joint for two miles had to be made over. In case the pipe laying cannot be put off until fall, then the only precautions possible are to have the pipe well wetted before laying, to backfill the trench promptly and deeply, to run water through the pipe at once, and possibly to lay pipe only from daylight to a few hours after sunrise and again after sunset. Customarily the pipe is covered only a couple of inches at first, the better to observe leaks when the pipe line is tested.

These precautions are not necessary in climates that are cool with cloudy days. But in parts of Arizona and neighboring states the summer temperatures are so high and the humidity is so low that it is doubtful whether cement and concrete work of this character should be attempted in midsummer. Certainly it is preferable to defer such work to the safer part of the year. The first and only recognition of this important limitation, so far as known, is in the contract of Yuma County for road culverts, dated December 15, 1915. The clause reads as follows: "It is further agreed that the contractor shall not do any concrete work from June 1st, 1916, to October 1st, 1916, unless with the written permission of the Board of Supervisors." This clause should be used in contracts for many kinds of cement work, possibly with the initial date changed to May 1. At Continental very little pipe was laid during the summer of 1917; the pipe making was continued, but special care was given to curing the pipe and part of the pipe in the stackyard was covered with arrowweed and brush.

On a pipe line in British Columbia, where contraction cracks were feared, slip joints were provided every 30 feet. They were made as follows: When the pipe molds were three-fourths filled, a galvanized iron thimble 5 inches wide was inserted and pressed down in the mortar. The thimble was coated with heavy oil and when half buried a layer of oil was poured on the mortar, after which more mortar was put in and the molds were filled.

EFFECT OF WETTING DRY PIPE

Another cause of expansion and contraction of cement pipe lines is variation in the degree of dryness. The drying out of mortar or concrete produces contraction, while the saturation of mortar causes it to expand. Running water through a line of pipe which has been thoroughly dried out before it is laid causes the line to expand with great force. This expansion may exert a tremendous pressure against structures such as gate pits, division boxes, and weir boxes. At Continental several of the gate pits as first constructed were destroyed in this way. Fig. 20 shows the cracks on four sides of a gate pit due to pressure from the south side. The pipe line at this point runs north with a lateral towards the east. The cracked gate pits were not removed, but the lower portions were enclosed in a

4-inch concrete jacket containing substantial horizontal reinforcement. After this experience the design of gate pits was changed and they were all built with the lowest section heavily reinforced. None of the reinforced pits gave any trouble.

In the early summer of 1918 a great deal of trouble was had with a 20-inch pipe line when the water was put in the line. The failures were by long longitudinal cracks running along the top and the

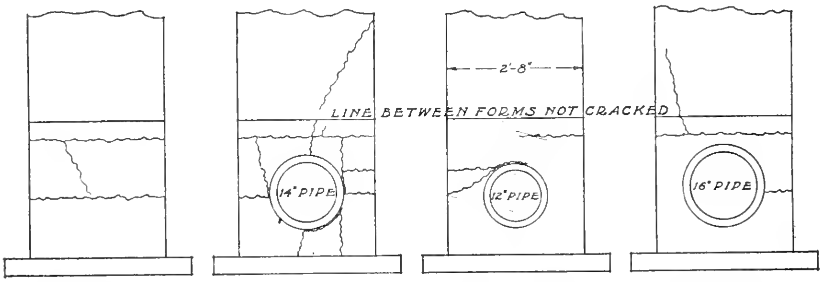

Fig. 20.—A cracked gate pit at Continental, caused by expansion of pipe line.

bottom of the line. In the first break twenty-two lengths of pipe were cracked both top and bottom. In this case the break occurred at a bend in the line about midway between two gate pits, both of which had been reinforced. The bend was the point of greatest weakness, and a heavy longitudinal shear must have been developed in the pipe. The line was under only three pounds internal pressure and the fractured pipe was found to be dense and hard. Fig. 21 is a picture of the second break. Each time, as soon as a break was repaired and the water was turned into the line another similar break occurred. The breaks were confined wholly to the 20-inch pipe, though one pipe line telescoped where a 14-inch pipe joined a 16-inch. The 20-inch pipe was made in the summer of 1917 and was stacked in the open air where it became bone-dry. The pipe was laid early in 1918, but no water was turned into it until April.

When it seemed apparent that the 20-inch pipe were failing from longitudinal compression, the line was broken open at intervals and expansion joints were put in. In some cases where the line was not under pressure the expansion joint was made by leaving about an inch between two pipe and wrapping a band of tar roofing paper around the line, fastening it with wire. Where the line was under some pressure the expansion joint was made with asphalt. A thimble of galvanized iron six inches long was first placed on the inside of the joint. The edges of the thimble were sealed with wet adobe

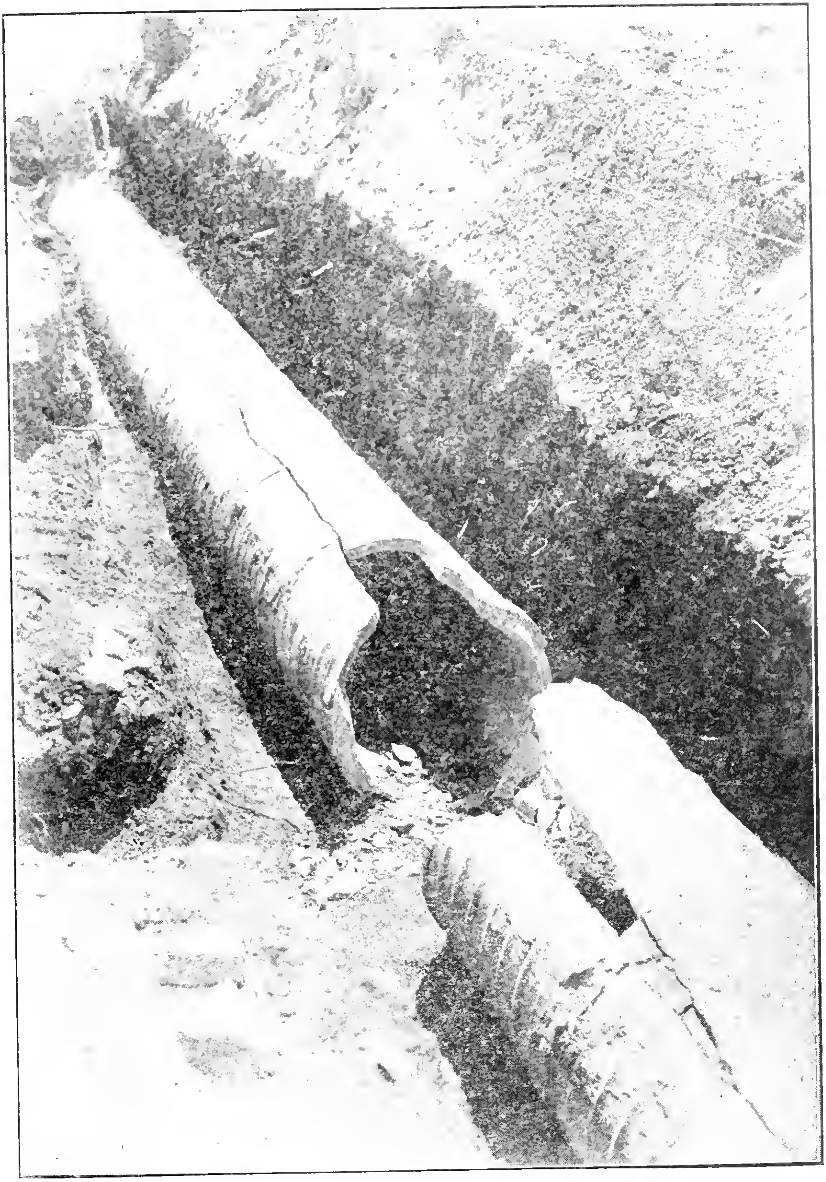

Fig. 21.—Longitudinal crack in 20-inch pipe line. The open section has been broken out with hammer. Photo by W. C. Axelton.

mud. A piece of tar paper was then placed around the outside but was left open at the top. Heated asphalt was then poured into the joint and allowed to harden there. The cost of these expansion joints was about $1.70 for each joint.

The cracks did not appear to come in the pipe for several hours or a few days after water was admitted, and in some cases one or two weeks elapsed before the cracks appeared. It was very desirable to ascertain more directly the relationship between the saturation of the pipe line and the expansion, to determine what may be

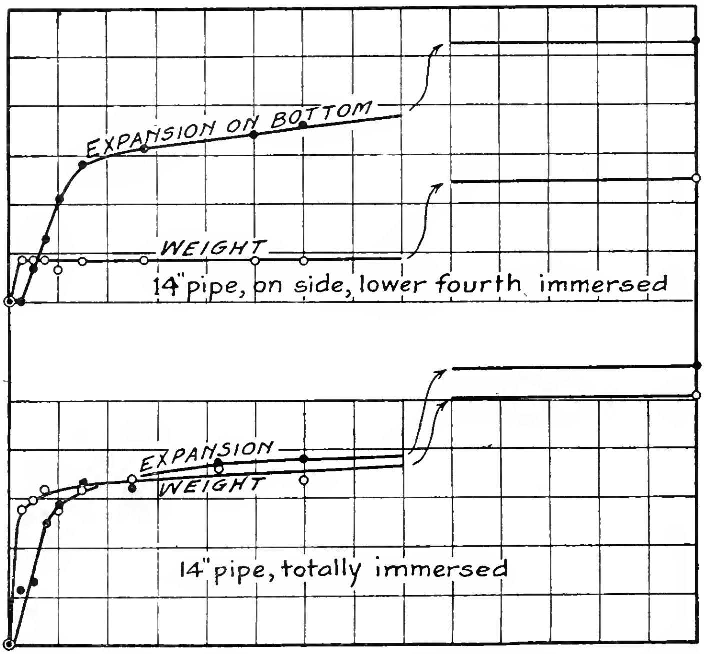

Fig. 22.—Increase in weight and expansion of two 14-inch cement pipes.

called a saturation-time curve showing the rate of absorption from the time of the immersion, and also an expansion-time curve showing the rate of expansion beginning at the time of immersion. This was studied by immersing two 14-inch pipe that were about one and a half years old and had been exposed to the sunlight and wind during all of this time, in consequence of which they were absolutely dry. The pipes were provided with metal discs inlaid on the surface 20 inches apart from each other, and the exact distance between points on these discs was determined to the nearest five-thousandth of an inch. After weighing, one of the pipes was immersed entirely and the other was laid on its side in shallow water so that the lower quarter of the pipe was immersed. The pipes were withdrawn frequently, well wiped with towels, and weighed and measured. The results are shown in the graphs of Fig. 22. The pipe which was immersed entirely gained about five percent of its weight by absorption of water, and gained it very rapidly. The increase in weight was practically completed in one and one-half hours. The second pipe gained about one-quarter as much in the same period of time. This indicates that the water does not creep upward through the concrete by capillarity except at a very slow rate. The expansion curves for the first pipe and for the lower side of the second pipe are almost identical. They exhibit a remarkable lag behind the saturation-time curve, suggesting that the expansion is due to recrystallization. The percentage of elongation is .0005. If this figure is multiplied by the modulus of elasticity for concrete it will give the internal stress which would result in a pipe line with immovable ends. The pipe being of a rich mixture and well aged, the modulus should be about three million, and, therefore, the internal stress equivalent should be at least 1500 pounds per square inch.

The saturation-time curve for internal wetting would be considerably different from that shown in Fig. 22. On account of the dense, hard interior surface of the pipe the absorption of water would be very slow. On the other hand, an internal pressure head of several pounds would tend to increase the rapidity of absorption.

The pipe that was immersed over one-fourth of its surface was observed to show a hair crack at the tongue end on the inside top, extending inward about 5 inches. Another experiment was made, therefore, by taking a 16-inch pipe that had been broken by internal pressure (see Fig. 25) and immersing it over one-fourth of its surface. The pipe was laid in the water with the open crack on top. Another broken pipe was immersed over one-half of its surface. These pipes had been provided with inlaid metal measuring points spaced 8 inches apart symmetrically across the top, so that the opening or closing of the crack could be measured. The results of these tests are shown in Fig. 23. The saturation of the lower part of the pipes caused the cracks first to close and then to reopen in part. This proves that the absorption of water was largely from the outside and, as the water penetrated toward the center, the pipe, like a compound spring, closed. When the penetration passed the center of the pipe wall, the spring began to open.

In the case of a dry pipe line in which water is admitted, the absorption is from the inside, though slow; and the expansion of the inner portion of the pipe tends to produce cracks in the outer portion. The inner portion, being of rich mortar and dense, has a relatively high percentage of expansion due to saturation. After a crack has started on the outside, internal pressure or other causes may complete the rupture. Test specimens while being tested for percolation and resistance to internal pressure sometimes fail as a result of the penetration of water into the inner wall.

In case, however, that the first flow into a dry pipe line does not fill the pipe, then the saturation and expansion of the invert creates

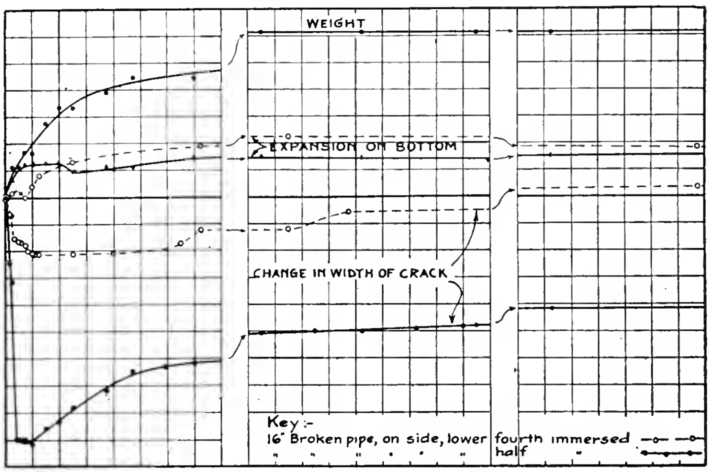

Fig. 23.—Effect of saturation on pipe that had been broken in internal-pressure testing machine.

a bending moment at the crown and tends to produce a crack which will begin to open from the inside. If the saturation is wholly from the inside, the first effect is tension throughout the section at the crown, and this is changed to a bending moment as the penetration of the water into the invert increases toward the outer surface of the pipe wall. The bending moment reaches its maximum when the saturation of the wall is complete. The expansion of the lower half of the pipe has the same effect as swelling a wooden wedge in the bottom. If the distortion is enough to cause failure, a crack will occur at the top and will show first on the inside at or near the crown. Rupture at the top may be followed by another crack at the bottom. The strain at the top of the pipe will be greatest when the pipe line is about half filled with water. In the case of freshly-laid dry pipe, therefore, it is preferable to run a full head of water the first time, or perhaps a very small stream at first to help cure the joint mortar, to be followed about three days later by a full head. The safest method is to leave the pipe line open at intervals so that a part of the water can rise and flow in the trench, and thus the walls will absorb water from the outside and from the inside simultaneously.

In the light of these experiments it seems apparent that the longitudinal cracks at Continental were due to progressive saturation of the pipe wall from the inside and greater saturation of the under side of the pipe than of the upper side. Of course, other forces were working. The expansion of the invert, together with the external load pressure, the internal hydraulic pressure, and longitudinal shear on curves, all produce tension at the top of the pipe, that is, these forces are all additive. A break may be the result of a combination of several or all of them.

It is known that concrete under high stress flows to a considerable extent and thus tends to relieve itself of stress.* It would appear, however, from the experience had at Continental and elsewhere that the mortar does not flow fast enough to prevent the development of very high stresses.

It is known also that concrete and mortar when wetted, after being cured in dry air, temporarily lose a considerable part of their strength. Van Ornum reports for short concrete cylinders a loss of forty percent.† In the case of rich mortars the percentage of loss may be even greater.

Failures of pipe lines have occurred in the San Joaquin Valley under similar conditions and for similar reasons. Scores of gate pits have been destroyed, curves have buckled out of line and pipe lines have opened at top and bottom. It appears that the true cause has never been assigned to these failures. In humid regions the pipe does not become dry enough to cause trouble.

Several important lessons are to be learned from the experiences at Continental. In the first place, it is much safer to do cement-pipe making and laying in the cooler part of the year. In arid climates extreme drying of the pipe in the stackyard should be prevented. If pipe is made in the summer time and must be stacked in the open it should be stacked high instead of being spread over a large area. The stacks should be covered with brush or should be under good roofs. The pipe should be wetted occasionally, especially for a few weeks before the pipe is to be laid. If it is necessary to lay bone-dry pipe, larger than 14-inch diameter, the pipe

*Jour. Amer. Conc. Inst., Feb., 1917.
†Trans. Am. Soc. C. E., Vol. LXXVII, p. 438, 1014.

should be given a three hours' dip in an irrigation ditch or in a vat shortly before laying; or water should be run down the trench on top of a shallow backfill at the same time that water is admitted into the line. This is easily accomplished by leaving the riser valves open.

At Continental there has been no failure of pipe smaller than 20-inches in diameter, though several gate pits were crushed by the longitudinal expansion of dry 12 and 16-inch pipe lines. Expansion joints placed near gate pits relieve the pressure against these structures and would be useful on curves. Accuracy in alignment is advisable. In hot weather the pipe making should be slowed down to the same rate as pipe laying, so that the pipe can be laid within a few days after its curing period. Cement pipe plants should not carry a large stock of pipe out of doors through the summer.

Accidents and failures are likely to occur on all pipe lines, whether clay or cement, when they are new. The pipe layer should stay on the work while the pipe is being tested and proven. Almost never does an accident occur on an old line.

TESTS

INTERNAL PRESSURE AND PERCOLATION TESTS

The resistance to internal pressure has long been a standard test for sewer pipe, but the test has not been applied to irrigation pipe or drain tile to any extent. Comparatively little irrigation pipe has been laid where it could be subjected to high pressure heads, and failures of drain tile are due invariably to external loads.

The test is made by sealing the ends of the pipe in some way and forcing the water into the pipe by means of a small pump, or admitting the water from a water pipe line. Usually a single joint of pipe is taken, but in some instances several joints of pipe have been cemented together and tested as a unit. An entire pipe line, or sections of a line, can be tested after the laying and backfilling are completed, but, of course, no effort is made to test such lines to destruction.

The equipment used for making the tests here reported is shown in Fig. 24. The equipment is at the Tucson city pumping plant. There is a heavy frame with a platform at the bottom and an inverted jackscrew at the top. On the platform is a heavy circular iron plate, through the center of which is connected a ¾-inch pipe. Gaskets of rubber three-sixteenths of an inch thick were used at both top and bottom. On the upper gasket a ¾-inch circular cast iron plate and a circular wooden cover 3 inches thick were placed, and over the latter a short block of wood 4 inches by 4 inches. The upper cover carried a small pipe outlet, to permit the escape of air. The maximum water pressure obtainable was about 50 pounds per square inch. A pressure gauge was attached so that it measured the pressure at the midheight of the pipe. In order to control the pressure readily and to apply it slowly without shock, a bleeder valve was provided as shown in the lower right hand corner of Fig. 24. This equipment had been used previously to test clay sewer pipe.

Usually, when the tests to be made are few in number, the pipe is laid on its side and two wooden or iron bulkheads are fastened on with one or several longitudinal rods running through the tile or just outside it. Nuts on the ends of these rods are tightened sufficiently to prevent leakage around the gaskets. The vertical frame and jackscrew have the advantage of convenience and speed.

Internal pressure tests are attended by considerable difficulty.

The ends of the tile are usually somewhat rough and may not lie in a plane, wherefore it is difficult to prevent leakage around the gaskets. Leakage is objectionable for two reasons; first, the overflowing water from the top gasket wets the outside of the tile and prevents observations on the percolation of water through the tile walls; second, the leakage is often so great as to reduce the pressure head that can be applied to the pipe. In order to make the gaskets

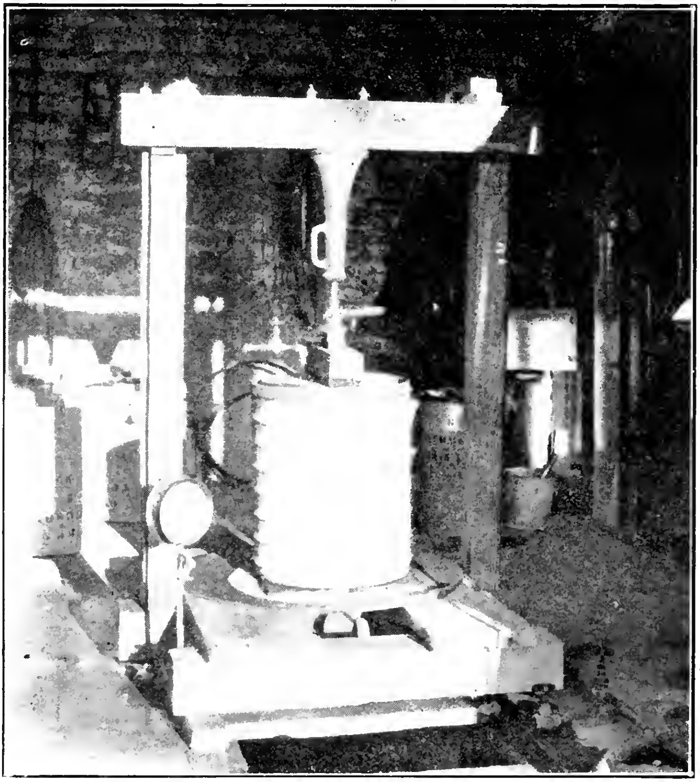

Fig. 24.—Testing 16-inch machine-made pipe for resistance to internal pressure, at the Tucson city pumping plant, in 1917.

tight, the jackscrew is likely to be turned down until an excessive pressure is put upon the test specimen.

The criticism is made that a heavy longitudinal stress must seriously affect the resistance to bursting. One specification has forbidden the tests to be made in such a way that the gaskets are held on the pipe ends by longitudinal pressure. Other engineers have asserted that the pipe would burst as the effect of the heavy compressive stress. As a matter of fact the ends of the pipe must be strengthened somewhat by anchored bearings, but at the center of the pipe a shearing stress is developed which might induce failure under some extreme conditions. This shearing stress will be a mathematical average in value between the unit tension and the unit compression, both being considered as positive and will be a maximum on an angle of 45 degrees. In all the tests at the City Water Works no pipe was observed to fail while the jackscrew was being turned in the effort to reduce the leakage past the gaskets.

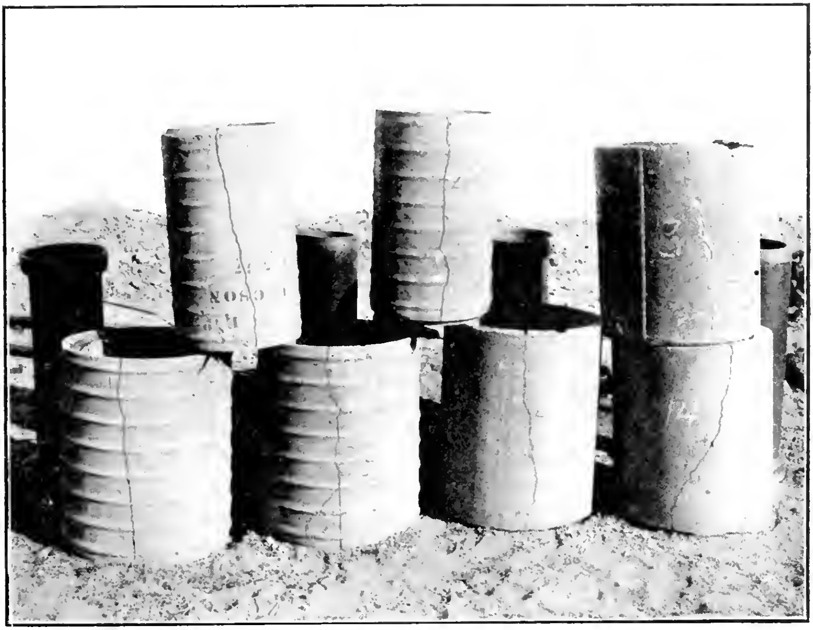

Fig. 25.—Test specimens broken in internal-pressure testing machine.

Nor were there any breaks which showed a failure in shear at the midheight of the specimen. On a similar testing frame recently three men attempted to break an 8-inch pipe by applying the utmost pressure, but were unable to injure the pipe.

The record of tests, excluding some that were rejected, is given in Tables VIII and IX. The first of these two tables gives the preliminary measurements and age of the test pieces, and the second table gives the results of the tests.

Examination of Table VIII proves that the wall thickness of machine-made pipe is very uniform, the variation being less than one-eighth inch. The thickness of hand-made pipe is uniform at the

TABLE VIII. MEASUREMENTS OF SPECIMENS FOR INTERNAL PRESSURE TESTS

No.	Kind	Inside diam.	Length	Thickness						Weight	Age
				Tongue end			Groove end				
				Max.	Min.	Aver.	Max.	Min.	Aver.		
		In.	*Ft.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*Pounds*	*Days*
1	McCracken 3:1	12.05	2.00	1.35	1.25	1.30	1.35	1.25	1.30	105.0	36
2	"	12.10	2.00	1.30	1.20	1.25	1.35	1.25	1.30	104.0	33
3	"	12.10	1.99	1.30	1.25	1.27	1.35	1.30	1.32	104.0	33
4	"	12.10	2.00	1.35	1.25	1.30	1.35	1.25	1.30	104.5	33
5	"	12.10	2.00	1.35	1.20	1.27	1.35	1.25	1.30	103.5	36
6	"	15.72	1.97	1.75	1.59	1.67	1.72	1.66	1.69	180.0	28
7	Hand-made 3:1	16.00	2.02	2.00	1.60	1.80	1.90	1.80	1.85	170.0	60
8	"	15.95	1.97	2.15	1.70	1.92	1.95	1.78	1.86	183.0	68
9	"	16.05	2.03	2.00	1.60	1.80	1.80	1.70	1.75	173.0	60
10	"	16.05	2.02	2.00	1.65	1.82	1.90	1.70	1.80	174.0	87
11	"	16.05	2.04	2.00	1.65	1.82	1.85	1.70	1.77	177.0	68
12	" 4:1	15.80	1.96	1.95	1.70	1.83	2.03	1.72	1.86	....	200
13	"	15.85	1.85	2.00	1.60	1.80	2.00	1.75	1.87	....	200

TABLE IX. INTERNAL PRESSURE AND PERCOLATION TESTS OF CEMENT PIPE

No.	Percolation in 5 minutes			Max.	Remarks
	at 5 lb.	at 10 lb.	at 15 lb.		
				Pounds	
1	None	Small wet spot near top	20 sq. ins. wet	39	Held 3 mins.; did not break
2	Small wet spot near top	Same	Same	40	Broke suddenly
3	None	None	Slight, near top	50	Did not break
4	"	"	" " "	45	Broke suddenly
5	Two wet spots near top	12 in. along top corrg.	Same	47	Held 19 mins.; did not break
6	One spot near middle	Also, along top corrg.	Same	39	Did not break
7	Sweats at 2 lbs.	Sweating freely		14	Broke
8	On one side	95% of surface wet	All wet	25.5	Broke
9	Wet all over	Percolates	Freely	21.2	Crack started at bottom
10	Part of surface	Same	Most of surface	22	Did not break
11	Percolates freely all over	Same		21	Broke
12	Sweats at 2 lbs.	Water runs out	Same	14.8	Broke
13	Percolates freely	" " "	Squirts in 4 places	14	Diagonal fracture

groove end, but is likely to vary a quarter inch or more at the tongue end. The reason for this eccentricity is that the pipe is made with the groove end on the ground, and that the forms become displaced somewhat by reason of unequal tamping as the forms are gradually filled. The machine-made pipe is accurate as to length and uniform in weight.

Usually the breaks occurred suddenly and a single crack opened about one-sixteenth inch or less, extending vertically from bottom to top. In one case the crack opened slowly, beginning at the bottom, and in several cases the crack appeared to start definitely at the bottom. A few of the cracks extended upward spirally. Inasmuch as longitudinal breaks in pipe lines produce cracks in both top and bottom, it might be expected that there would be two cracks in the broken test pieces. There was no indication, however, of a second crack in the pipe wall with two exceptions. The cracks in the machine-made pipe opened much wider than those in the hand-made pipe.

In the author's tests there were six or eight cases in which the pipe broke at very low pressure. Three of the machine-made pipe broke at less than ten pounds per square inch. Several possible explanations of these tests should be considered. They are:

1. Injury to the pipe in hauling or unloading.
2. Water hammer or pulsations due to the proximity of the testing machine to the city pumps.
3. Eccentric loading or combination of central load at top with two side supports at bottom. The location of the breaks might indicate this.
4. Reduction of strength due to saturation.
5. Expansion of the interior part of the pipe wall, perhaps one-third or one-fourth of the thickness, due to partial penetration of the water. The pipe were dry when tested.

It is believed that the last named was the main cause of the early failures. Expansion of the inner shell would produce tensile stresses in the outer portion which would increase with the penetration of water. This tension, added to that due to internal pressure, might crack the outside portion, and the remaining wetted portion would be too thin to resist even the low internal pressure.

More recently the author, while visiting another pipe yard, watched the testing of two specimens. Both withstood 80 pounds pressure. He then asked to make a test in the same manner as practiced at Tucson, and picked a pipe which had been lying in the sun for two months. It broke at 15 pounds. The first tests were made by running the pressure up quickly; the last test and all the tests at Tucson were preceded by a 15-minute seepage test.

These results demonstrate that consideration should be given to the condition of the pipe specimens and to the technique of testing. Specifications do not mention either of these matters, but merely fix a minimum pressure, usually 33 pounds, which the pipe must stand.

Four of the 12-inch pipe, two of which could not be broken in the tests of 1917, were tested in June, 1918. The results are given in Table X. All of these pipes were machine-made. During this

TABLE X. TESTS OF FOUR 12-INCH MCCRACKEN PIPE UNDER VARYING CONDITIONS OF SATURATION

No.	Condition	Percolation 10 lbs. for 5 mins.	Max. pressure	Remarks
			Pounds	
1	Dry; stood in open air for 15 months	Small wet spot under top corrugation	38	Full city pressure; did not break
1	(On following day)	Two small spots	38	Stopped to remove obstruction in supply pipe
1	After holding water a total of 31 mins		33	Broke suddenly
2	Immersed 51 hrs prior to testing	No seepage	35	Full pressure; did not break
3	Immersed 1½ hrs prior to testing	No seepage	35	Full pressure; did not break
4	Dry; in open air 15 months		10	Failed at tongue end first; then at groove end

long period the four pipes had stood in the open air at the City Water Works. Two of the four pipes were tested dry; the others were immersed in water, one for 1½ hours, the other for 51 hours. The two dry pipes failed; the wet ones could not be broken. One and a half hours, in the case of No. 3, was long enough to expand the pipe and stabilize the even distribution of stresses in the pipe wall. In the case of No. 1, tested dry, the pipe was weakened by holding water 31 minutes. During 10 minutes of this time the pressure was kept at 10 pounds and twice the full city pressure of 38 pounds was turned on. Finally the pipe broke at 33 pounds, although in March, 1917, before the pipe had become dry, it had withstood 47 pounds for 19 minutes. Pipe No. 4, also tested dry, failed a quarter of a minute after the pressure reached 10 pounds, although it had withstood 50 pounds pressure in March, 1917. These tests tend to confirm the conclusions reached above.

The sweating through the walls of the hand-made pipe at 5 pounds pressure was quite strong, and with 10 pounds pressure the percolation was rapid. Even at 2 pounds or less, the uneven character of the pipe was apparent, the less carefully tamped portions becoming wet on the outer surface immediately. It has been noted often in the field that a new pipe line is quite porous; but it has been found that the pipe improves rapidly in this respect and soon becomes impervious except perhaps at occasional spots where tamping was poorly done. Hand-made pipe is usually coated on the inside with a wash of neat cement, partly to make it watertight and partly to increase its carrying capacity.

The machine-made pipe was practically impervious at 15 pounds pressure. The slight sweating on the top corrugation is believed to have come through the joint under the gasket. The inner surface as made by the packer-head is very dense. Where the pipe is laid in a trench with rich mortar in the joints, even the slight sweating on the corrugation at the groove end is impossible. In no other way is the superiority of the machine-made pipe so pronounced as in the percolation test.

Some advocates of clay pipe for sewers are asking that the percolation test be discontinued. However, the American Society for Testing Materials, in standard specifications just adopted, has included percolation tests at 5 and 15 pounds for both clay and cement sewer pipe. The test can be made in connection with the internal pressure test without additional apparatus, and undoubtedly it will be used increasingly in the future. The specifications of the A. S. T. M. should be amplified to cover the condition of the pipe.

One advantage of the hydrostatic tests is that they test every part of the pipe in detail. For instance, if the tongue end is made with an insufficiency of mortar in the hopper, or if the wall on one side is thin, or in spots the mortar was not well tamped, the pipe will fail because the defective part fails. On the other hand, the external pressure test is much less likely to reveal a local weakness.

Records of pipe tests have been noted in which the pipe stood considerably over 100 pounds pressure with no seepage. These tests have been made usually on 8-inch pipe, which has thicker walls comparatively than the larger sizes commonly used in irrigation pipe lines.

The question of what pressure heads can be considered safe for machine-made cement pipe lines is an important one. A considerable factor of safety must be used by designers to allow for occasional defective pipe that may get past the inspector and for the effect of water hammer. The evidence of tests indicates that pipe lines made of 1:3 mortar will be safe with 20 or 25 feet pressure head, or with 30 feet head if there is no possibility of water hammer and if the full pressure need not be applied until the pipe line is well cured in the trench. In case higher heads must be provided for, the mortar can be mixed in the proportions of 1:2½, the walls can be made thicker, and, if necessary, wire reinforcement can be used.

Hand-made pipe made of 1:3 mortar (or of 1:2½:1½ concrete) withstands pressures about one-half as great as machine-made pipe. Applying the same factors of safety, hand-made pipe can be considered safe under 10 or 12 feet head, or under 15 feet head if there is no danger of water hammer. Several hand-made pipe lines are under heads exceeding 20 feet. The strength of 1:4 pipe is about two-thirds as great as that of 1:3 pipe. Where the line is under little or no pressure 1:4 pipe may prove successful, but the added security, less breakage in handling, and slight difference in cost will justify the stronger pipe in almost every case.

EXTERNAL PRESSURE TESTS

In order to test the resistance of cement pipe to external pressure, a testing equipment, as shown in Fig. 26, was prepared. The joint of pipe to be tested was bedded on a box of sand so that one-fourth of the perimeter of the center line of the shell was supported in the sand. A bottomless box or frame was then placed over the pipe and filled with sand so as to distribute the pressure similarly

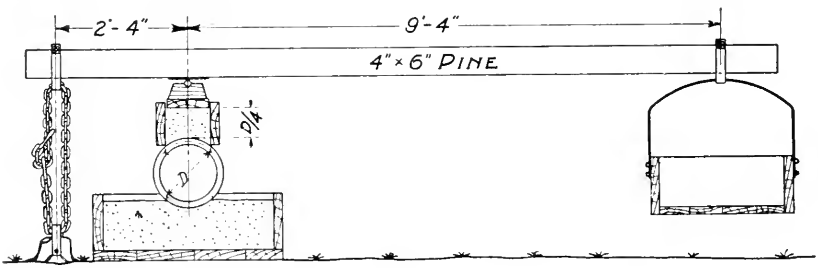

Fig. 26.—Apparatus for making external-pressure tests.

over the upper fourth of the pipe. A short piece of plank rested on the sand and on that was a steel knife edge. No support was given to the sides of the pipe. This arrangement of bearing at top and bottom is called the sand bearing; it is known also as the Iowa bearing. It has been found by experiment that the breaking loads as found with sand bearings approximate very closely to the actual

TABLE XI. EXTERNAL PRESSURE TESTS AT CONTINENTAL, ARIZONA, 1917

Number	Date Tested 1917	Age months	Internal Diam. Feet Vert.	Internal Diam. Feet Horiz.	Average Thickness Inches Top	Average Thickness Inches Bottom	Average Thickness Inches Right	Average Thickness Inches Left	Length Inches	Weight Lbs.	Breaking Load Lbs.	Absorption Percent	Segments	Remarks
	12 inch, machine-made, dry													
1	Apr. 11	4			1 7/16	1 15/16+	1 15/16	1 7/32	24	105	5700	6.03		
2	"	4	1.003	1.003	1 5/16	1 1/4+	1 1/4	1 1/4	24		5614	5.72		
3	"	4	1.003	1.000	1 9/32	1 1/4	1 9/32	1 5/16	24		5354	5.42		
4	Aug. 31	4	1.013	.984	1 11/32	1 9/32	1 3/8	1 11/32	24	105	5513			Washed Sand
5	"	4	.995	1.010	1 5/16	1 9/32	1 9/32	1 1/4	24	100	5652			" "
6	"	4	1.005	1.000	1 9/32	1 1/4	1 9/32	1 9/32	24	104	4622			" "
7	"	4	1.005	.995	1 3/16	1 9/32	1 1/4	1 5/16	24	105	4407			" "
									Av.	104	5266			
	12 inch, machine-made, soaked in water before testing													
8	Apr. 19	4	.995	1.005	1 9/32+	1 9/32	1 1/4	1 5/16	24	106.5	4558	5.86		WT. 108.# after soaking 36 min.
9	"	4	1.000	.998	1 1/4	1 1/4	1 9/32	1 5/16+	24	104.5	3534	5.80		" 107.# " " 46 "
10	"	4	1.005	1.000	1 9/32	1 1/4	1 5/16	1 11/32	24	102.5	3622	5.54		" 104.# " " 46 "
									Av.	104.5	3905			
	14 inch, machine-made, dry													
11	Apr. 19	1	1.160	1.160	1 7/16	1 3/8	1 1/2−	1 11/32	24	129.5	3994	5.87		
12	"	1	1.180	1.181	1 1/4	1 11/32	1 11/32	1 5/16	24	124.0	3694	5.54		Had a good "ring"
13	"	1	1.157	1.160	1 3/8+	1 3/8	1 3/8−	1 7/16	24	128.0	2639	6.58		" " poor "
									Av.	127.2	3442			
	16 inch, machine-made, dry													
14	Apr. 18	3	1.345	1.335	1 5/8−	1 3/4	1 3/4−	1 5/8	24	176.5	5974	5.49		
15	"	3	1.335	1.345	1 11/16−	1 3/4	1 11/16	1 3/4−	24	179.0	5706	5.15		
16	"	3	1.340	1.349	1 9/16	1 23/32	1 11/16+	1 1/2+	24	178.0	5288	6.06		
									Av.	177.8	5656			
	16 inch, hand-made, dry													
17	Apr. 18	4	1.330	1.333	1 11/16	1 25/32	1 25/32	1 21/32	24	170.5	2906	10.3		
18	"	4	1.315	1.340	1 13/16	1 13/16−	1 13/16−	1 3/4−	24	170.5	3659	7.85		
									Av.	170.5	3282			
	18 inch, hand-made, dry													
19	May 7	5	1.485	1.515	1 7/8	1 29/32	1 29/32	1 25/32	24	208	3438	6.61		Wet mix Good "ring," Perfect joint
20	"	5	1.500	1.500	1 7/8	1 25/32	1 15/16+	1 7/8	24	203	2174	9.93		Dry mix Good "ring," part of bell off
									Av.	206	2806			
	20 inch, machine-made, dry													
21	Sept. 1	4	1.688	1.688	1 7/8	1 7/8	1 13/16	1 13/16	24	240	6300	4.2		Washed Sand
22	"	4	1.688	1.667	1 7/8	1 27/32	1 13/16	1 3/4	24	240	5195	4.5		" "
23	"	4	1.682	1.672	1 25/32	1 25/32	1 27/32	1 7/8	24	240	6140	5.2		" "
24	"	4	1.682	1.688	1 7/8	1 27/32	1 25/32	1 25/32	24	236	5265	4.7		" "
25	"	4	1.688	1.682	1 25/32	1 27/32	1 25/32	1 27/32	24	240	5770	4.7		Unwashed Sand
26	"	4	1.677	1.688	1 27/32	1 27/32	1 25/32	1 13/16	24	239	4695	4.6		" "
									Av.	239	5561			

supporting strength of tile in ditches*; the bedding of the tile in the sand is not difficult or onerous, and this method should be preferred to the other methods in use, all of which depend upon doubtful conversion factors.

Downward pressure was provided by means of a lever. The fulcrum was fastened to a tree stump, and the free end carried a suspended box into which pails of sand could be poured. The ratio of lever arms was one to five. Proper allowance was made for the weight of the apparatus resting on the pipe. The time required, including the measurements, was from 25 to 50 minutes per pipe.

The internal diameters were measured vertically and horizontally, and the wall thickness was measured on top, bottom, and each side at the tongue end. Each pipe was weighed before testing. The data of the tests in 1917 are given in Table XI.

The 12-inch, 16-inch, and 20-inch machine-made pipe, tested dry, were of almost identical strength. The breaking loads ranged from 4400 to 6300 pounds. The 14-inch pipe were weaker, the average breaking load being 3440 pounds. This is due in part to the age of the pipe, but an additional reason for the low strength is evident from an inspection of the wall thicknesses. To be consistent, the 12-inch pipe might be one-eighth inch thinner or the 14-inch pipe an eighth inch thicker. An accurate comparison can be had by computing, for each group of pipe tested, the modulus of rupture, that is, the maximum stress in pounds per square inch in the pipe shell at the moment of failure. This comparison is made in Table XII†. Inspection of the last column shows the highest modulus of rupture for the 12-inch pipe and the least for the 14-inch pipe. Apparently there is considerable gain in strength after the first month. Excluding the 14-inch pipe, which was only one month old when tested, the evidence is that the smaller the pipe the better and more densely it was packed. This is perhaps characteristic of packer-head pipe and indicates that the packer-head principle is better adapted to small sizes of pipe than to large sizes. All the moduli are high as compared with other tests on 1 :3 cement mortars.

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*Report of Investigations on Drain Tile of Committee C-6 of the American Society for Testing Materials, published as bulletin of Iowa State College of Agriculture and Mechanic Arts, Vol. XII, No. 34, p. 102.

†For method of computation, see Ibid., page 87.

TABLE XII. MODULUS OF RUPTURE OF MACHINE-MADE CEMENT PIPE, DRY

Group	Diam.	Min. thickness	Breaking load per lineal foot	Radius of center line	Maximum bending moment	Modulus of rupture
	Inches	*Inches*	*Pounds*	*Inches*	*In.—Lb,*	*Pounds*
1	12.0	1.28	2633	6.64	291	1067
2	14.0	1.35	1721	7.68	220	725
3	16.1	1.62	2828	8.86	417	953
4	20.2	1.84	2780	11.02	510	904

The strength of the machine-made pipe in each group is comparatively uniform. This should be characteristic of pipe made by machinery, all pipe being compressed exactly the same way and the same amount. Such uniformity is very improbable in the case of hand-made pipe.

The 16-inch hand-made pipe broke at loads three-fifths as great as the machine-made pipe. This may be accepted as the approximate ratio of strength of the two classes of pipe, inasmuch as the wall thicknesses and ages were approximately the same.

The data obtained on pipe made of washed sand are somewhat equivocal. The tests on 12-inch pipe do not show any advantage from the washed sand, and the tests on 20-inch pipe are not conclusive.

Owing to the difficulties previously had with the internal pressure tests, it was thought that the strength might be reduced seriously by thoroughly wetting the pipe just before testing them. To investigate this possibility, pipes Nos. 8, 9, and 10 were immersed in a tank of water, then weighed and tested immediately. No. 8 was immersed 36 minutes, it gained 1.5 pounds, and broke at 4560 pounds, a reduction of 18 per cent from the strength when tested dry. Nos. 9 and 10 were soaked 46 minutes, and lost 36 per cent in strength.

These tests, while few in number, are sufficient to establish the point that cement pipe, cured and dry, is weakened by immersing in water. The weakening may be due, in part, to differential expansion, or it may be due wholly to the condition of saturation. Van Ornum found that the loss of strength of concrete cylinders is temporary, and the original strength is regained and perhaps exceeded in the course of a few weeks*; but the maximum load on a pipe line, laid dry, may occur when it is at the lowest point of its strength. Usually it is possible to apply the load by degrees; deep trenches can be backfilled in part only, until sometime after water has been

*Trans. Amer. Soc. C. E., Vol. LXXVII, p. 438.

TABLE XIII. EXTERNAL PRESSURE TESTS OF CEMENT PIPE AT CONTINENTAL, APRIL 27, 1918

Number	Mixture	Age months	Average Thickness Inches				Length Inches	Weight Lbs.	Breaking Load Lbs.	Segments	Remarks
			Top	Bottom	Left	Right					
			14" machine-made, in pipe line 1 year, then dried out								
1	3:1	15	1 5/16	*	*	*	24 1/16	125	5434		*Bell and tongue badly broken
			14" machine-made, dry								
2	3:1	5	1 7/16	1 3/8	1 3/8	1 3/8	24 3/8	134	6409		
3	"	5	1 5/16	1 1/2	1 5/16	1 1/2	24 1/4	130	5499		
4	"	5	1 3/8	1 7/16	1 7/16	1 3/8	24	132	5979		
							Av.	132	5962		
			20" machine-made, dry, 2 3/4:1 mix.								
5	2 3/4:1	10	1 3/4	1 3/4	1 15/16	1 13/16	23 3/4	239.5	5495		Irregular Segments
6	"	10	1 7/8	1 3/4	1 7/8	1 3/4	23 3/4	237.5	4640		
7	"	10	1 3/4	1 7/8	1 7/8	1 3/4	23 3/8	237.5	3810		Irregular Fracture
8	"	10	1 3/4	1 13/16	1 13/16	1 3/4	23 7/8	238	4015		
							Av.	238	4490		
			20" machine-made, dry, 3:1 mix.								
9	3:1	10	1 13/16	1 5/8	1 5/8	1 7/8	24 1/16	243	5105		
10	"	10	1 3/4	2	1 7/8	2	23 7/8	239	5300		
11	"	10	1 13/16	1 3/4	1 3/4	1 13/16	23 3/4	240	5755		
12	"	10	1 3/4	1 7/8	1 11/16	1 7/8	23 3/4	238	4150		Misshapen, part of tongue & bell off
							Av.	240	5078		

TABLE XIV. EXTERNAL PRESSURE TESTS OF CEMENT PIPE AT CONTINENTAL, JULY, 1918

Number		Age days	Average Thickness Inches: Top	Bottom	Left	Right	Length Inches	Weight Lbs.	Breaking Load Lbs.	Segments	Remarks
			Tests on 20-16" machine-made pipe, square ends Cured 7 days in shade								
1		7	1 3/4	1 13/16	1 15/16	1 5/8	23 7/8	190.5	2379		
2		7	1 3/4	1 15/16	1 7/8	1 15/16	23 7/8	195	2536		
3		7	1 7/8	1 11/16	1 13/16	2 1/16	23 3/4	194.5	2226		good fracture
4		7	1 7/8	1 3/4	1 13/16	1 7/8	23 15/16	195	2606		" "
							Av.	194	2437		
			Cured 10 days in shade, then dried in sun								
5		28	1 11/16	1 7/8	1 15/16	1 7/8	23 7/8	189.5	5214		
6		28	1 15/16	1 13/16	1 15/16	1 3/4	23 7/8	188.5	5239		
7		28	1 15/16	1 7/8	1 13/16	1 15/16	24	190	4959		good fracture
8		28	2	1 13/16	1 7/8	1 15/16	23 7/8	185.5	5579		" "
							Av.	188	5248		
			Cured 28 days in shade								
9		28	1 3/4	1 15/16	1 3/4	1 3/4	23 3/4	188	4054		
10		28	1 7/8	1 7/8	1 13/16	1 15/16	23 7/8	195	3431		
11		28	1 15/16	1 15/16	1 7/8	1 7/8	23 13/16	192	3664		
12		28	1 7/8	1 13/16	1 7/8	1 7/8	23 7/8	191.5	3429		good fracture
							Av.	191.5	3644		
			Cured 10 days; then dried; soaked in water 5 hrs. before testing								
13		28	1 15/16	1 5/8	1 13/16	1 7/8	23 7/8	191.5*	2639		
14		28	1 15/16	1 7/8	1 3/4	1 7/8	24	196.5	3859		poor fracture, 3 segments on upper 1/2
15		28	1 13/16	1 7/8	1 7/8	1 3/4	23 7/8	193.5	3717		
16		28	1 15/16	1 15/16	2	1 13/16	23 13/16	192	4107		
							Av.	193*	3580		*weights taken after soaking
17		52	2	1 13/16	2	1 3/4	23 7/8	185.5	4186		Cured about 30 days, then dried out.
18		52	1 15/16	1 7/8	2	1 3/4	23 3/4	188.5	3956		Av. Wt. 187 lbs. Breaking Load 4071 lbs.
19		52	1 13/16	1 15/16	1 15/16	1 7/8	23 7/8	190	3956		Cured 10 days, then dried out.
20		52	1 13/16	1 15/16	1 13/16	1 15/16	23 7/8	186	4416		Av. Wt. 188 lbs. Breaking Load 4186 lbs.

put in the line, and the first run of water should fill the pipe without subjecting it to much pressure head.

The exact relation between the loss of strength and the absorption of water can be obtained only by systematic testing on a comprehensive plan. The hypothesis is offered, however, that the weakening can be reduced by extending the period of curing, and this should be done in most cases. Most pipe makers cure their pipe only from six to ten days, and the duration of time of curing of large sized pipe or of pipe that is not to be laid immediately may well be extended to 15 or even 30 days.

External pressure tests were made on another group of pipe on April 27, 1918. The data are given in Table XIII. Pipe No. 1 of this group was a 14-inch pipe, which had been in use in the ground for over a year but was removed during some change in the line. It was dried in the sun before testing. The pipe was under the usual weight because the tongue and groove were broken off. The next three pipe were five months old and were tested dry.

The 20-inch pipe consisted of four specimens that were made of mortar mixed in the proportions of one of cement to three of sand, and four specimens of 1:2¾ mortar. The two lots were approximately the same age. The leaner mixture showed the greater strength. This is contradictory to common knowledge of the variation of strength with richness of the mortar. Possibly it would be better not to publish the results. It may be, however, that these results are linked in some way to the pipe failures described on page 110. If differential expansion causes weakening of the pipe, differential contraction at some stage of the curing or just afterward may have caused minute shallow cracks, which would be more likely to come on the outer surface of the pipe, and would tend to weaken the pipe permanently.

Another test series was made in June, 1918, to determine the effect of variations in the curing of pipe. All of the test specimens were of 16-inch pipe and were taken at the pipe plant at one time, so that they were of the same proportions and consistency. The original program of testing was not carried out, however, because the pipe maker failed to follow instructions for curing the test specimens.

The results are given in Table XIV. Four pipe were tested at the end of seven days. After 28 days 12 pipe were tested. Of these 12, four had been kept wet by sprinkling, four had been cured for 10 days and then placed in the stackyard, and four had been cured and stacked but were soaked in water for 5 hours just before testing. At the end of 52 days tests were made on four pipe, of which two had been cured by sprinkling for 30 days, and two had been stacked after 10 days. Through a mistake a top sand box 14 inches wide was used during all of the tests of this series. The average results are as follows:

The first group of four pipe, age 7 days, broke at an average of 2437 pounds. This is about half of the strength which the pipe should attain ultimately. The second group, after 28 days curing, broke at 3644 pounds, an increase of about 50 percent over the strength at 7 days. From a consideration of the 14-inch pipe in Table XIII a further increase in strength could be expected if the curing were continued.

The third group, four pipe, were cured in the usual way. The average breaking load was 5248 pounds. The next group were cured in the usual way, but were immersed in water for five hours just before testing. The effect of the soaking was to reduce the strength 32 percent.

The last four tests included two pipe that were cured 10 days and two that were supposed to have been cured 30 days. The two former had a slightly higher average strength, but the number tested was so small that no conclusions can be drawn.

The resistance of cement pipe to crushing depends to a large extent on the moisture content of the pipe. It is useless to standardize the details of testing and disregard the condition of the test specimens. The object of testing is not to obtain the maximum possible strength, but to ascertain the strength under actual working conditions. Cement pipe is used to convey water, and after laying it is certain to become saturated. The strength of dry pipe, therefore, is artificial and abnormal, and does not measure the strength of the pipe when buried in a trench. At the present time specifications for pipe testing do not stipulate the condition of the pipe. The following clause should be added to cover this feature.

> All test specimens shall be tested when wet. Preferably they shall be kept thoroughly wet for at least a week prior to testing. If it is necessary to test dry pipe on short notice, they shall be immersed in water for at least four hours before testing.

Pipe tests at the University of Arizona hereafter will be made with the pipe in a thoroughly wet condition.

LOADS ON PIPE IN DITCHES AND DESIGN OF PIPE LINES

The external loads which are borne by a pipe line are due to the backfilling in the trench and any superimposed loads, such as the weight of a wagon or tractor. Both theory and experiment have shown that the pressure due to the backfilling is a function of the width of the trench, and not a function of the width of the pipe.

The downward pressure of backfilling can be approximated from the following formula developed by Professor Anson Marston at the Iowa State College*.

$$L = C\ W\ B^2$$

in which

L=the load on a pipe in a ditch, in pounds per lineal foot, from the weight of ditch filling.

C=coefficient, taken from a table or diagram.

W=weight of ditch filling material, in pounds per cubic foot.

B=the breadth of the ditch, a little below the top of the pipe, in feet.

The coefficient "C" depends upon the nature of the ditch filling material and upon the ratio of the height of fill above the pipe, H, to the breadth of ditch, B. Marston has provided a table of safe working values of C, and also a convenient diagram from which the values can be taken†. A much condensed table is given here in Table XV for the convenience of designers.

TABLE XV. APPROXIMATE SAFE WORKING VALUES OF "C"

Ratio $\frac{H}{B}$	Minimum—Damp soils before setting	Maximum for ordinary sand	Saturated black loam	Maximum—Completely saturated clay
0.5	.46	.46	.47	.48
1.0	.83	.85	.86	.90
2.0	1.40	1.47	1.51	1.62
3.0	1 78	1.90	1.99	2.19
4.0	2.04	2.22	2.35	2.65
6.0	2.34	2.61	2.81	3.32
8.0	2.48	2.82	3.06	3 74
10.0	2 54	2.92	3.20	4.01

Trenches are dug about ten inches wider than the outside diameter of the pipe. For 12-inch pipe and 20-inch pipe, therefore, the trenches are 25 and 35 inches wide, respectively.

The downward pressure for 12, 16, and 20-inch pipe under various depths of filling, as computed by the Marston formula, is given in Table XVI. The filling is assumed to be sandy soil.

*Bulletin of Iowa State College of Agriculture and Mechanic Arts, Vol. XII, No. 34, p. 96.

†Ibid., pp. 95-96.

TABLE XVI. DOWNWARD PRESSURE ON PIPES IN DITCHES IN POUNDS PER LINEAL FOOT

Diameter of pipe	Breadth of ditch B	Depth of ditch filling in feet			
		2.5	5	10	15
Inches	*Inches*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
12	25	480	840	1240	1450
16	30	600	1130	1680	1990
20	35	710	1350	2160	2660

Comparing these loads with the strength of the pipe as shown in column 4 of Table XII, it is apparent that while the smaller sizes of pipe have ample strength, the 20-inch pipe, when buried over 10 feet, has a very small margin of safety. It is recommended that designers should use a factor of safety of 1.25 to 1.5, depending on how much care is likely to be taken in laying the pipe. It is not practicable ordinarily to demand pipe of varying wall thicknesses because pipe makers cannot afford to carry more than one set of pallets for each size; but the requisite strength can be secured in other ways, especially by the control of the curing of the pipe, and in important cases it may be necessary to require extra thick pipe walls.

Although the external pressure tests exhibit approximately equal supporting strength for the various sizes of pipe, this is not a rational relation; the larger pipe should have greater strength. The present-day practice with respect to thickness of pipe is exhibited in Table II. The practice should be changed by using slightly thinner walls for small pipe and increasing the wall thickness of the larger sizes. A great deal of 36-inch pipe is made with 3-inch walls. It is said in defense that more gravel can be used in the concrete in large pipe and that it can be better tamped than can small pipe. But the percentage of failures of 36-inch pipe is greater than for any other size. Thirty-six-inch pipe should have walls 3⅝ inches in thickness.

From the few tests made on hand-tamped pipe, it is seen that 16-inch pipe of that character is in danger of crushing if buried 10 feet in depth.

Unlike drain tile and sewer pipe, both of which are laid on even gradients, irrigation pipe can follow the surface undulations, and hence it is seldom laid over six feet in depth. Usually the internal pressure head is the limiting factor for which the strength of the pipe must be designed. Occasionally, however, a pipe line is placed under a deep fill, and in those cases the considerations relating to external pressure cannot be overlooked.

ABSORPTION TESTS

The absorption is determined in the following manner: A piece of concrete, weighing from one to two pounds, is broken out of each pipe to be tested. These test pieces are dried in an oven at a temperature of 110° F. for at least seven days, and are then weighed. They are then soaked in water for three days and weighed again. The gain in weight, expressed as a percentage of the dry weight, is called the absorption.

The absorption is a measure of the watertightness of concrete. The test is especially important if the pipe is to be used under considerable water pressure or in alkali soil. With clay pipe, however, the test is not a positive indication of perviousness. If the pipe is thoroughly vitrified the absorption may be low and yet the pipe may be pervious.

Absorption is a measure, also, of the density, and the density of concrete is an index of its strength. Given the ingredients and the proportions, the strength depends directly upon how densely the concrete is packed. It is possible to tamp pipe by hand so thoroughly as to give it great density; much depends on the man who does the tamping and on the rate at which the mortar is fed into the molds. It is likely, even, that pipe made in the morning will be denser than that made in the afternoon, and different parts of the same pipe must vary in density. On the other hand, the density of machine-made pipe is very uniform.

The results of the tests for absorption are placed in Table XI in order to study the effect of the porosity upon the strength. The absorption for the machine-made pipe varies from 5.15 to 6.58 per-cent, average 5.7 per cent. The absorption for the hand-made pipe is shown to be considerably higher.

Test pieces from pipe Nos. 4 to 7 of Table XI were boiled three hours and then were left in the water for three days before weighing. The average absorption was 7.6 per cent. The figures are not placed in the table because they are not comparable with the others. The tentative specifications adopted recently by the American Society for Testing Materials for sewer pipe require that, after thorough drying at a temperature not less than 110°, the specimens shall be kept in boiling water five hours. Doubtless this method of making the absorption test will come into general use. Boiling must result in expelling all the air from the test specimens, but the acceleration of the hydration of the cement is likely to make the porosity appear to be greater than it is.

In November, 1916, some McCracken sewer pipe made of one part cement to two and a half parts of sand, and some vitrified clay sewer pipe were tested for absorption. The clay pipe was being used for street sewers in Tucson. The McCracken cement pipe had been offered in the bidding, but was not accepted on account of undue prejudice against the use of cement pipe for sewers. The results of the tests are given in Table XVII. They show that clay pipe may have a very low percentage of absorption and yet be very pervious to water.

TABLE XVII. ABSORPTION TESTS ON SEWER PIPE, TUCSON, 1916

No.	Sample	Absorption	Perviousness
		%	
1	Clay tile, nearly vitrified	3.07	No seepage 15 pounds 5 minutes
2	" " thoroughly vitrified	2.43	Sweat uniformly all over.
3	" " nearly vitrified	2.98	" on ⅔ of surface
4	" " semi-vitrified	5.59	" all over in ½ min.
5	Cement pipe, body	4.61	Not tested for seepage
6	" " bell	2.89	

INTERNAL FRICTION TESTS

Tests to determine the friction loss in hand-made cement pipe were made at the University Farm in 1916. The object was to furnish a basis for the design of two additions to the distributing system.

All of the old line was 12 inches in diameter and all except the first 360 feet was built with rectangular outlet boxes spaced every 36 feet. These boxes are 22 inches long by 30 inches wide, and have two discharge notches at the top, one toward the right of the pipe line, one toward the left. The flow of water expands on entering a box and contracts on leaving, so that there is a considerable loss of head in each box. These boxes were designed by a former superintendent of the farm. The design is not to be recommended.

In making the tests, the discharge of water was measured over a weir just before entering the pipe line, and the water levels were noted in each box by measuring down from a point on the top. A line of levels had been run to determine the elevations of the points on the tops of the boxes. The cement pipe when new had received a coat of neat cement wash on the inside surface.

After the additional pipe line had been laid in the summer of 1916, pipe friction tests were made in that portion which had 12-inch outlet risers and valves of the California pattern; that is, the riser is a joint of pipe cemented into an opening in the top of the pipe line. In this case the loss of head must be moderate since the flow of water is expanded on the top side only, the filaments of water on the lower side moving in straight lines. The results of all the tests are given in Table XVIII.

TABLE XVIII. FRICTION LOSSES IN HAND-MADE CEMENT PIPE AT THE UNIVERSITY FARM

Pipe line	Discharge	Loss of head per 100 feet	Increase in loss	Loss per box or riser
	Second-feet	*Feet*	%	*Velocity.heads*
Straight, no boxes	1.6	.222	..	....
Rectangular outlet boxes every 36 ft.	1.6	.368	66	0.87
Circular outlet risers every 36 ft...	1.6	.300	35	0.47

The results in Table XIX will be of value to designers of pipe lines. While pipe friction tables are easily available, data on the effect of boxes and risers have not been published. The value obtained in the straight pipe without risers corresponds to a value of "n" in Kutter's formula of .013. This is the value most used for cement and concrete surfaces.

Tests of pipe friction were made at Continental in 1917. The flow of water is northward from the pumping plant, through about a mile of machine-made pipe, thence eastward across the railway and through a quarter mile of 16-inch hand-made pipe. Readings were taken at the several gate pits built at intervals along the line. There are no outlet risers on the line of pipe as tested except in the 16-inch line, where the risers are 280 feet apart. A summary of the tests is given in Table XIX.

TABLE XIX. FRICTION TESTS ON CEMENT PIPE LINES AT CONTINENTAL'

From	To	Dist.	Diam.	Dis-charge	Loss of head	Time after adjusting gates		Value of "n"
		Ft.	*In.*	*Sec.-ft.*	*Ft.*	*Hr.*	*Min.*	
April 26, 1917								
Lateral No. 2	Lateral No. 3	897	14	2.44	2.85	0	18	....
Lateral No. 3	R. R. Crossing	2063 / 1100	14 / 12	2.44	11.83	0	18	....
R. R. Crossing	Riser No. 4	1120	16	2.15	0.99	0	18	.013
Sept. 27, 1917								
Lateral No. 2	Lateral No. 3	897	14	2.49	2.77	1	40	....
Lateral No. 3	R. R. Crossing	2063 / 1100	14 / 12	2.49	9.82	1	40	0124
R. R. Crossing	Riser No. 4	1120	16	2.36	1.09	1	40	.013
Oct. 8, 1917								
Lateral No. 2	Lateral No. 3[1]	897	14	2.08	1.59	1	02	0130
Lateral No. 3	R. R. Crossing[2]	2063 / 1100	14 / 12	2.08	8.65		37	....
" " "	" " [1]			2.08	8.22	1	02	0133
" " "	" " [3]			2.08	8.00	1	24	0130
R. R. Crossing	Riser No. 4[1]	1120	16	2.00	0.82	1	02	.0130
Oct. 8, 1917								
Lateral No. 2	Lateral No. 3[4]	897	14	2.49	2.13	3	20	0130
Lateral No. 3	R. R. Crossing[4]	2063 / 1100	14 / 12	2.45	8.26	3	20	0117
R. R. Crossing	Riser No. 4[4]	1120	16	2.38	1.21	3	20	.0135

1—3:00 P. M. 2—2:35 P. M. 3—3.22 P. M. 4—5:20 P. M.

Tests were made on three different dates. Considerable difficulty was experienced in getting consistent results in these tests. For example, in the first set of tests the friction losses between Lateral No. 2 and the railroad crossing appeared to be inexplicably large. In the tests as repeated on September 27, the loss between Lateral No. 2 and Lateral No. 3 is too great.

It was thought at first that the reason might be that considerable portions of the pipe were not running full, even though all pipe ends in the gate pits were well covered. This hypothesis was disproved when it was found that the friction losses were less in the second set of tests, although the water levels in the gate pits were lower than in the first set. A better explanation is that in the long line running north from the pump to the railroad on a descending grade, a great deal of air is trapped. This air cannot work back upstream against the water friction, and so it is slowly rolled along downstream until it escapes at the gate pits. At one gate pit, where the author had a chance to observe, great globules of air, from one to three quarts at a time, were still coming out of the pipe line at intervals of about a minute, and this was an hour and forty minutes after the gates had been adjusted. On the east side of the railroad this effect was not encountered. On that side the line has an ascending grade and the entering water doubtless carries all the air out promptly.

The important bearing of these observations is that, as in many other lines of design, a factor of safety is necessary in designing pipe lines on descending grades, and, furthermore, there should be many air vents or open standpipes on descending grades. In computing capacities, pipe lines are assumed to be running full of water, but no recognition is made of possible unfavorable conditions. It is interesting to note from Table XIX that the friction loss between Lateral No. 3 and the railroad was 43 percent greater in one test made 18 minutes after adjusting the gates than in another test made 3 hours and 20 minutes after adjusting the gates. Also, in the same line, on October 8, with a discharge of 2.08 second-feet, the loss of head decreased from 8.65 feet 37 minutes after adjusting the gates for this test to 8.22 feet one hour after adjusting the gates, and 8.00 feet 1 hour and 24 minutes after adjusting the gates.

From all the above tests it may be concluded that the friction factor, "n," for hand-tamped and washed pipe is .013 and for machine-made pipe the factor is a little less than .013. This assumes that the joints are well made by careful workmen. If it is assumed that the joints will be left rough and projecting on the inside, then the designers should use a friction factor of .014 or .015.

CAPACITY TABLES

As a basis for determining the proper sizes of pipe required in the design of any particular project, Table XX has been prepared. This table is computed from Kutter's formula, using a friction factor of .013. This is a conservative basis for straight lines without risers, and well executed machine-made cement pipe lines may have somewhat greater capacities than those given.

In the case of lines with tee risers of the same size it will be about right to assume an increase of friction loss of 12½ per cent for each riser in 100 feet of pipe*. Thus, if the risers are spaced 50 feet apart, increase the allowance for friction 25 per cent; if they are spaced 33 feet apart, increase the allowance about 38 per cent. Sometimes tee risers of smaller size than the pipe line are used. In

*See page 136.

such cases the increase in friction loss will be less than 12½ per cent for each riser in 100 feet.

The horizontal lines which occur in Table XX indicate the minimum grades allowable for each size of pipe in cases where the water carries much sediment. For example, a 12-inch pipe line must have a fall of at least 0.4 foot per hundred feet in order to prevent the deposition of sand in the pipe. In case the water is clear or can be passed through a settling basin before entering the pipe, the flatter grades can be used, or perhaps the line can be flushed out occasionally through cleanouts.

The capacities are stated in cubic feet per second, but the quantities can be reduced to Arizona miner's inches by multiplying by forty.

TABLE XX. CAPACITIES OF VARIOUS SIZES OF CEMENT PIPE RUNNING FULL

Grade Per 100 ft.	Inside diameter							
	8 in.	12 in.	15 in.	18 in.	20 in.	24 in.	30 in.	36 in.
Feet	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*
1.0	1.10	3.40	6.29	10.38	13.88	23.3	41.4	67.6
.6	0.84	2.64	4.88	8.04	10.71	17.6	31.8	52.2
.4	0.69	2.15	3.97	6.55	8.75	14.3	25.9	42.5
.2	0.48	1.51	2.79	4.60	6.20	10.83	18.2	29.9
.1	0.34	1.06	1.96	3.23	4.39	7.12	12.9	21.1
.08	0.30	0.94	1.73	2.88	3.92	6.33	11.5	18.8
.05	0.25	0.73	1.35	2.24	3.10	4.97	9.0	14.8

DURABILITY

It is assumed frequently by those who are unfamiliar with its use that cement pipe is of doubtful permanence. Advocates of clay tile have disparaged cement pipe many times and have magnified the significance of such failures as have occurred. In most cases these failures have been traceable easily to preventable causes.

On the contrary, cement pipe improves with age. Sewer pipe that has been in use for over thirty years has been examined and single joints removed to show that it is in perfect condition. The *Cloaca Maxima,* one of the sewers of Rome, built about 700 B. C., is still in use. It is an accepted fact that concrete is not injured by ordinary sewage. There are many hundreds of irrigation pipe lines which have been in the ground from ten to thirty years, and which are stronger now than when they were laid.

In some parts of the United States concrete placed in strong alkali soils has been injured or destroyed. The exact action and conditions of the injury have been the source of much inquiry and discussion. Cooperative investigations of the effect of alkali on tile are being made by the U. S. Bureau of Standards with several other organizations. Eight carloads of tile were shipped to eight of the best known concentrated alkali districts, one of them being Yuma, Arizona. The progress report* at the end of two years states that tile made of cement mixtures, not leaner than one part cement to three parts aggregate, made by the wet process, which requires that the molds be held in place for several hours after molding, are apparently unaffected structurally when exposed for two years in operative drains in concentrated alkali soils similar to those included in this investigation. There was no evidence of alkali in the walls of any of these tile. The great majority of the tile manufactured by the dry process, which is now the most commonly used commercial method of manufacturing cement tile, were also unaffected, but there were some exceptions, as indicated by strength tests and by the appearance of alkali salts in their fractured surfaces. The exceptions, however, occurred in other states than Arizona. The tile placed at Yuma, in Section 4, Township 16 South, Range 23 East, S. B. M., in concentrated alkali soil were not injured.

The third progress† report shows considerable effect from alkali, particularly in Colorado. Yuma stands at the foot of the list, show

*Reclamation Record, Vol. 7, No. 8, August, 1916, p. 369.
†Bureau of Standards, Technologic Paper No. 95, November, 1917.

ing the least effect. The grand average crushing strength of the 16 kinds of tile in the eight locations has not diminished in the three years, but many tile show alkali salts in the fracture. Some of the tile, notably the leaner and drier mixtures, are partly disintegrated. It is concluded tentatively that the injury to cement pipe is proportional to the sulfate and magnesia present in the soil water and to the degree of concentration of the salts. Hand-tamped tile are not so resistant as machine-made tile, and tile made of sand cement

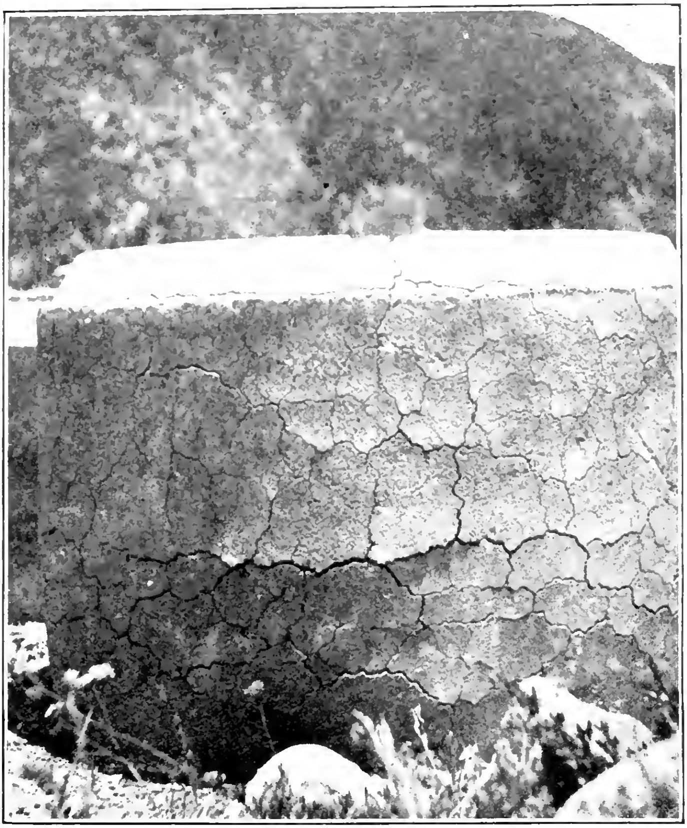


Fig. 27.—Cement pipe, completely disintegrated while curing, due to unsound cement. This is not an argument against the use of cement pipe, but it demonstrates that good material and skill must be utilized in its manufacture.

have less resistance than those made with Portland cement. It is recommended that tile should be made not leaner than 1 : 3, of quaking consistency, and as dense as possible.

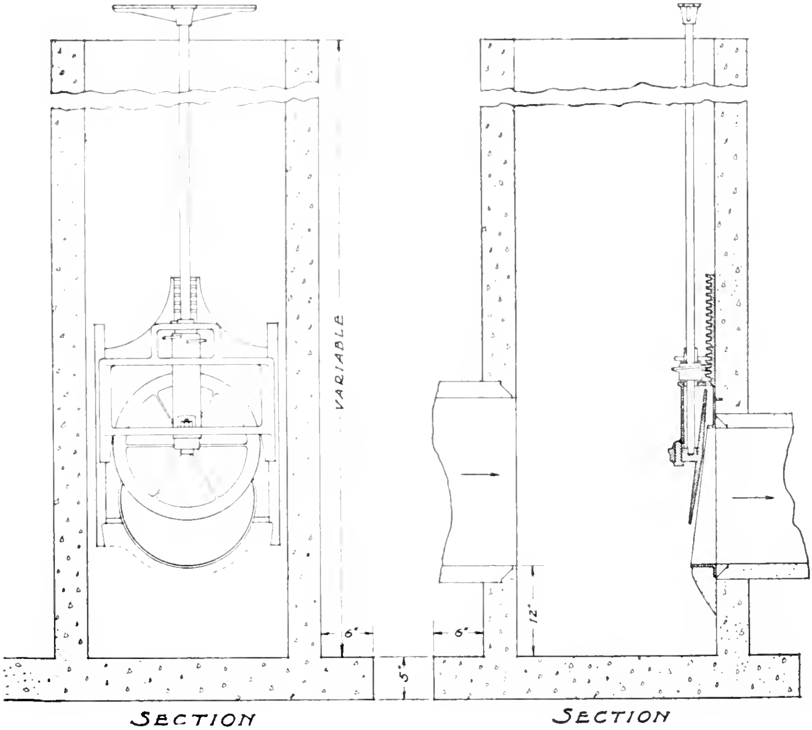
In the Salt River Valley concrete structures in great numbers have been built by the U. S. Reclamation Service and other parties, but there is not a single instance of disintegration or weakening due to alkali. Only one case has been observed by the author of possible deterioration from alkali. In that case the pipe was made by a novice and was poorly tamped. The seepage through the porous spots, which are usually narrow, perhaps one-half inch to an inch along the pipe line, has apparently carried away the cement in solution. The intervening portions are still hard and ring when struck with a hammer. This pipe line is ten years old.

It has long been known that certain pozzuolanic cements are exceedingly resistant to the action of sea water and consequently to similar soil alkalies. Some efforts are now being made to produce a "marine cement" or "alkali-proof cement" by regrinding Portland cement with pozzuolanic materials, especially diatomaceous earth. Laboratory tests show such mixtures to be resistant to chemical action and to be actually stronger in sea water than in soft water.

Good cement pipe cannot be made from unsound cement. Fig. 27, reprinted from Bulletin 55, shows cement irrigation pipe which disintegrated while curing and for which the cement manufacturers paid damages. Cement should be purchased with the standard specifications of the American Society of Civil Engineers. Unsound cement is met with much less frequently than it was twenty years ago.

GATES

After the pipe line is laid in the trench, the auxiliary structures are built in place. Gate pits are located at frequent intervals, depending on the fall, or gradient, and the location of laterals. A



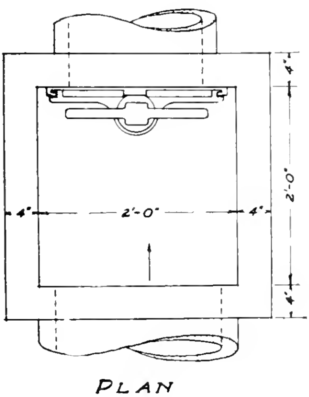


Fig. 28.—Design for square pit, with bevelled-seat gate. Circular gate pits are more easily reinforced and can be made in sections in pipe molds.

design for a square gate pit is shown in Fig. 28. The walls are of 1:2:4 concrete 4 inches thick. The base is extended to prevent undercutting in case the flow overtops the pit. The largest size of gate that can be set in so small a pit is 18 inches in diameter. If the pit is at the head of a lateral, two gates are set, one on each outflow. No gate is put on the inflow pipe because the pit serves as an outlet for air. The most frequent type of gate pit is made of regular lengths of cement pipe. Usually small sizes are employed and it is not possible to descend into the pit to repair or replace the gate, as would be feasible in a pit 30 inches in diameter. In general, gate pits, like tanks and reservoirs, should be circular in section.

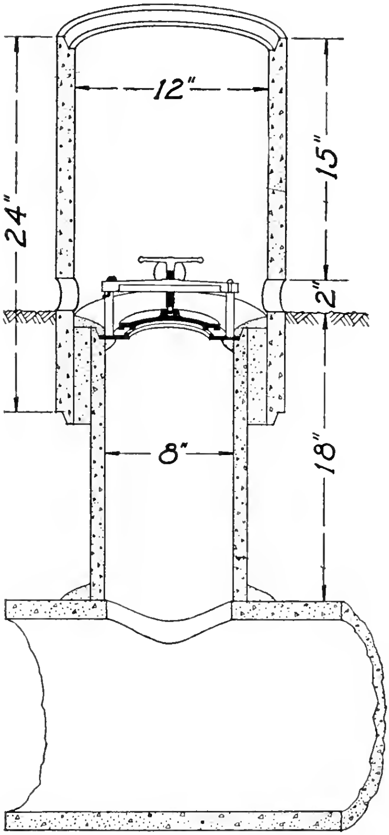


Fig. 29.—Riser and circular valve for taking out water for orchards or row crops.

Several good designs of gates are on the market. One has a beveled seat and is brought to place by means of a square-threaded nut engaging a long rack. There can be no water hammer caused by a gate of this type. Another design has a lock-nut and, when it is loosened, the gate can be lifted or dropped to another position and there clamped. The plain slide gates are not to be recommended; they depend upon the water pressure to make them tight, and they usually leak.

RISERS

The ordinary risers used in orchards are as shown in Fig. 29. A riser is placed at the head of each row of trees and the four small streams of water taken through the small openings are run down four furrows, two on each side of the trees. From 5 to 30 gallons a minute are run in each stream, depending on the character of the soil, the slope of the land, and the length of run

In clay soil it is easy to keep the four streams separate, but in sandy soil the streams are apt to run together. Usually 12-inch pipe is used for four side openings, and 16-inch pipe or pipe hoods for six openings. For easily eroded soil, the 16-inch hoods are advisable for four openings.

Risers and hydrants of various designs are used for alfalfa, but it is believed that a simple riser and valve terminating 2 inches

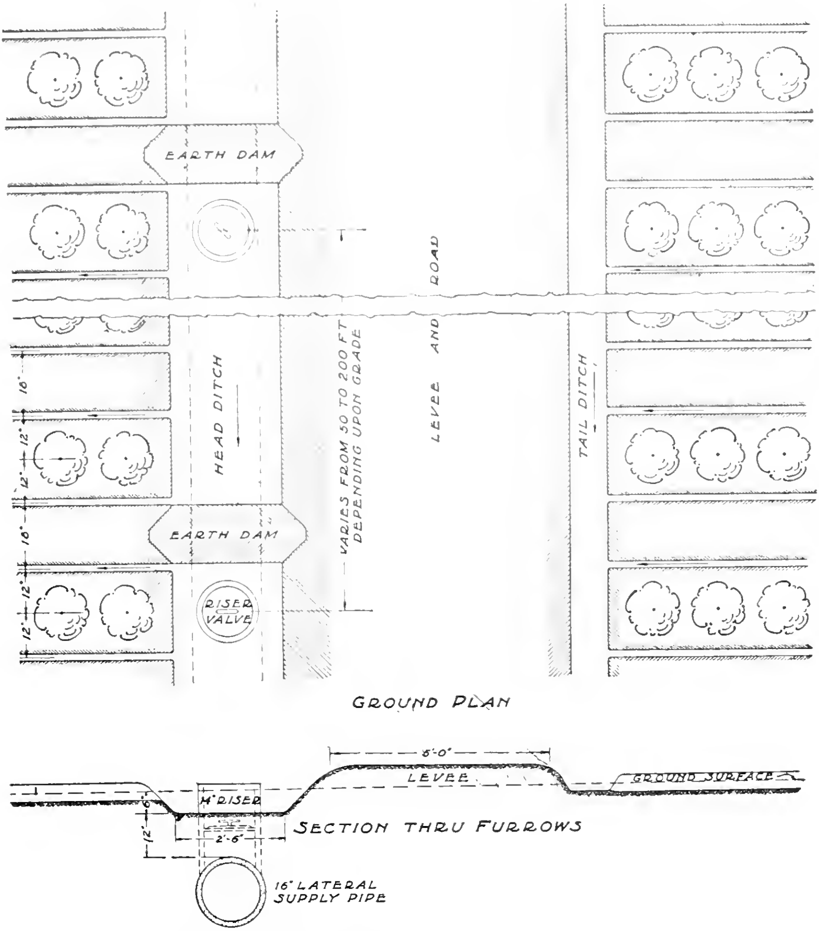


Fig. 30.—Method of irrigation from pipe line at Continental, used on the bottom-land where the general slope is about 20 feet per mile.

below the ground level is preferable to the more expensive systems. The long lines of 6-inch light galvanized iron pipe with taper joints, called "surface pipe," are a source of much labor, expense, and leakage, and their use should be discouraged. Surface pipe of canvas is sometimes employed, but it is most unsatisfactory.

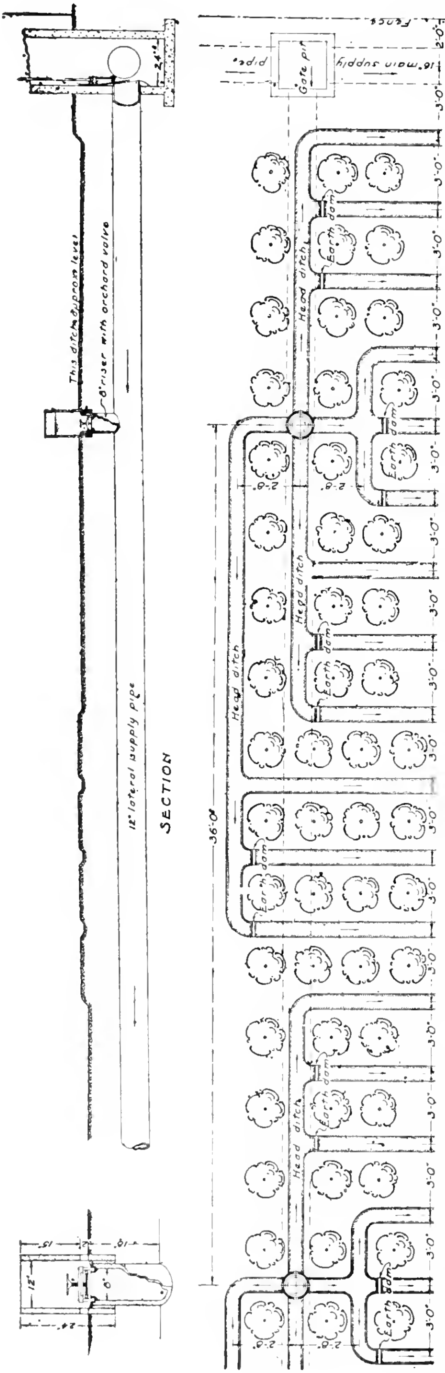


Fig. 31.—Method of irrigation from pipe line at Continental, used on the side slopes of the valley, where the fall is from 50 to 150 feet per mile.

For row crops there is no uniform practice. The systems at Continental are shown in Figs. 30 and 31. For laterals on the flat bottomland, risers are provided in the pipe line at intervals depending on the slope, so that the fall from one riser to the next shall not exceed 6 inches. An open ditch is maintained directly over the pipe line.

This system requires only short risers and the ordinary circular valves placed at intervals along the pipe line. Where the heads are high and the escaping stream erodes the ditch banks, a short length of pipe is cemented on above the valve. The head of water, 1100 gallons a minute, is divided between three risers, and the stream from each riser is divided between from 15 to 25 furrows, the number depending on the soil, the slope, and the length of the furrows. The furrow interval in 1917 was three and a half feet, but in 1918 the interval was reduced to three feet. Where necessary, the field is cross-leveled for about 50 feet near the head ditches, so that the water flows out into all the furrows equally well.

Fig. 31 illustrates the system used on the sloping lands which border the bottomland. These sloping lands have grades of from one to three feet per hundred feet, and the soil is gravelly loam or sandy loam. The furrows are run straight down the steepest slope or nearly so. Risers are placed on the main supply pipe line and on the laterals. Each riser hood has four 2-inch side openings, and each opening serves three furrows, not simultaneously but in rotation, beginning always with the highest. Cultivation is in many cases continuous across more than one plat.

The quantity of water per furrow is regulated by means of the valve and is measured by the height of the water level above the center of the openings. The discharges per opening were measured and are given in Table XXI.

TABLE XXI. DISCHARGE FROM 2-INCH SIDE OPENINGS IN HOODS

Head above center of openings	Discharge
Inches	*Gallons per minute*
1	9.4
2	14.0
3	18.0
4	22.0
5	25.0
6	28.0
7	31.0

In California small galvanized iron tubes with slip gates are much used in place of the open holes. A correspondent, in reply to a request for measuring the discharge from the galvanized tubes, states that the discharges are as given in Table XXII.

TABLE XXII. DISCHARGE FROM GALVANIZED GATES 2½ INCHES LONG

Diameter of gate	Head over top of gate	
	3½ inches	7 inches
Inches	*Gallons per minute*	*Gallons per minute*
1½	17	24
2	30	43
3	62	88

A system which is still found occasionally consists of risers with the top sealed by a cement plug while the galvanized gates are on the outside instead of inside. The gates leak and the system is unsatisfactory. Another system that should be discontinued is one in which the pipe line is only half buried in the ground and galvanized gates are placed directly on the pipe line at intervals equal to the furrow spacing. A light earth covering is placed on the pipe line between the galvanized gates, but the line is not protected adequately against changes of temperature and against being damaged by farm machinery.

The systems of outlets and gates used in California are of many designs. One of the ingenious schemes, Fig. 32, is that used by orange growers near Riverside, for small streams, where the slopes are from one to four feet per hundred. The gate pits are made of

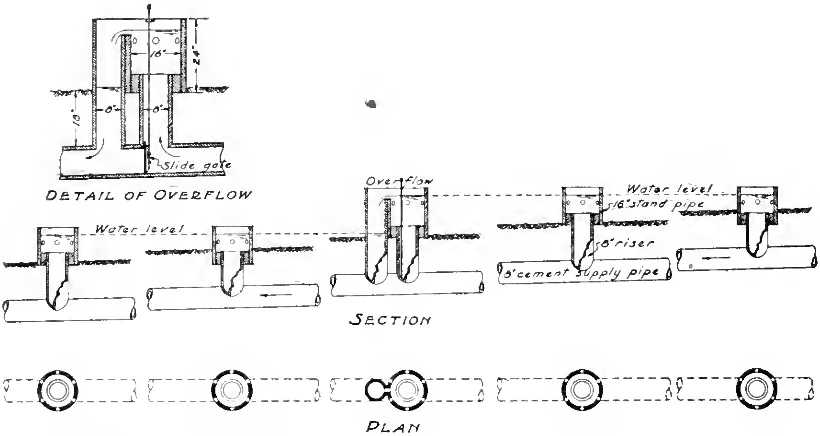


Fig. 32.—Method of construction of orchard pipe lines in the citrus district around Riverside, California. Each overflow stand holds back the water at a definite level and permits irrigating from the risers between it and the next overflow stand.

8-inch and 16-inch pipe. Their frequency on the line depends upon the fall. When the gate is closed, the water rises in one column and overflows into the line again. The water level is held at the desired height without the aid of valves. This system is modified

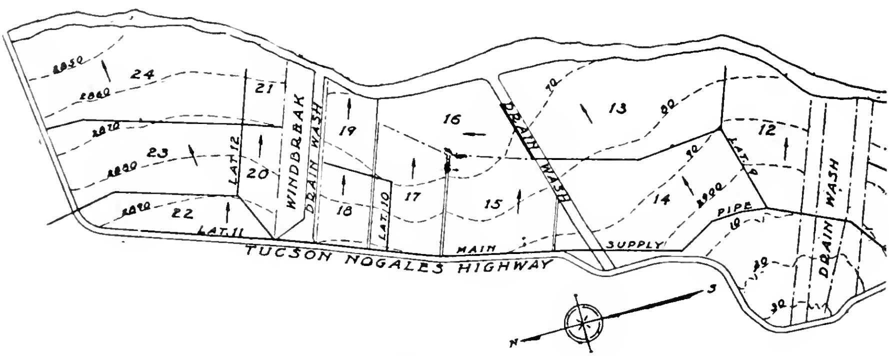


Fig. 33.—Map of a 540-acre field at Continental, showing

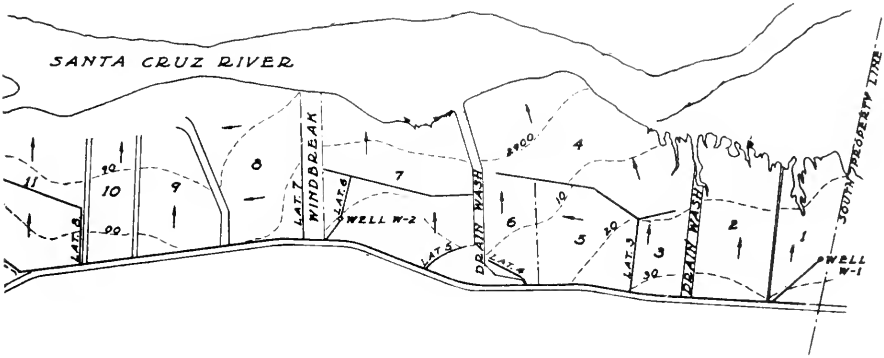
sometimes, where the slopes are steeper, by using valves in the upward-flow branches of the standpipes.

Many citrus groves in California are on land which has a natural slope of 10 to 40 feet per 100 feet. It is impracticable to run the furrows down the slope; they are made to follow the contours of the land with just a little fall. The cement-pipe head ditches for these orchards are run down the hillsides, often following a ridge, with overflows at such intervals that the fall from one to another is not over six or eight feet. Water is taken from riser valves, through hoods, and is run along the contours to both right and left of the head ditches. This practice is well exemplified in the La Habra Hills, where the soil is of a clayey composition and resists erosion.

Terracing and heavy grading have the disadvantage that the good soil is removed from certain parts of the ground and on such places the trees or other vegetation may be stunted and unproductive.

The overflow system may be called the open system, while the systems at Continental are closed, that is, each riser requires a valve. The closed system is better adapted to uneven land, and it permits of the use of slightly smaller pipe sizes. The open system requires more carefully executed surveys.

Riser valves are of brass. In some makes sheet rubber gaskets are used, in others braided hemp boiled in tallow. The valves are set, sometimes on the groove ledge at the top of the riser, sometimes in the riser so that the top of the valve handle is at the level of the top of the riser. Two to one mortar is used for setting the risers and valves.



10-foot contours and layout of main supply line and laterals.

PIPE LINE SYSTEMS

A key map of a 540-acre field at Continental is shown in Fig. 33. The arrows indicate the direction of irrigation. The 10-foot contours exhibit the steepness and the rolling character of the land. The field is composed of a succession of fans built by the intermittently flooded side washes. The pipe-line system is laid out so as to divide the land into fields of quite uniform slopes. The possibility of running the main supply line over fans and through the intermediate low districts is of great advantage over open gravity ditches. The supply line shown in Fig. 33 continues a total length of over six miles, the entire water supply, 7.6 second-feet, being derived from the two wells shown.

On important pipe-line systems, where many men are permitted to adjust the gates and riser valves, a set of rules for the operation of the system will be useful. The three following rules may be placed at the head of the list.

1. Always provide some place for the water to go. Begin the irrigation with too many valves open and regulate by closing one valve at a time until the desired head is flowing from each of the open valves.

2. Open or close each gate or valve slowly.

3. Do not shut off one gate or set of valves until another has been opened.

SPECIAL STRUCTURES

Special structures are often required. A division and measuring gate pit is shown in Fig. 34. In this case it is necessary to divide the flow from the 20-inch supply line into two equal parts. Two equal weirs are provided. The certainty of equal division is assured, for if it is assumed that the irrigators on Line A do not take their full half of the water and that the water in their line is backed up onto the weir, then the hydraulic gradient in the pit at the head of Line A will be higher than in Pit B and will also be flatter than the normal gradient, while the gradient in Line B will be steeper; hence the gate pit with closed gate on Line A will be the first to overflow. Therefore, the irrigators on Line A will be warned by the overflowing gate pit and will open more valves. The irrigators are instructed to watch their gate pit and keep water level at normal elevation.

Another special structure at Continental is a gate pit in the corner of the nursery. The nursery lateral is on a 1.66 percent ascending grade, and if the ordinary gate pit had been built its height would have been 21 feet. The covered compartment is reinforced with steel and corrugated iron. When the gate is closed or partly closed, water can be taken from any or all risers on the nursery line. At other times the gate is kept open.

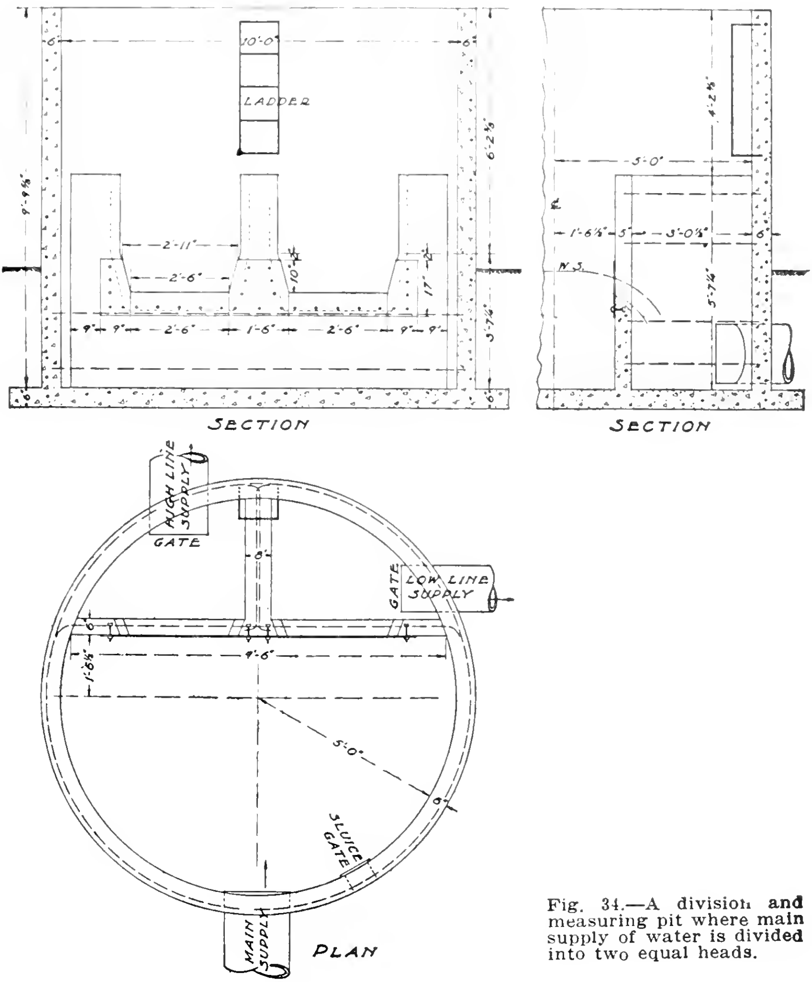


Fig. 34.—A division and measuring pit where main supply of water is divided into two equal heads.

Many unusual cases arise and require special treatment, particularly on rolling and hilly topography. Many of our Southwestern valleys, however, are almost plane surfaces and only standard structures are needed.

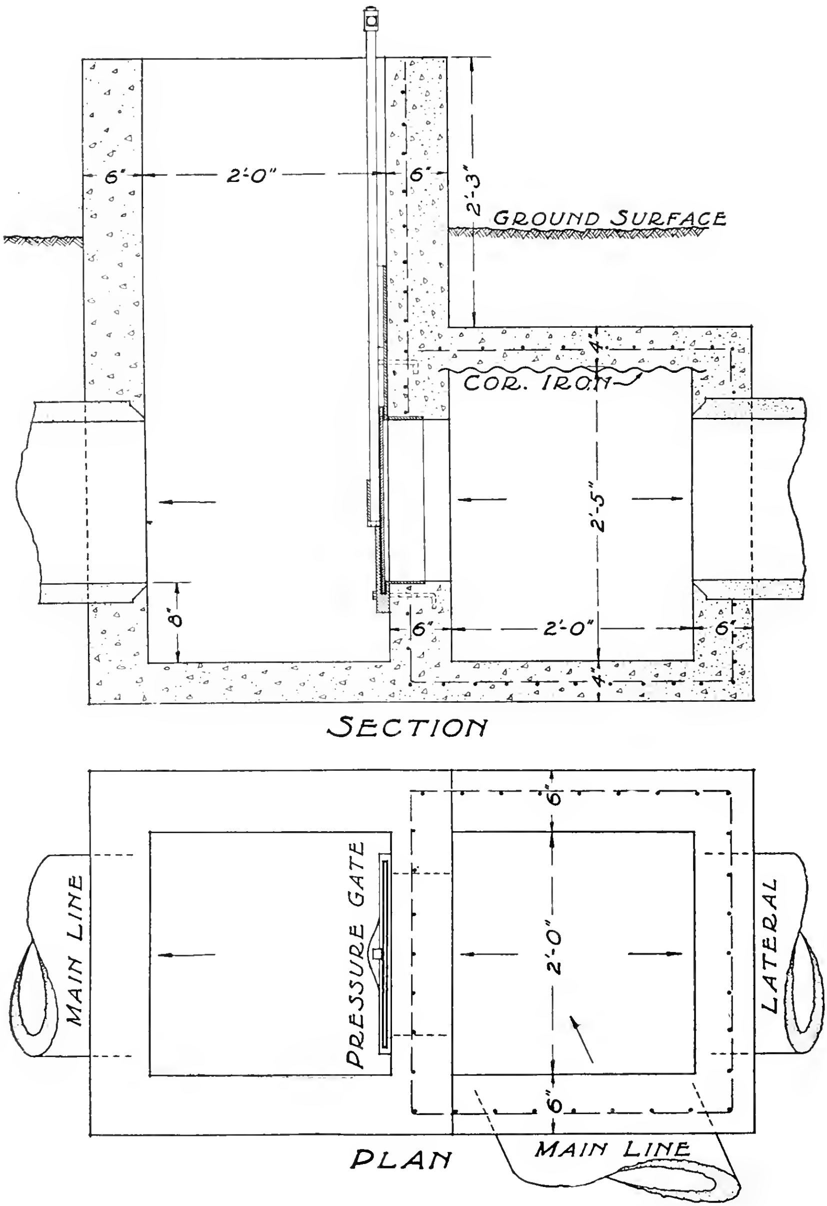


Fig. 35.—Special gate pit for forcing water up a lateral on a steep grade. An alternative is a gate stand with closed top, the gate stem passing through a stuffing box.

OTHER USES OF CEMENT PIPE

In addition to irrigation systems, there are many other forms of construction for which cement pipe is admirably adapted. Among them are sewers, culverts, drain tile, gates, underflow collecting flumes, and water pipe lines.

SEWERS

At the present time over eighty American cities are giving the preference to cement pipe for sewers. Bulletin 55, issued by this Station in 1907, advocated its use very strongly. Quoting from that bulletin, page 181,

"For many years it has been an active competitor of clay tile in sewer construction despite the usually much lower cost of the latter. The city of Brooklyn, N. Y., has used cement sewer pipe almost exclusively for forty years, and now has over 400 miles of cement sewers in active use. No less an authority than Rudolph Hering advocates it in preference to clay tile*. Its advantages are many. It can be molded to any sectional form and will retain it, while vitrified pipe shrinks and warps while burning. It is tougher than vitrified pipe and withstands rough handling with less breakage. When washed inside with pure cement it is equally as smooth and frictionless as clean glazed tile, while both pipes soon become so coated with sewage that the character of the original surface is lost.

In Arizona, conditions are especially suited to the use of cement sewer pipe. The long freight haul makes vitrified tile very costly. For the 8-inch size the cement pipe will cost 30 per cent less than the tile, and in the larger sizes the economy will be still greater. Throughout Arizona these conditions are practically the same, and it is to be recommended that each city use the cement pipe. It can be made by the city or contracted to an experienced cement worker, in either case under the supervision of the city engineer."

Despite this publicity, Arizona cities have continued to use clay pipe for sewers. A large sewer contract was let in Tucson in 1916. The lowest bid for the inside city work (excluding the outfall sewer) was $66,305 for McCracken machine-made cement pipe. But, owing to a malicious campaigner against the use of cement pipe for sewers, the city accepted a bid of $73,612 for vitrified clay pipe. Inconsistently, however, at the same time the city accepted a bid of $41,750 for a 30-inch *cement* pipe outfall sewer.

When the contract was about half completed controversy arose over the quality of the clay pipe that was being furnished for the

*The Concrete Review, Vol. 1, No. 4, March, 1907.

inside city sewers, and the contract was held up for several weeks. The pipe was from a Los Angeles factory and was mostly 8-inch pipe. Many tests that were made showed that the pipe did not measure up to the specifications. A committee of engineers was appointed by the mayor to report on the quality of the pipe, particularly "as to whether the pipe is of good, first-class, and standard quality, such as will provide this city with good sewers when laid." The report of this committee follows:

REPORT OF COMMITTEE

Nov. 8th, 1916.

To the Mayor and Common Council of the City of Tucson.

Gentlemen: The undersigned, your committee appointed to investigate and report relative to the quality of the sewer pipe now being laid in your city, under contract with T. J. Shea, begs to submit the following report.

In a letter from the Mayor dated Nov. 7, it is stated that you desire our views "as to whether this pipe is of good, first-class and standard quality, such as will provide this city with good sewers when laid."

The committee has personally inspected considerable of the pipe stacked up alongside the streets in the north part of the city, and has selected and tested nine of those pipes. We tested also three pipes said to have been taken from the last carload and one additional pipe.

The first test stipulated in the city specifications is that of percolation. Our tests show that the pipes with few exceptions do not withstand 15 pounds per square inch hydrostatic pressure, and some of them do not stand a pressure of even 5 pounds. Tests were made also with a pressure of 2½ pounds per square inch lasting 20 minutes. One specimen was sweating at the end of this time, but the others were dry on the outside.

The importance of the percolation test is mainly with reference to its bearing upon the strength of the pipe, inasmuch as slow percolation is of little moment from a sanitary or engineering point of view, in all but rare cases, such as when the sewer line is laid below the groundwater level and drinking supplies are obtained in the vicinity. It is the common opinion of all engineers that the pores of both clay and cement tiles gradually close up after they are put in service. Certainly it is unnecessary to demand that new tiles should stand as high as 15 or even 5 pounds internal pressure, equivalent to 35, or 12 feet head of water. Our special test of 2½ pounds pressure approximates the actual conditions of the pipe in the trench, and we feel safe in saying that the percolation under these conditions will be negligible.

The important test in the case of sewer pipe is that of strength, particularly strength to resist external pressures, for practically all failures of sewer pipe are due to crushing in by the overlying load. The specifications require that the pipe should withstand an internal pressure of 25 pounds per square inch, and also the equivalent of a 20-foot backfill. Our tests show that with few exceptions the pipe will stand much higher internal pressures than 25 pounds. The implication, therefore, is that the sewer pipe is of exceptionally strong quality.

However, inasmuch as the relationship between the hydrostatic pressures and the equivalent external pressures has never been determined, we recommend that the pipe shall be tested also to determine its resistance to external loads, according to any one of several methods that are in use in other places. It is not essential that the pipe laying shall be held up while the apparatus for making these tests is being prepared.

We find a small percentage of underburned, cracked, and warped tiles, but these are discovered and thrown out by the inspector, according to the system universally in use.

In conclusion, we would say that in our judgment the pipe being laid is the equal of the average of such pipe; that from the standpoint of durability, sanitation and general fitness for the service to which it will be subjected it will be satisfactory. But we believe that in general the pipe is somewhat overburned and would advise that the pipe to be delivered for the balance of the contract shall be somewhat less vitrified, so as to have a breaking strength of from 25 to 40 pounds and so as to make a better showing in the percolation test.

Respectfully submitted,

G. E. P. SMITH,
J. C. MCCLURE,
I. MCAVOY.

In general, it may be said that the sewer pipe is as good as can be obtained from California factories, presumably as good as can be made from California clays. It is unfortunate that the specifications were drawn so rigidly as otherwise lower bids might have been received.

In making the tests it was noticeable that there were two kinds of vitrification exhibited. In one case the surface was of a purple black color, excessively fused and glazed, and the interior was burned black. This pipe was found to be very strong, but also pervious. In the other type the surface color was a dark neutral tint, the glazing smooth and pimply, apparently less fused, and the color of the fracture was slightly yellow instead of solid black. This pipe was less strong than the other type, but much more impervious. It can be concluded that excessive burning in the kiln hardens the pipe, increasing the strength but making it porous. A small percentage of the pipe were light on the exterior, yellow on the fracture, and were therefore much underburned.

After these tests the author took steps to ascertain the practice in other cities. The first city to use a percolation test was Brooklyn, and the reason there was that many of the sewer lines are below groundwater level and the sewage has to be pumped into the seas; therefore, if the pipe is pervious a considerable volume of groundwater will have to be handled by the pumps. Kansas City adopted the Brooklyn specification, although the reasons for using it at Brooklyn did not exist at Kansas City. Furthermore, it was found very early that any pipe which stands the internal pressure test of 33 pounds per square inch will stand the percolation test of 10 pounds (no duration of time being stated), and hence the test fell into disuse, although it was still retained in the specifications. At the author's request, the city engineer of Kansas City on December 11, 1916, kindly tested six clay pipe for percolation. The sizes ranged from 8-inch to 21-inch, and all six pipes withstood 15 pounds for 5 minutes with "no percolation." It is evident that the pipe clay of the Middle West is superior to that of California or that the art of burning the pipe is better developed in the Middle West.

It has been suggested* that the percolation test be replaced by the test for absorption, that is, to ascertain not under what pressure the pipe begins to sweat, but what proportion of the pipe is voids. However, in the tests of sewer pipe at Tucson the pipe which showed the least porosity was one which sweat freely and uniformly all over when tested for perviousness. Also no definite relation between porosity and strength of clay pipe has been determined. The absorption test is easier to make than internal pressure and percolation tests, but since it fails of having a definite significance, it would seem that in those cases where percolation is of importance the percolation test should be retained. The specification requirements for percolation should be modified to fit the actual conditions in each case.

Sewer pipe is not subjected, ordinarily, to more than one or two pounds pressure, and it is the common belief of engineers that sewer pipe, either clay or cement, soon becomes sealed up and covered with a slime. A slight percolation when the pipe is new might result in a damp soil surrounding the pipe, but oxidation would prevent any objectionable result, excepting in those cases where the pipe is laid below or near the water table and in the vicinity of domestic water supplies.

*Engin. News, Vol. 77, No. 8, Feb. 22, 1917, p. 329.

The town of Glendale is the first in Arizona to use machine-made cement pipe for sewer lines. (See page 73.) The town has voted additional bonds and will enlarge its sewer system, using the same kind of pipe. The city of Globe, also, is to adopt machine-made cement pipe for an extensive sewer system. Other cities in Arizona may well follow the example of Glendale and thereby save the difference in cost between cement and clay pipe.

BRIDGES AND CULVERTS

Pipe culverts are much used for stormwater conduits on public highways, though in Pima and some other counties the substitutions of dips (depressions in the grade) is increasing. Where the watershed to be drained is local and the maximum flow can be estimated with some certainty the culverts are advisable, on account of the even grade of the road, the low cost to install, and practically no upkeep. But there are thousands of drainage crossings where a usually insignificant channel overflows into a river torrent occasionally, usually for an hour or less at a time, and for such places the dip is advisable. Dips should be floored with concrete; "gravel dips" are a failure, but in a few localities, where the best caliche binder is available, "lime-bound" gravel dips may be justifiable. Dips should have thick, heavy, and sloping cutoff walls on the downstream side and thin but deeper walls on the upstream side. The dip is not a suitable type of construction for rivers, since it is impossible to design them to resist undermining at reasonable cost.

For road culverts a range of sizes from 18 to 30 inches is feasible. Smaller culverts become clogged with floating debris; larger than 30 inches are expensive and with much less capacity than dips or slab bridges.

The culverts should be sunken so that the thickness of earth covering over the crown is equal to the diameter of the pipe. The backfilling should be done very thoroughly, so that the bottom and sides of the pipes are well supported. End walls of concrete or rubble are necessary to prevent cutting out by the swirl of the water or by the flow creeping along the outside of the pipe.

Pipe culverts offer an ideal substitute for the wooden bridges over irrigating ditches both in the fields and in highways. It often happens that a single ranch owner has from six to twenty such bridges to build and maintain. The pipe culverts are actually less costly at the outset and cost nothing at all for maintenance. Culverts of 15 to 24 inches capacity have been installed for ditch crossings with only a few inches of earth over them. Usually they support the loaded farm wagons that pass over them, but not always. It is safer to give them a good cover, even though the road grade has to be raised.

During the past few years most of the culverts built in Arizona have been of corrugated iron, usually the so-called ingot-iron culverts. Ingot-iron is said to be nearly pure iron and to resist corrosion as well as wrought iron. A comparison of the merits of ingot-iron and cement pipe is presented in the hope that it may be of value, especially to state and county officials.

1. *Portability:* Here the ingot-iron culverts have some advantage in case the cement pipe must be hauled a long distance. If the cement pipe can be made in the vicinity it may be easier to transport it on a short haul than to haul the iron culverts from a distant railway station.

2. *Strength:* The crushing strength of eleven 12-inch corrugated iron pipes were tested at the University of Maine*. The actual inside diameters varied from 10 to 12½ inches. The crushing loads per lineal foot for five lap rivetted pipes averaged 4470 pounds. This is somewhat more than the average for 12-inch cement pipe as given on page 125. Instances have been observed on Arizona state highways where ingot-iron culverts, placed too near the grade line, have been flattened, crushed, and broken through by freight wagons. Cement pipe culverts have failed when placed too near the surface. Both classes of pipe are safe if buried their own depth.

Yuma County has employed McCracken cement pipe culverts for the extensive bond-built highways of that county. The specifications called for 12, 18, and 24-inch diameters, and mortar proportions of 1 to 3½. An interesting test was made of this pipe by the county engineer. He states†:

"Before we used the pipe, a test was made at the factory, on 12-inch pipe covered with one foot of dirt. A wagon was loaded at about approximately three tons on the rear wheels. A 6 by 6 was laid across the driveway just before the wagon was driven over the pipe, thus throwing the load six inches higher and dropped from this height onto the ground just above the pipe. The load was run across and dropped onto the pipe repeatedly. Upon taking up the pipe, no defects whatever could be found. This machine-made pipe

*Univ. Me. Technol. Exp. Sta., Bul. II, 1. (1916).
†From a private communication from C. M. Hindman, County Engineer, August 10, 1916.

has been much more satisfactory for our use than the hand-tamped. Have purchased and used both and very much prefer the machine-made."

In answer to an inquiry some months later as to how the cement pipe culverts were withstanding the traffic, the county engineer states*:

"These culverts are in good condition and show no signs of weakness. After being laid, heavy rollers and motor trucks have run over them. Since road has been completed heavy motor trucks

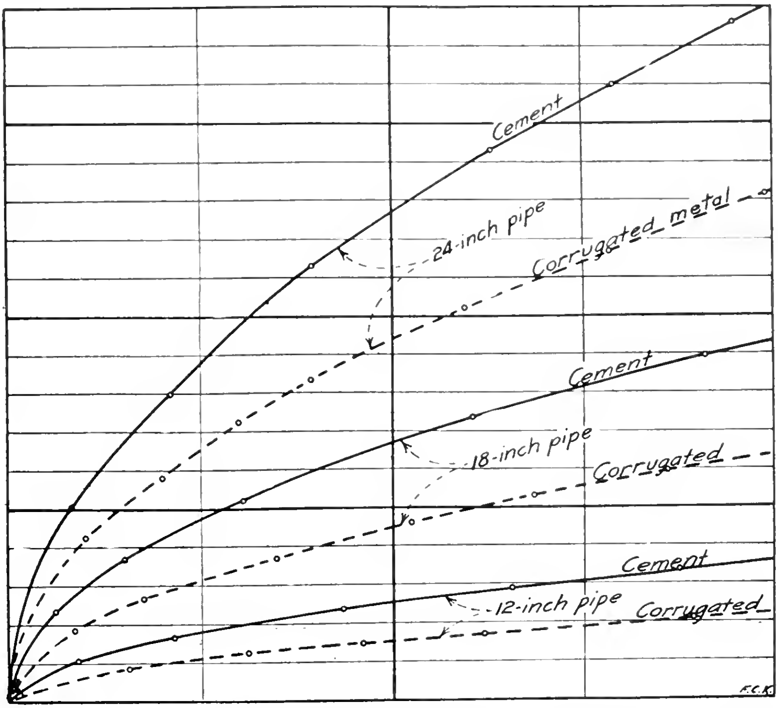


Fig. 36.—Carrying capacities of cement pipe and corrugated iron culverts of equal diameters.

weighing, when loaded twenty-two thousand pounds, including load and weight of vehicle, have been operated over road and have not injured the concrete pipe culverts in the least."

For culverts for special service, where great strength is required, reinforced concrete pipe can be used. (See page 93.)

3. *Capacity:* The smooth interior of cement pipe has a great advantage over the corrugated interior of metal culverts. Every corrugation causes eddies with consequent loss of head. The carrying capacities of long pipe lines of corrugated iron have been found to

*From a private communication from C. M. Hindman, May 11, 1917.

be only one-half as great as for cement pipe lines of equal diameter. For short pipes, such as culverts, the differences are not so great. Fig. 36 is presented to show the relative capacities of 25-foot culverts of the two kinds and of three sizes. The capacities as given in Fig. 36 are computed according to the principles of hydraulics. Actual experiment might vary them to a slight degree. Many scores of small corrugated iron culverts in Arizona have become clogged and filled with earth.

The uncovering and washing out of corrugated metal culverts has been very frequent in the past. Doubtless these misfortunes have been due, in part, to the fact that the county officials who purchased the culverts have not appreciated the low carrying capacity of the corrugated culverts, and have purchased culverts too small for the locations where they have been installed.

4. *Permanence:* Both classes of pipe may be expected to have long life. Good cement construction grows harder with age, and the ingot-iron, also, has been proven to resist oxidation much more than ordinary steel.

Metal culverts may be subjected to two destructive influences: the erosive action of water carrying sharp sand, and chemical action. Galvanized metal flumes have been used extensively in the U. S. Reclamation Service projects during the past ten years, and experience indicates that unprotected galvanized flumes will have a life of 10 or 12 years, except under the most trying conditions, i. e., high velocity of water carrying sand and fine gravel, where the life in one particular instance was only four seasons use*. Tests were made on a flume of the Uncompahgre project using various protective coatings such as paints, elastic graphite, and tar compounds. The conclusion reached after the coatings had been on one season was that coal tar is the best and cheapest mixture available. The erosive action of sand or grit, carried at velocities over 3 feet per second, is quite pronounced, but road culverts in Arizona, as a rule, do not carry water save for a few hours each year. In other states both kinds of culverts have been destroyed by alkali, but no cases of injury of this sort in Arizona are known.

5. *Cost:* In Arizona the cost of ingot-iron culverts up to 30 inches in size is just about double the cost of cement pipe culverts of the same nominal diameter. On the basis of carrying capacities, the ratio is about two and a half to one. The cement pipe culverts are admittedly much more economical.

*Reclamation Service Record, Vol. 7, No. 11, 1916, p. 519.

6. *A home industry:* Another argument of considerable importance is that nearly all of the cost of metal culverts is sent away from the county purchasing the culverts, while in the case of cement pipe only the cost of the cement is sent away, while the balance of the cost is paid locally for labor, sand, and gravel, and a home industry is encouraged.

DRAIN TILE

Drainage is coming to be known as concomitant to irrigation. Due to the downward percolation of water from irrigation conduits and from irrigated fields, the water table rises over large areas, and valuable cultivated lands become water-logged, and in some cases

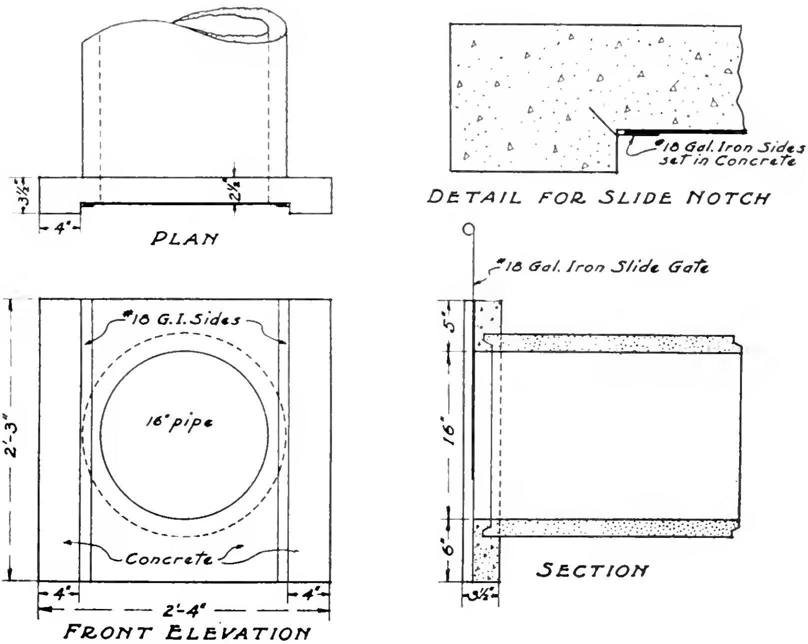


Fig. 37.—Common type of gate in canal bank at head of lateral.

alkalied. Two drainage districts, one near Tempe and one near Thatcher, organized under state laws are now engaged in reclaiming areas which had become alkalied, and in preventing the extension of the injury to adjacent lands. The Reclamation Service is carrying out a drainage scheme for the whole Yuma Valley. Other sections of the Salt River Valley are facing the same problem.

Drain tile is made with square ends, without bell or socket, and is laid end to end with open joints to admit water. Cement pipe cannot be recommended for drain tile except with some qualification. A chemical analysis of the groundwater to be drained should first be made. As noted on page 141, the action of alkali on concrete depends on the character of the alkali, the degree of concentration, and the density of the concrete. The evidence at hand indicates that wet-poured or machine-made cement pipe, made of carefully selected materials so as to have great density, would prove satisfactory in Arizona. More evidence as to the life of cement pipe in drainage ditches is very desirable. When the Tempe drainage canal was first opened the water at the outlet contained 1665 parts per 100,000 of soluble solids, but after one year the soluble solids had decreased to 351 parts per 100,000.

The Thatcher drainage district is using clay tile. The cost is about 50 percent greater than for machine-made cement pipe.

GATES

The cheapest material for directing water in and out of laterals and open head ditches and for taking the water from the head ditches onto the lands is the earth always close at hand, but the time consumed in building and removing the earth taps makes its use very arduous and costly. Lumber gates are, therefore, employed sometimes, but the alternate wetting and drying soon destroys them. Cement pipe in 2-foot lengths with sheet-iron curtains are to be recommended for this purpose. A good type of cement pipe gate is shown in Fig. 37. If the ditch banks are high and wide, an additional 2-foot length of pipe should be used so as to reach entirely through the bank.

UNDERFLOW COLLECTING FLUMES AND INVERTED SIPHONS

Many of the dry water courses of the Southwest carry a strong underflow, and after the flood seasons are past much water is obtained by opening ditches or burying wooden flumes as deeply as possible in the river beds. But the recurrent floods fill the ditches and oftentimes float away the buried boxes so that the expense of maintenance and the loss of water at critical times is very discouraging.

Frequently, too, canals and ditches have to be carried across and beneath rivers. The Woodruff (Arizona) canal intersects the Little Colorado River three times. The Flowing Wells ditch is carried under the Santa Cruz River in an inverted siphon 3200 feet long.

It is evident that conduits for these purposes should have weight or be anchored down with piling, and they should have great bending strength, as portions of them may be undermined during floods. Some form of reinforced concrete pipe should be used. The amount of steel reinforcement can be varied to meet the requirements and although the pipe line should be buried beyond the probable reach of floods, yet if a portion is undermined by the scour or is subjected to lateral pressure, the longitudinal reinforcement will be very effective in maintaining the stability of the line.

For that portion of the line safely outside of the river bed plain cement pipe will be adequate.

DOMESTIC SUPPLY PIPE LINES

The excellent characteristics of machine-made pipe suggest another use for it. In view of the almost prohibitive price of cast-iron and wrought-iron pipe at the present time, it may be practicable to substitute cement pipe, in some cases reinforced, in cases where the internal pressure is less than 20 pounds per square inch. Twelve-inch cement pipe of an extra rich mixture, extra thick, and containing some steel reinforcement can be made in Tucson for about one-sixth the cost of standard W. I. pipe of the same diameter and capacity. Under favorable conditions the cement pipe will not deteriorate, while iron pipe does. The only disadvantage on the side of the cement pipe, probably, is the great danger from water hammer, but this could be obviated by careful designing. In small villages, mining camps, cantonments, and for farm homes much cement pipe could be employed economically.

COSTS

The cost of cement pipe or of cement pipe lines cannot be stated readily because of the variable local conditions. For example, the cost of good, clean sand in the Casa Grande Valley is two or three times the cost at a point situated close to a good supply. The location with respect to the railway, living accommodations, the character of labor, and the size of the job all have a bearing on the cost.

In Iowa and neighboring states the custom is to establish large factories at central points and to ship the pipe by rail to the points where it is needed. The pipe is used mainly by drainage districts, and in large quantities. The manufacturers furnish pipe to the contractors, or they take the full contract themselves.

In the Pacific Coast states contracts are taken for the pipe line laid complete, and the contractors make their own pipe. This has been the custom in Arizona also. It has the advantage that there is no divided responsibility. If the pipe line fails, the layer cannot claim that the pipe was defective while the manufacturer claims that the pipe was injured in handling, or the trench bed was not brought to grade, or the joint mortar was not properly cured.

The cost of making can be estimated in advance for a particular case where conditions and prices are known. Some assumptions must be made, such as for rate of work per day. Depreciation and maintenance of the plant, taxes, and interest on the investment should be computed. Maintenance of equipment is costly on account of the wear on packer-heads, rings, and other parts. A liberal percentage should be added for contingencies, for the work may be stopped, due to non-arrival of cement, severe storms or freezing weather may cause delay or damage, and there are many other unforeseen difficulties that may arise.

The following estimate of the cost of McCracken machine pipe is presented as illustrative of the method to be used. It is based on Tucson prices in 1918. The figures should not be quoted as general or average costs.

TABLE XXIII. ANNUAL FIXED CHARGES ON INVESTMENT OF $6,000

Item	Percent	Amount
Maintenance and depreciation......	25	$1500
Interest	8	480
Taxes	1	60
Total	34	$2040

If we assume that the plant is in operation 250 days per year, the fixed charge is $8.00 per day. Continuous operation requires that a good business has been established, that ample capital is available to carry a large amount of pipe in the stackyard during the winter seasons, and that it is not necessary to move the machinery from place to place.

The total cost given in Table XXIV does not include any office expenses, or the cost of a traveling salesman or the cost of collections. When expenses of this nature and a good working profit are added, the pipe should sell at about 22 to 25 cents per foot for the 12-inch size, and 45 to 55 cents for the 20-inch size. No allowance has been made for the cost of water supply for the plant. This item is usually negligible. The allowance for contingencies is ten percent.

TABLE XXIV. COST PER FOOT OF MCCRACKEN MACHINE PIPE

Diam. of pipe	No. of feet per day	Fixed charges	Cement @ $3.45 per bbl.	Sand @ $1.50	Power	Labor $20 per day	Contingencies	Total
Inches	*Feet*	*Cents*	*Cents*	*Cents*	*Cents*	*Cents*	*Cents*	*Cents*
12	1600	0.5	12.3	2.2	0.3	1.2	1.6	18.1
14	1400	0.6	15.7	2.7	0.4	1.4	2.0	22.8
16	1200	0.7	22.1	3.7	0.5	1.7	2.8	31.5
18	1000	0.8	24.6	3.9	0.6	2.0	3.2	35.1
20	800	1.0	27.8	4.9	0.7	2.5	3.7	40.6

The cost of hand-tamped pipe is necessarily higher than that of McCracken pipe, since the rate of making is only about one-seventh as fast. If we assume an investment of $1500 in equipment, the fixed charges will be only $2 per day, but the fixed charges per foot of pipe will be twice as great as for the machine pipe. The labor cost will be three times as great. Sand and cement are likely to cost more for the hand-tamped pipe.

There is an advantage in a permanently-installed, centrally-located plant, especially for the engine-driven machine plants. The plant should be situated close to an abundant supply of good sand and on a railroad spur. Unless the cost of transportation from the plant to the point of use exceeds 25 percent of the cost at the plant, it will be more economical usually to buy the machine pipe than to make the pipe on the ground by hand tamping.

The contracts made at Continental in 1916 were of an unusual character. The company preferred to furnish both sand and cement, so as to have control of the quality of each and of the proportions of the mortar. The contractors furnished the equipment. All hauling was done by the company. Sixteen-inch pipe will be taken as a basis for comparison. The first contract was for two miles of the McCracken pipe. The price for making and curing the 16-inch pipe was 8 cents per foot, and the price for laying was 5 cents per foot. The second contract was for 6500 feet of hand-tamped pipe and included opening the trench and backfilling, the earth cover above the pipe to be at least 12 inches. The price for the 16-inch size was 22½ cents per foot. The price bid for the making and curing alone was 12 cents. In the other sizes there was a little more economy in the machine-made pipe in the smaller sizes, a little less economy in the larger sizes. Both contracts proved to be profitable for the contractors.

Another bid received was for hand-made pipe for the whole system, and was from a very reliable pipe maker. His bid for 16-inch pipe, for making and laying but no trenching, was 20 cents per foot.

List prices of hand-tamped pipe in southern Arizona vary from 25 to 40 cents per foot for 12-inch pipe and from 40 to 50 cents for 16-inch pipe, these prices being at the pipe yard. List prices are usually intended to apply for small quantities; discounts can be given on large contracts.

The unit prices for the pipe at Glendale could not be learned. The unit prices for the pipe laid in the trench were as follows:

14-inch	pipe,	$0.90	per	lineal	foot	of	trench
15- "	"	1.14	"	"	"	"	"
18- "	"	1.40	"	"	"	"	"

The contractor's bid included prices also for 8 and 10-inch pipe, 55 and 62 cents per foot, respectively, but no pipe of those sizes was laid.

The item of cement in Table XXIV constitutes about two-thirds of the cost of the pipe. The price per barrel as stated, $3.45, is 50 percent higher than the price one year ago. Since no cement is made in Arizona, the price is relatively high. There are many localities where cement pipe can be produced much more cheaply, on account of the lower cost of cement.

The cost of pipe laying consists of the labor and the cement, sand, and water distributed along the ditch. According to the data on page 107, the labor cost varies from 2 cents a foot for 12-inch pipe to 4 cents a foot for 20-inch pipe. The cost of the mortar materials will be about an equal amount, and a contractor must charge an additional sum for taking the responsibility for obtaining a strong and durable pipe line.

The cost of trenching depends upon the depth of the trench and the nature of the material. For deep trenches and for hardpan, a steam-driven trenching machine is advisable, provided one can be secured at favorable terms. But for shallow trenches in soil that requires little or no pick work, excavation with a shovel is cheaper than by machine. The cost of shovel trenching where the depth does not exceed 4 feet is from 15 to 30 cents per cubic yard, equal to from 4 to 8 cents per lineal foot for a trench 30 inches wide and 3 feet deep. Deep trenches should not be opened much in advance of the pipe laying, because the caving of the side walls increases rapidly after the earth is exposed to the weather.

Hauling is a matter of some importance. Each length of pipe should be laid on its side lengthwise of the wagon bed. It is customary to haul about fifty feet of 12-inch pipe or twenty feet of 20-inch pipe on a two-horse load. The pipe are packed in cars similarly, on side and longitudinally with the car.

The cost of pipe distribution systems varies from $15 to $30 per acre of land. Assuming 12-inch lateral lines 1000 feet apart, the cost is about $13 per acre for these laterals and the main supply lines may cost as much more.

In the sewer contract referred to on page 153, the vitrified clay tile cost 22½ cents per foot f. o. b. Tucson, while the proposal was made to furnish 8-inch McCracken cement pipe at 15 cents per foot. The clay drain pipe used at Thatcher in 1916 cost 20, 29½, and 39 cents per foot, respectively, for the 8, 10, and 12-inch sizes. The pipe was of the weight known as double-strength, the 12-inch pipe weighing 46.2 pounds per foot.

Prices of pipe culverts, in place, in Pima County in 1917 were as shown in Table XXV.

TABLE XXV. PRICES BID ON CULVERTS FOR PIMA COUNTY, 1917

Quantity	Size	Corrugated iron	McCracken pipe
Feet	*Inches*		
308	12	$ 432	$ 200
1232	18	2340	1232
1280	24	3200	1935

For large streams of water which would require pipe greater than 36 inches in diameter, cement-lined ditches are advisable*, provided the line can be laid out with a suitable gradient.

*See U. S. Department of Agriculture bulletin, No. 126, "Concrete Lining as Applied to Irrigation Canals."

SUMMARY

This bulletin is a general treatise on cement pipe, its manufacture, its characteristics and its applications. The bulletin describes the various machines used in pipe making, the details of making and of laying, the dangers inherent in cement pipe making and in pipe lines, the testing of pipe and the results obtained, the design of pipe lines and structures, and the utility of cement pipe for various purposes.

PIPE MACHINES

1. Pipe-making machines of many designs have proven successful, not only for plain tile, but for jointed pipe also.

2. The two general classes of pipe machines are: first, those employing the tamping principle, and, second, centrifugal or packerhead machines. The latter type have greater speed and capacity per day and are especially adapted to small sizes of pipe.

3. Pipe making by machinery requires skill and experience and will always depend upon specially trained operators. The purchase of a machine and equipment requires an investment of from $4000 to $10,000.

4. Good pipe requires good materials—cement, sand, and small broken rock; thorough mixing; expert handling of the machine; and careful, thorough curing, preferably under protection from sun and drying winds.

5. Machine-made pipe has admirable qualities; it is true in dimensions and shape, smooth inside, dense, strong, impervious, and of relatively low cost.

6. Some problems relating to machine-made pipe are still to be solved, notably the problem of how to make steel reinforcement effective in such pipe.

HAND-MADE PIPE

7. Making pipe by hand in molds has been done successfully for many years. Such pipe has been widely used. Its use is now being supplanted by that of machine-made pipe. However, there will always be a field for hand-made pipe, particularly for small jobs and in localities far removed from railroads.

8. Hand-made pipe, as produced in different pipe yards, is extremely variable in quality, ranging from weak, porous, misshapen pipe, mostly sand, cured in the open air, to sound, well-

tamped pipe, made of rich well-proportioned mortar, under a roof, and thoroughly cured.

9. Tamping alone does not produce a smooth interior, and the pipe should be washed inside with neat cement.

10. Greater strength can be secured by increasing the thickness of the pipe wall and by using a wet consistency of the mortar.

WET-POURED PIPE

11. Wet-cast pipe is usually of large diameter, and is reinforced. When properly made, it attains great strength, and is adapted for use under high heads, as in water-supply mains and in important siphons. On account of the great number of forms required, its cost is relatively high.

PIPE LAYING

12. The bell and spigot joint is used largely in the East and the tongue and groove joint in the West. While the former is the logical joint for cast-iron pipe, the latter has important advantages for cement pipe and can be recommended for sewer pipe as well as for irrigation pipe.

13. Pipe should not be laid in hot weather, except in the early part of the day before the pipe becomes heated, as otherwise contraction cracks may occur. All concrete work of similar nature should be done in cool weather if possible.

14. Pipe should be laid with straight alignment and even grades. The cover of earth should be at least 12 inches. Mortar of one to two proportions with 8 percent hydrated lime is best for the joints.

FAILURES OF CEMENT PIPE

15. The ordinary causes of failure are excessive internal pressure (in irrigation pipe), great depth of backfill (in sewer pipe and drain tile), contraction while curing, unequal settlement, and water hammer in pipe lines in which air is trapped.

16. In hot, dry climates there are special dangers in the use of pipe that is allowed to become dry after it is cured. When such pipe absorbs water again, it may destroy pipe-line structures, may buckle on curves, and may fail by distortion of the pipe section or by differential expansion of the pipe wall. The best remedy is prevention; dry pipe should not be laid.

17. The nature of the soil and the character of the bedding are

important factors of the resistance of cement pipe to external pressure.

18. From the records of tests that have been published, designers can draw plans and prepare specifications. Specifications for important contracts should provide for ample tests of the pipe before it is laid, and for trial tests of the line when completed.

19. Injury from alkali in water or in soil depends upon the quality and concentration of the alkali and the density of the pipe. Little difficulty from this cause is to be anticipated in Arizona, but very alkaline soils should be analyzed before pipe lines are built in them.

STRENGTH AND WATERTIGHTNESS

20. Cement pipe gains in strength for at least one month, and probably for three months, after its manufacture.

21. Tests of cement pipe should be made with the pipe in a wet condition. The strength of dry pipe is abnormally high.

22. When dry pipe is wetted by immersion, the internal stresses become entirely equalized within a few hours. If the pipe is laid and is wetted from the inside only, it may be many days before the penetration of water causes the maximum internal stresses in the pipe wall.

23. Machine-made pipe, as ordinarily made, is safe when subjected to hydrostatic heads up to 25 feet. The strength of hand-made pipe of good quality is about one-half as great. Wet-cast pipe can be designed to carry water under heads of somewhat over 100 feet.

24. Machine-made cement pipe up to 20 inches in diameter is safe in trenches under ten feet of backfill and the smaller sizes are safe for much greater depth. Hand-made pipe 16 inches in diameter, well made and cured, can be used under ten feet of earth. Tests should be made, however, in all important cases, to determine the strength of the pipe.

25. Machine-made pipe is practically impervious. Good hand-made pipe washed inside with neat cement, is nearly impervious and becomes entirely so in time.

PIPE FRICTION AND CARRYING CAPACITY

26. Friction factors are well known and permit close designing. The value of "n" in Kutter's formula should be taken as .013. Proper allowance should be made for the effect of frequent risers on the line, and on descending grades an allowance should be made for the effect of entrapped air.

USES OF CEMENT PIPE

27. Cement pipe is eminently adapted for irrigation pipe lines. It effects a great saving of water and land and labor; the pipe lines can be run through low places and over ridges, making it possible to square up the fields and reducing the cost of grading; ditch cleaning is obviated, and burrowing animals are defeated. Cement pipe is the logical conduit to replace small earth ditches as soon as the land owners are financially able to make the change.

28. Pipe line structures for the division and application of the water have been ingeniously developed in various places, to suit the local conditions and purposes. Various designs are cited in the bulletin.

29. Cement pipe of good quality is in all respects the equal of vitrified clay pipe for use in sewer lines. In Arizona, where the cost of cement pipe is much less than that of clay pipe, the cement pipe should be employed.

30. Cement pipe, likewise, should have the preference for farm and road culverts. When properly made and placed, it is more durable, has a greater carrying capacity, and is much cheaper than corrugated iron pipe.

31. Cement pipe, if used for drain tile in alkaline areas, should be of great density and impervious. Before it is adopted on important drainage projects, advice should be sought and chemical analyses should be made of the soils and soil waters.

32. There are sundry other applications for cement pipe, such as for ditch gates, and around farm buildings. It is likely to replace iron pipe to some extent as a conduit for domestic water supplies that are under low head.

COSTS

33. The cost of cement pipe depends on prices, which at present are on a relatively high level, and on local conditions, such as the distance from a good gravel supply and from the railroad.

34. If the volume of business is ample, packer-head machine-made pipe can be produced more cheaply than hand-made pipe.

The University of Arizona

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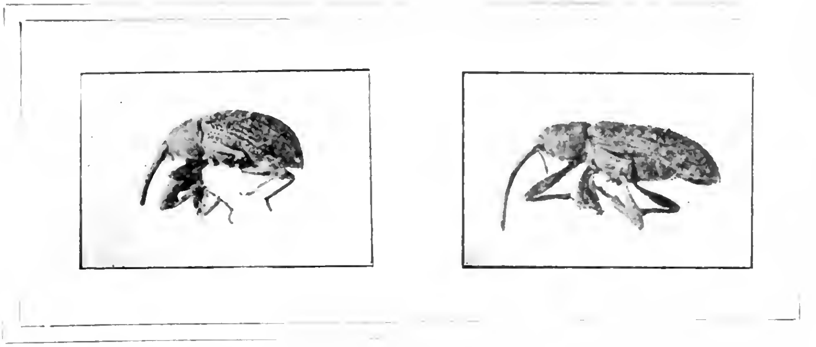
Agricultural Experiment Station

Bulletin No. 87



At the left the cotton boll weevil. At the right a native non-injurious weevil which is frequently mistaken for the boll weevil by Arizona cotton growers. Both insects enlarged 3½ times.

Insect Pests of Interest to Arizona Cotton Growers

By A. W. Morrill

Tucson, Arizona, December, 1918

The University of Arizona

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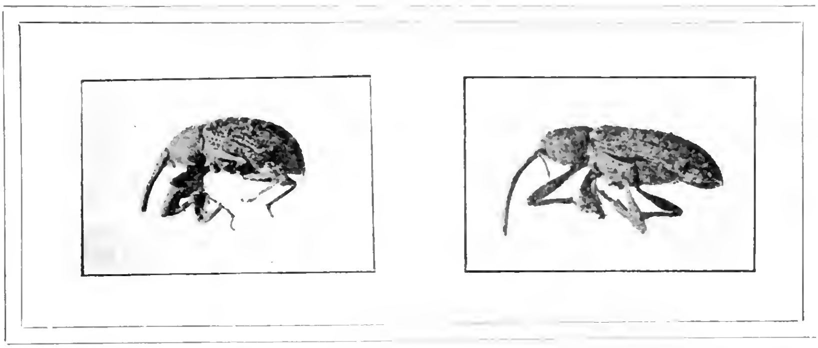

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The Experiment Station offices and laboratories are an integral part of the University at Tucson. The Salt River Valley Experiment Station Farm is situated one mile west of Mesa, Arizona. The date palm orchards are three miles south of Tempe (co-operative U. S. D. A.) and one mile southwest of Yuma, Arizona, respectively. The experimental dry-farms are near Cochise and Prescott, Arizona.

Visitors are cordially invited, and correspondence receives careful attention.

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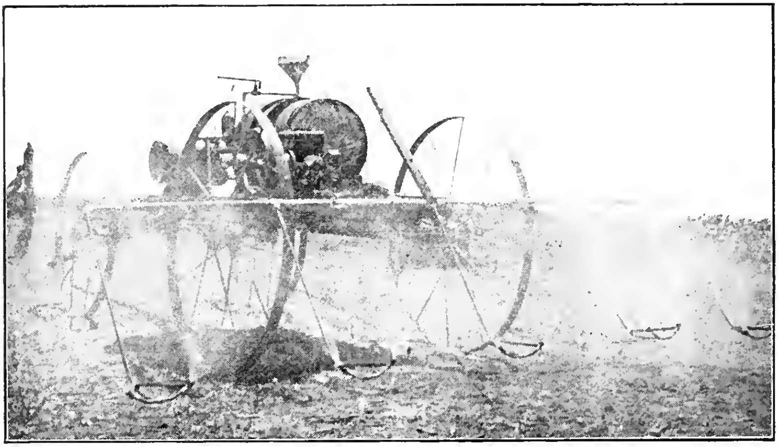

Power sprayer and spray boom arranged for spraying cotton for aphis (Lauderdale)

Sprayer in use in cotton field (Lauderdale)

Insect Pests of Interest to Arizona Cotton Growers

By A. W. Morrill

Cotton growers in Arizona should know something about the general appearance and methods of attack of the more important insect enemies of cotton, including those which already occur in the State as well as those which the State Commission of Agriculture and Horticulture and its agents are trying to keep out. This bulletin has been prepared to give in concise form general information concerning the principal cotton pests which are of interest to Arizona cotton growers. For those who need or desire more detailed information references are given at the end to a few reports of the Arizona Commission of Agriculture and Horticulture and to bulletins of the U. S. Department of Agriculture.

THE MEXICAN COTTON BOLL WEEVIL

Every cotton grower has heard of the Mexican cotton boll weevil (*Anthonomus grandis* Boh.) and many farmers now located in Arizona have had experience with it in Texas, Oklahoma, and other states of the so-called cotton belt. This pest has never as yet been found in the cotton fields in Arizona, altho a variety (*Anthonomus grandis thurberiae* Pierce,) is known to exist in certain mountain ranges in southern Arizona where it infests a wild cotton plant (Fig. 3) known botanically as *Thurberia thespesiodes.*

There are many different kinds of weevils and several of these are confused by cotton growers with the boll weevil. This is not strange, for in some cases weevils of entirely different habits resemble one another so closely that only an entomologist can distinguish the difference between them. While it is important for cotton growers and others to watch carefully for the appearance of strange cotton pests, it is desirable that specimens of such pests be submitted to an entomologist for identification.

Acknowledgments: The illustrations used in this bulletin are from bulletins of the U. S. Department of Agriculture and annual reports of the Arizona Commission of Agriculture and Horticulture, except figures 7 and 8 which are used through the courtesy of Florida Plant Commissioner Wilmon Newell, figures 15 and 16 which are reproduced from Bulletin 346 of Cornell Agricultural Experiment Station, and the frontispiece cuts which are from original photographs by Mr. J. L. E. Lauderdale.

The adult boll weevil is usually about one-fourth inch in length, some specimens being as small as an eighth inch and others as large as one-third inch. This measurement includes the snout which is about one-half the length of the body. The color of the adult is almost uniformly grayish or brownish. The adult weevil may hibernate in cotton seed, weeds, trash, haystacks, etc. It flies to the cotton fields in the spring and breeding soon begins. The eggs are

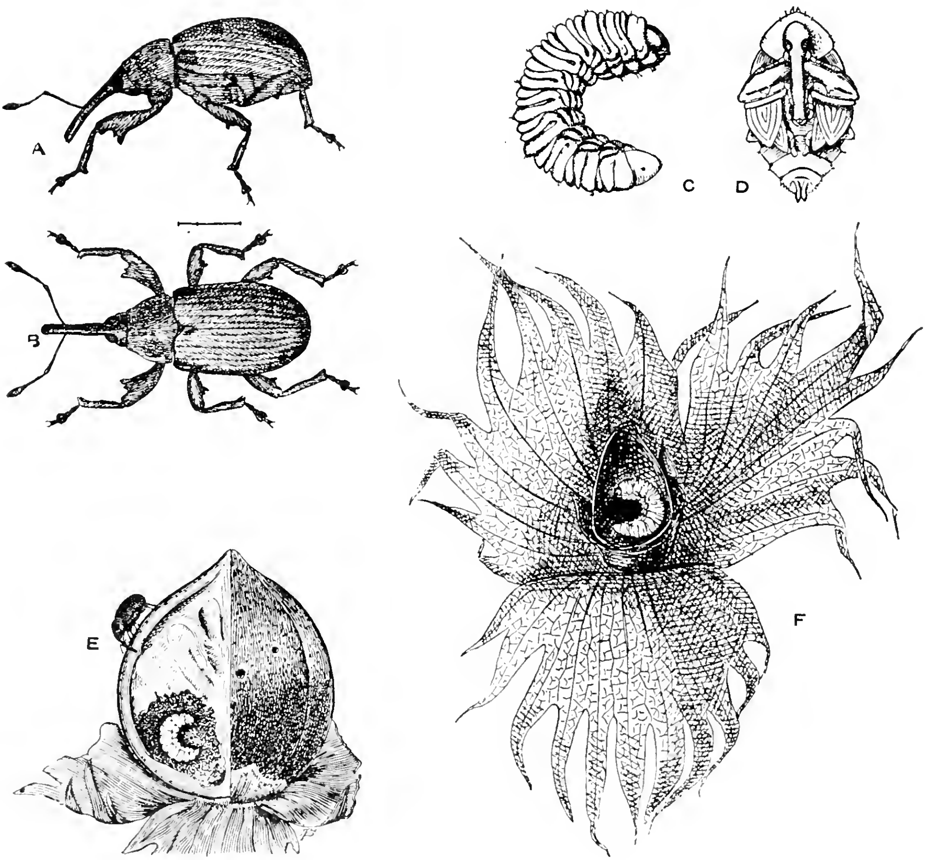

Fig. 1—The cotton boll weevil. a and b, adults. c, larva. d, pupa. e, adult feeding on cotton boll, section removed to show larva within (natural size). f, larva in square.

laid in cavities eaten by the female weevils in cotton squares and bolls. The grub lives entirely inside the square or boll and in from seven to ten days changes to the pupa. In this stage it does not feed, but in about five days transforms into the adult or winged stage. The boll weevil adult is not known to feed on any other plant than cotton and never lays eggs except in the cotton square or boll. The cell in which the pupal stage is passed in the boll, after going thru a gin, resembles a seed in form and size. The weevil is rarely found inside the seed hull, but nevertheless is frequently found with cotton seed, since squares, small bolls and pupal cells containing the adult insects usually go thru the gin without being

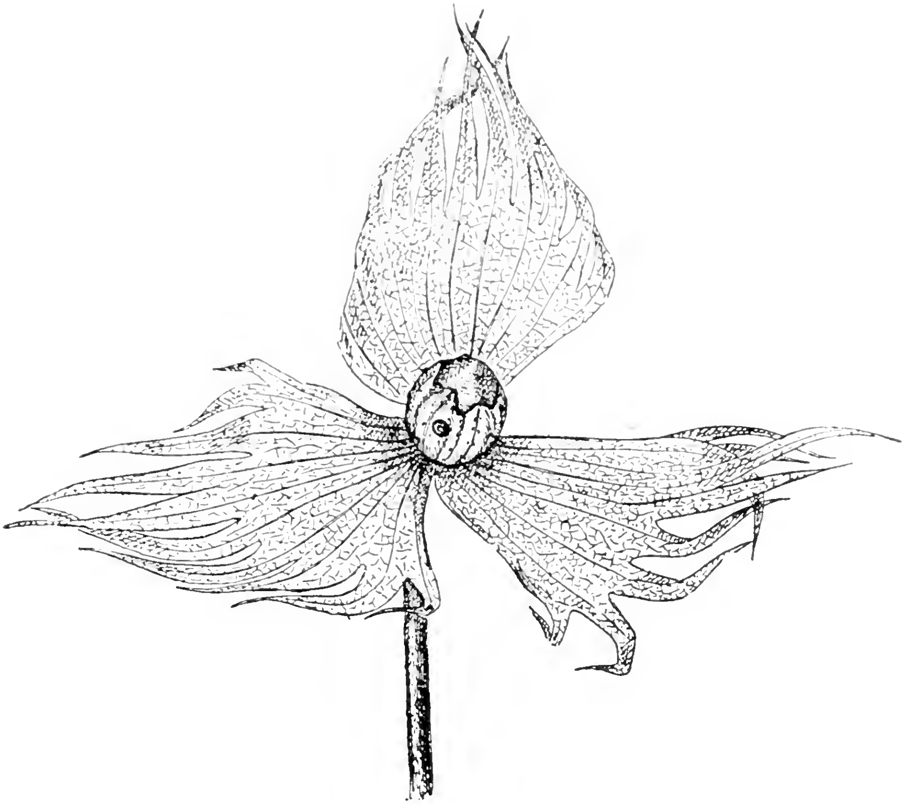

Fig. 2—Cotton square with bracts spread to show boll weevil puncture.

crushed. Cotton seed and seed cotton from boll weevil infested sections are therefore very likely to carry the boll weevil even tho the seed itself is not, strictly speaking, infested.

THE COTTON BOLLWORM

The cotton bollworm *(Chloridea obsoleta* Hubn.) is an entirely different insect from the boll weevil, but the two are frequently confused. The adult of the bollworm is a large moth which lays its eggs in large numbers on various parts of the cotton plant. The eggs are laid singly and not in clusters like the eggs of certain other moths. The larva or worm hatches in the course of a few days, and after feeding for a short time on the leaves it bores into squares and bolls. When first hatched the bollworm is so small that in feeding on a cotton square it makes only a very small hole. As it passes from square to square and finally to the bolls, it eats larger and larger holes and when full grown may make an opening a quarter inch in diameter. The bollworms are very variable in color and markings, including pale green, pinkish and dark brown as the

Fig. 3—Arizona wild cotton (*Thurberia*) growing in mountain canyon of Southern Arizona.

ground color, with markings of green and brown. The cotton bollworm is the same as the corn ear worm and is found everywhere in the country where either cotton or corn is grown. The female moths may lay as many as 3000 eggs. They prefer to lay these on the fresh silks of corn and consequently this crop may be used as a "trap crop" for the protection of cotton. The bollworm also breeds on alfalfa and attacks bean pods and green tomatoes, in the latter case sometimes being known as the green tomato worm.

The cotton bollworm passes the winter in a cell in the ground, and fall and winter plowing of cotton and corn fields breaks up many of these cells and exposes the pupae to destruction by birds and rodents. Injury to cotton by the bollworm in Arizona has not proved of much consequence except in a few sections of the Salt River Valley in 1917 where as high as 20 percent of the bolls were destroyed by the pest. In cases of serious attack on cotton the plants should be poisoned with powdered arsenate of lead or with calcium arsenate.

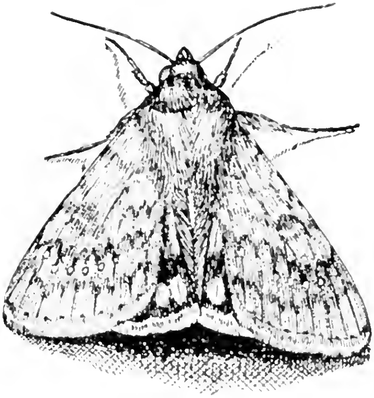

Fig. 4—The cotton boll worm moth (enlarged).

Fig. 5—The cotton boll worm caterpillar feeding on a cotton boll.

The eggs of the bollworm are attacked by parasites which help greatly to keep the pest in control. It has many other insect enemies but in a sense it may be said to be its own greatest enemy.

The worms are quarrelsome and cannibalistic; whenever two of them meet a deadly combat follows, and as a result both worms sometimes die. The concentration of a large number of eggs on the silks of an ear of corn saves the egg parasites much trouble in hunting out scattering eggs and insures a heavy mortality from cannibalism. Altho the average number of bollworm eggs on the silks of each ear is high, sometimes in excess of 100, it is rare that more than one or two worms succeed in penetrating into the tip of the corn ear and developing to maturity.

THE PINK BOLLWORM

During the past year occasional references have been made in newspapers and farm journals to the Egyptian pink bollworm

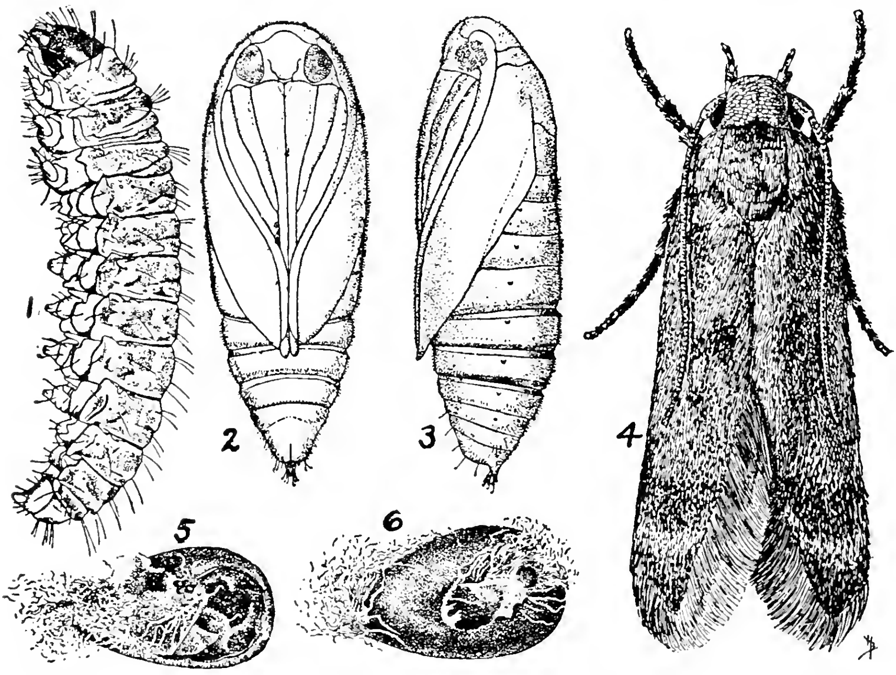

Fig. 6—The pink bollworm. 1, Fullgrown larva. 2 and 3, Pupae. 4, Adult. 5 and 6, Injured cotton seeds. (Hunter)

(*Pectinophora gossypiella* Saunders). This insect is reported to be even more serious than the cotton boll weevil. It is supposed to have originated in India and to have been shipped in cotton seed from India to Egypt several years ago. From Egypt the pest has been distributed in cotton seed to various parts of the world including Brazil and Mexico.

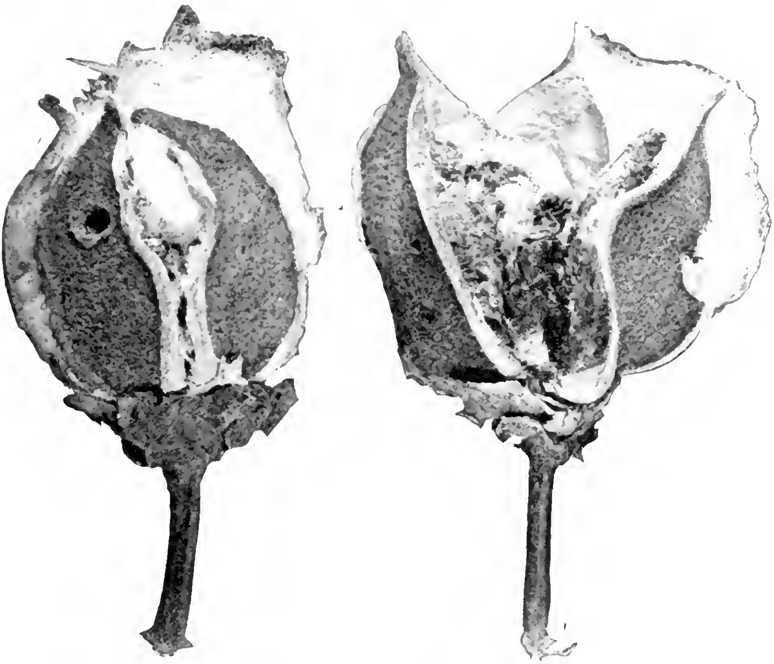

Fig. 7—Cotton bolls showing difference between injury by common bollworm and pink bollworm. At left injury by common bollworm (*Chloridea obsoleta*)—note the large orifice and raised edges; at right injury by pink bollworm—note the comparatively small clean cut orifices in carpel. (Hunter, from Quar. Bull. State Plant Bd. of Fla.)

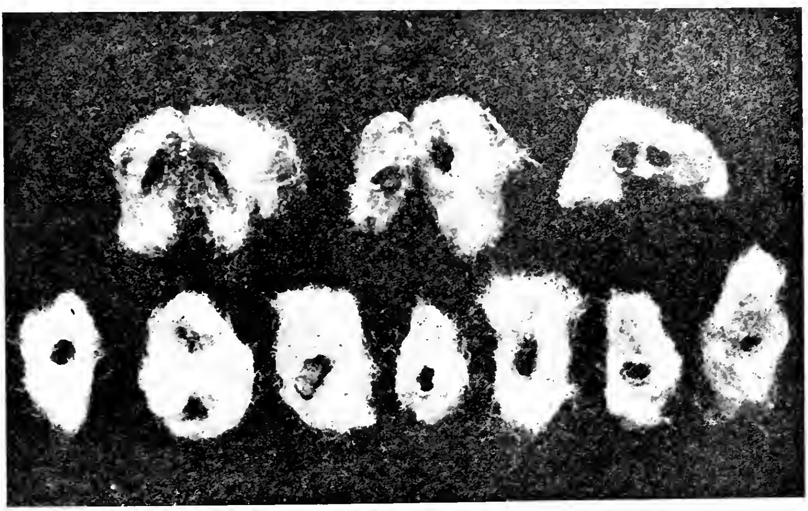

Fig. 8.—Cotton seeds infested by pink bollworm. Above "double" or "twin" seeds characteristic of the work of larva of this insect in its last stage. (Hunter, from Quar. Bull. State Plant Bd. of Fla.)

In 1914 a shipment of cotton seed from Egypt was received by the president of a cotton ginning company in the Salt River Valley of Arizona. Upon examination at the office of the State Entomologist this seed was found to be grossly infested with the Egyptian pink bollworm and was consequently destroyed by burning. It is safe to say that if the condition of this seed had not been discovered the pink bollworm would have become established in Arizona and have made Egyptian cotton growing unprofitable. Unfortunately there were no agencies in Mexico to prevent the importation and planting of infested Egyptian seed in that country. As a consequence the insect was established in the Laguna district of Northern Mexico. From there it has been scattered to other cotton growing districts, including two or three points in Texas. The Texas state government has passed a very drastic law and the Federal government has appropriated a large sum of money for the eradication of the pink bollworm. No effort will be spared to make this undertaking a success.

The pink bollworm moth is a small gray colored insect less than half an inch long. The eggs are deposited on the cotton bolls as a rule. These hatch in the course of a few days and the habits of the larva or worm are similar to those of the bollworm. The grown worm is a little less than half an inch long. Very young worms are white in color but become pink when full grown. The worm bores into the interior of the boll and feeds upon the cotton seed. Frequently two or more seeds are fastened together by the worm in such a way as to allow of its passage from one to another. The "double" seeds are regarded as a sure indication of the presence of the pink bollworm altho the live worms may also be found in single seeds. There is no other cotton pest so well adapted for transportation in cotton seed as this one. In addition to cotton, this insect attacks hollyhocks and species of hibiscus, the two species so far recorded as subject to infestation being known as Indian hemp and okra. No doubt other species of hibiscus will also be found to be subject to attack by this insect. The fact that the pink bollworm is not confined to cotton as is the cotton boll weevil adds somewhat to the difficulties in controlling or eradicating it.

The misfortune of the introduction of the pink bollworm into Egypt will add to the expense of producing long staple cotton in that country, and consequently the freedom of the cotton fields of the arid Southwest from this pest represents a distinct economic advantage for the Egyptian cotton growing industry in this section.

THE COTTON LEAF WORM

The cotton leaf worm, (*Alabama argillacea* Hubn) is one of the best known cotton insects of North America. It is not known to have any other food plant than cotton, including the Arizona wild cotton. This insect is believed not to winter over as rule in the United States but to come in each season by flight of the adults from Central and South America. The moth is of an olive gray color, with a wing expanse of one and one-third inches. Eggs are laid singly on the under surfaces of the leaves near the top of the plant. Each female lays about 500 eggs. These hatch in three or four days and the larvae at first are of a pale yellow color but soon become greenish. The full grown worms are nearly half an inch long, slender, bluish green in color with black spots and frequently with black stripes along the back. They walk by looping and when disturbed drop from the plant. When full grown the worms spin light silken cocoons on the cotton plant, usually within a fold of the leaf, and transform to brown pupae. The moth develops from the pupa in the course of a week in warm weather. Several generations occur during a season, and the insects multiply at an almost unbelievable rate. It has been estimated that if it were not for the destruction of many of the insects by natural enemies the progeny of one female moth in four generations would amount to more than 300,000,000,000 individuals. The third generation, if placed end to end, it is said, would encircle the earth more than four times at the equator.

Fortunately there are a great many natural enemies of the cotton leaf worm which help to prevent excessive multiplication. In past years before the boll weevil entered this country, the cotton worm was regarded as a pest and poisoning of the cotton plants for its destruction was commonly practiced. Since the boll weevil made its appearance, however, the work of the cotton worm has not been regarded as serious as a rule, and in a great many cases it has been recognized as a distinct advantage, owing to the fact that the partial defoliation has tended to hasten maturity of the bolls, and the stripping of the plants has deprived the late emerging boll weevils of a much needed food supply.

In Arizona the cotton leaf worm has been found attacking cotton in the Salt River Valley, the Gila Valley, and near Tucson. It has also been found attacking the wild cotton plant, which has already been mentioned as a food plant of a variety of the cotton boll weevil. The cotton leaf worm does not appear every year in

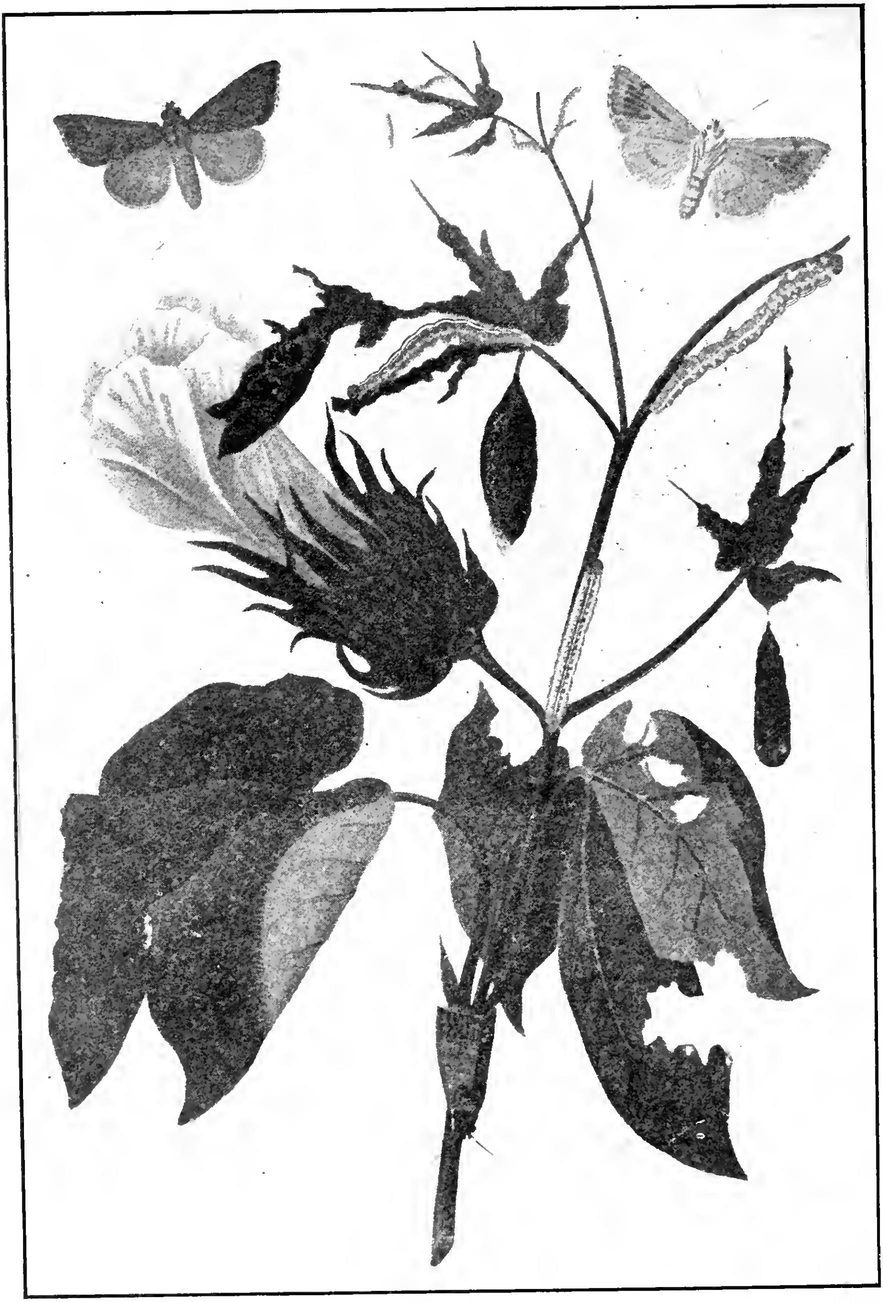

Fig. 9—The cotton leaf worm: Larvae, pupae and adults.

southern Arizona and from observations so far made it does not seem likely that it will ever prove to be a serious cotton pest in the arid Southwest. The tendency seems to be for Egyptian cotton plants to grow too rank, and in most cases the partial defoliation which results from an attack of the cotton leaf worm late in the season will prove a decided benefit in maturing the cotton crop. If, however, the insect should make its appearance earlier than usual in the season, and consequently multiply to injurious numbers and threaten serious injury to the crop, it may be poisoned by dusting the plants with Paris green, arsenate of lead, or calcium arsenate as is still done occasionally in parts of the eastern cotton belt.

THE SALT MARSH CATERPILLAR

The salt marsh caterpillar (*Estigmene acraea* Dru) appears every year in greater or less numbers in the cotton fields in southern

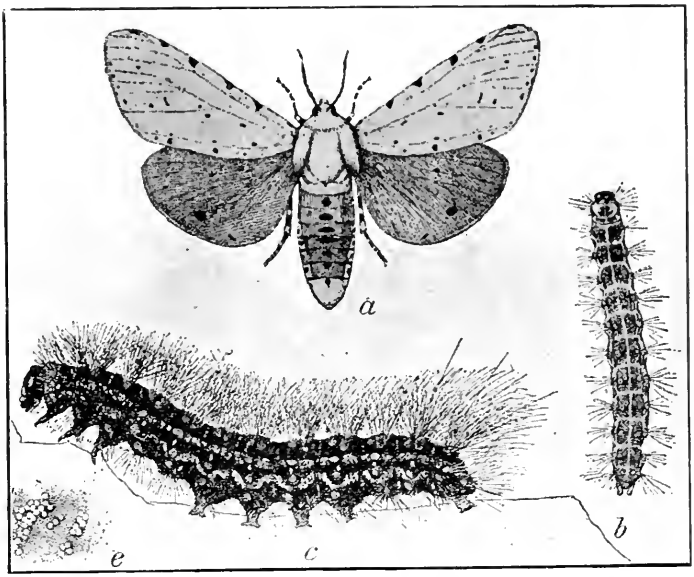

Fig. 10—Salt marsh caterpillar. a. Female moth; b. halfgrown larva; c. mature larva, lateral view; d. egg mass.

Arizona. It has many food plants in addition to cotton and may be found multiplying on trees, field crops or weeds. In the Salt River Valley it sometimes does considerable damage to the bean crop. Among the weeds probably its favorite food plant is one known as the yellow flowered ground cherry (*Physalis angulata* variety *linkiana*). In the only instance when the salt marsh caterpillars were found in excessive abundance in Arizona cotton fields, the insects had first attacked the ground cherry and turned their attention to the cotton plants only after they had completely stripped the weeds. The salt marsh caterpillar is one of those commonly known as "woolly bears." The hairs are black and red. The general appearance of the caterpillar and moths is well shown in the illustration.

THE COTTON LEAF PERFORATOR

A very conspicuous type of insect injury to cotton plants is produced by the larvae of a tiny moth which has a wing expanse of

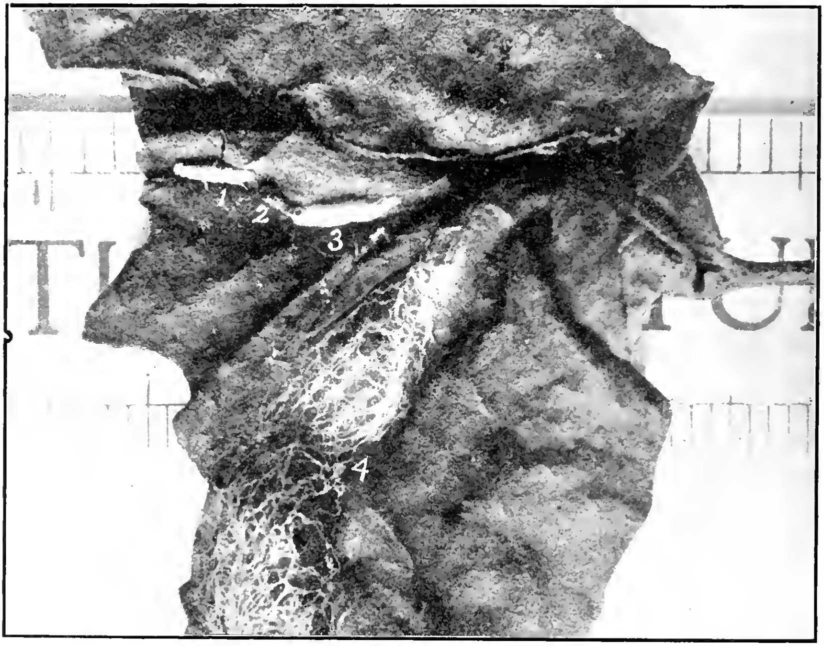

Fig. 11—The cotton leaf perforator: 1, adult. 2, pupa skin attached to cocoon. 3, cocoon of leaf perforator. 4, cocoon of salt marsh caterpillar.

only about a third of an inch. The larvae during the first stages are so small that they live inside the leaf tissue where they produce a serpentine mine. When nearly full grown they eat their way to the surface of the leaf and during the last stage feed on the surface of the leaves in which they make small perforations. On account of this injury, which suggests the effect of small shot from a shotgun, the common name "cotton leaf perforator" (*Bucculatrix thurberiella* Busck) has been suggested. During the period when the larva is living on the surface of the leaf it molts once. This process takes place inside of a thin, white silken cocoon which is formed on the surface of the leaf and in which the caterpillar, bent in the form of the letter "U," can be faintly seen. Finally, when the worm is full grown, it spins a white, ribbed cocoon about five-sixteenths of an inch long. This is attached to the cotton stalk or to other parts of the plant. In this cocoon it transforms first to a pupa, from which the delicate, grayish white moth eventually

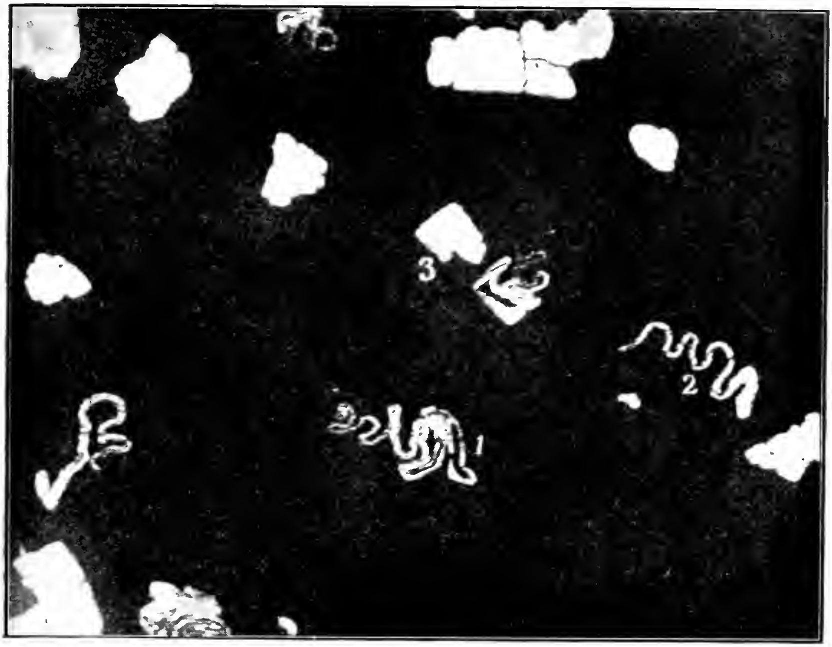

Fig. 12—Work of cotton leaf perforator on Egyptian cotton leaf (greatly enlarged). 1, mine containing larva. 2. mine which has been vacated by larva. 3, work of caterpillar after leaving leaf mine.

emerges. These insects are subject to attack by minute wasp-like parasites which some seasons keep them so reduced in numbers that they are not conspicuous. So far no distinct damage to cotton plants has been noted in Arizona, although it is not impossible that, with a start unusually early in the season and with conditions unfavorable for the activity of the parasites, some damage might be done. As observed so far, however, the perforation of the leaves has usually been a benefit rather than otherwise, for the same reason as has been noted in the case of the partial defoliation of cotton plants by the cotton leaf worm.

Fig. 13—Egyptian cotton plant, showing work of leaf perforator.

THE COTTON SQUARE DAUBERS

The most destructive pests in Arizona up to this time are certain sucking plant bugs of the tarnished plant bug group which, on account of the characteristic effects upon the cotton plant, may be called the "cotton square daubers"[1] (*Lygus elisus hesperus* Knight and *L. pratensis* var. *oblineatus* Say). There are several closely related species and varieties of the tarnished plant bug genus and while representatives are common in the eastern cotton growing states, they have not so far proved destructive to cotton except in the arid southwest.

The cotton square daubers were first noted as cotton pests in Arizona in 1914 when they became noticeably destructive in one locality in the Salt River Valley a few miles southwest of Phoenix. The next season they did sufficient damage in a large cotton field near Glendale to make the crop unprofitable· Since then they have been destructive in one locality or another each season[2]. In 1918

[1]Seventh Annual Report, Ariz. Comm. Agr. & Hort., pp. 44-45.
[2]Eighth Annual Report, Ariz. Comm. Agr. & Hort., p. 49. Ninth Annual Report, Ariz. Comm. Agr. & Hort., pp. 58-59.

the average loss from these insects in Arizona is estimated to have been between 3 and 5 percent. Accordingly the total loss would be placed between $420,000 and $700,000.

The cotton square daubers are usually destructive to cotton only during the month of August. The immature stages have never

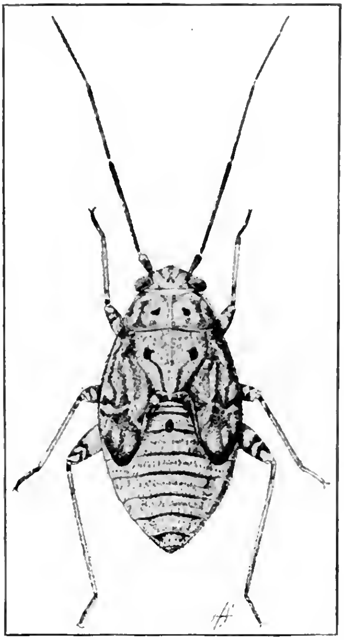

Fig. 14.—Nymph of tarnished plant bug (enlarged nine times).

Fig. 15.—Adult tarnished plant bug (natural size and enlarged).

Fig. 16.—Adult cotton square dauber (enlarged about twice).

been found in abundance on cotton plants. Evidently they do not find the cotton field a suitable breeding place. Alfalfa fields appear to be the principal source of the adults which invade the cotton fields. In one instance it was estimated that there was an average of one adult square dauber to each square foot of area in an alfalfa field. If all of these insects in a single acre of this alfalfa were distributed in cotton fields so that there would be an average of one per plant there would be more than sufficient to prevent all setting of bolls in from 6 to 8 acres of cotton. The insects were observed in one instance exceeding 20 per plant on a few rows on one side of a cotton field. An average of one of the bugs per plant is believed by the writer to be sufficient to cause maximum damage, and all in excess of this may, therefore, be considered harmless. This matter will be considered later in connection with the discussion of remedies.

The adult cotton square daubers are about a fifth to one-fourth of an inch in length. They are very variable in color. One form, *Lygus elius* var. *hesperus* Knight,[1] is pale brownish green or greenish brown, the males conspicuously marked with red on the wing covers and with more or less black on the front third of body, the females being paler and more uniformly colored than the males. The darker form, found on cotton less commonly than the first mentioned, is the true tarnished plant bug, *Lygus pratensis* var. *oblineatus* Say.[1] The general color is yellowish or bronzy brown, with black and grayish or yellowish markings.

The adults feed inside the bracts of the cotton square, sucking the rich plant juices from the developing parts of the flower bud. The sucking organs are more slender than the finest needle and leave no trace where they penetrate, but the interior of the injured bud quickly decays, the bracts flare and the whole square becomes yellowish in color and drops from the plant within a few days. Shedding of the squares frequently follows irrigation or heavy rainfall. Shedding caused by the square daubers can be distinguished by the daubs of yellow excrement which the insect leaves on the inside of the bracts and on the flower bud. This excrement is a liquid which has a varnish like appearance when dry. Squares which show this characteristic daubing, with no other external evidence of injury, are invariably in process of decay. Very small bolls are also subject to attack but the principal damage is to the squares. Cotton growers should learn to recognize the appearance of the squares and bolls destroyed by the daubers in order to distinguish between the shedding of the forms from natural causes and from the insect attack.

The cotton square daubers have been found in injurious abundance in a cotton field two miles from the nearest alfalfa, but, as a rule, excessive infestations are traceable to surrounding or adjoining alfalfa fields. The adults can not be destroyed by any spray as far as known and their habits of feeding inside the bracts would make the use of any spray impracticable even if an effective one were known. The problem of controlling the insects in cotton, therefore, centers in preventing their undue spread from neighboring alfalfa fields and in taking advantage of their activity, when disturbed, to drive them out of a cotton field or to concentrate them in such a way as to reduce the damage.

[1]Specimens determined by Mr. H. H. Knight of Cornell University.

The greatest damage to cotton arises from cotton square daubers being driven in from an adjoining alfalfa field when the crop is cut. If the cutting begins on the side farthest from the cotton and continues toward the cotton the square daubers and grasshoppers are gradually concentrated on the side of the field and finally when the last land is cut large numbers of the pests are virtually driven into the cotton fields. In one such case an average of one of the daubers to each cotton square was noted on a few rows.

On account of both the square daubers and grasshoppers alfalfa cutting and raking should be started on the sides of a field and continued toward the central land which should be left temporarily as a trap. When concentrated on a limited area in this way large numbers of the insects can be captured with a hopper dozer such as is used for grasshoppers. In one instance where the daubers averaged one to a square foot, or about 43,000 per acre, more than 7000 of the insects were captured on a little less than an acre in the course of fifteen minutes. In addition to the square daubers about 3500 specimens of the alfalfa hopper (*Stictocephala festina* Say) and about 1000 specimens of the differential grasshopper (*Melanoplus differentialis*) were captured at the same time. This was accomplished after dark with two lanterns suspended over the pans of oil and water.[1] Further experience is necessary in order to perfect this method, but the results so far justify the use of the hopper dozer against the square daubers in alfalfa fields in cases of excessive infestation, and especially after the insects have been concentrated as advised above. Even if no attempt is made to destroy the insects after concentrating them near the center of the field the method will be of great advantage. The strip or patch of uncut alfalfa should be left undisturbed until the rest of the field has made considerable new growth. In the meantime, the grasshoppers should be poisoned with poisoned baits, or both the grasshoppers and square daubers collected with a hopper dozer, used at night to avoid unnecessary scattering of the insect pests by driving away from the trap patch many of those not captured. After the insects are concentrated near the center of the field, prompt action against the grasshoppers must be taken when necessary in order to prevent their cleaning up the alfalfa leaving nothing but the bare stems. In this condition the trap patch would not be effective in holding the active square daubers.

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[1]To Mr. J. L. Moore, a cotton and alfalfa grower located west of Phoenix, credit is due for the idea of using the hopper dozer at night.

The plan suggested can be modified to suit the conditions and individual ideas of the alfalfa grower. For instance, instead of a single land or strip across the middle of a field a square patch extending across two or three lands may be left in the center of the field. This method is specially desirable when there is cotton on more than two sides of the alfalfa.

Alfalfa growers who have no cotton of their own to protect will frequently secure full returns in benefits to the alfalfa crop itself from the adoption of the foregoing suggestions. Owners of neighboring cotton fields should be given an opportunity to assume the expense of these measures, rather than be obliged to suffer without recourse severe losses from insects driven in from alfalfa fields. Cotton growers should keep in touch with their neighbors and arrange with the owners of adjoining alfalfa fields for cooperation in the control of pests.

Reference has been made to the matter of driving the cotton square daubers out of a cotton field or of concentrating them within the field. Attention has also been called to the fact that an excess of the insects above the number capable of causing maximum damage may be considered as harmless, for the time being at least. The unusual activity of the adult cotton square daubers can, the writer believes, be taken advantage of in driving the insects by means of a device which he has designed. A second device is designed to capture the insects after they have been concentrated on a few rows. One of each of these devices has been constructed and the work of perfecting them will be continued as the opportunity for further field tests is presented.

THE SOUTHWESTERN COTTON STAINER

The Southwestern cotton stainer *(Dysdercus albidiventris* Stal.) has been found on cotton in various parts of the Salt River Valley and at Sacaton. This insect is related to the Florida cotton stainer, which is a well known cotton pest in the Sea Island cotton growing district of Northern Florida. Other species occur in the West Indies, Central, and South America. The adult cotton stainer is from six to seven-sixteenths of an inch in length, the males being considerably smaller than the females. The adults are strikingly colored with a combination of black, straw yellow, orange brown, and orange red. The insects breed upon the cotton plants. In the immature or nymphal stages the bright orange red is the predominating color. The cotton stainer does its damage by feeding on the immature bolls. By means of delicate, threadlike parts of the mouth organ known as setae the bug punctures the carpel of the boll and the seed coat, and sucks the juices from the inside of the seed. This results in an abnormal growth or proliferation being produced on the inside of the carpel at the point of entrance of the setae and in the decay of the attacked seed and surrounding lint. There is no mark on the outside of the boll to indicate this internal injury. In the West Indies investigations have shown that a similar decay is caused by a fungus which is supposed to be introduced into the interior of the bolls by sucking bugs, principally cotton stainers. It is probable that the internal

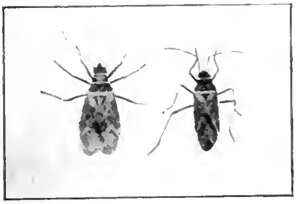

Fig. 17—Southwestern cotton stainer. Female at left, male at right. (About natural size).

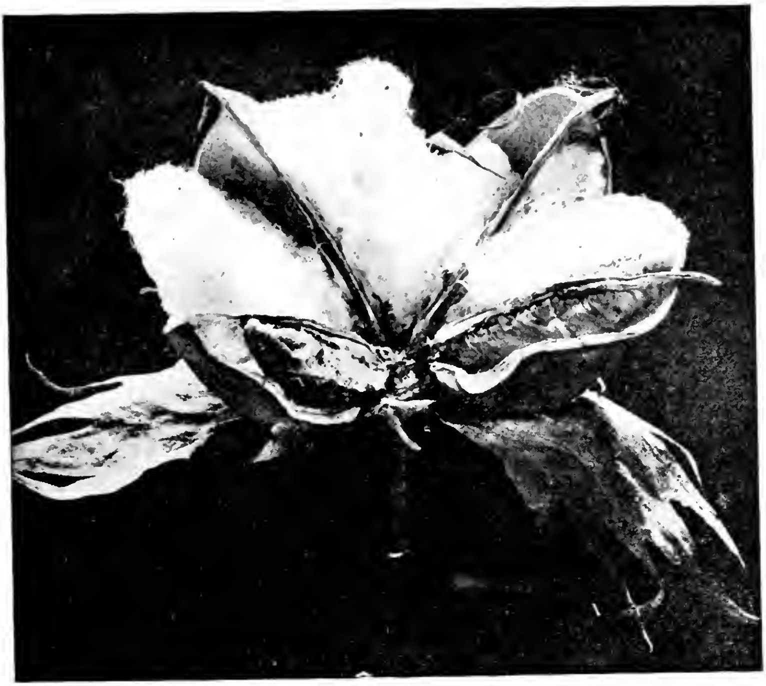

Fig. 18—Work of cotton stainer. One lock shrivelled and decayed.

decay of cotton bolls which occurs in the United States is also due to a fungus introduced by sucking bugs.

The Southwestern cotton stainers are not generally injurious throughout the Salt River Valley, but in one locality during the year 1916 they were destructive on several farms, destroying from 50 to 75 percent of the immature bolls. In one section of a cotton field comprising four or five acres it was estimated that the insects had destroyed fully 90 percent of the bolls.

In addition to the complete destruction of young bolls cotton stainers do much damage by attack on bolls which are mature or nearly so. When such bolls are attacked the injury appears in the form of stained lint. In one instance observed by the writer the Florida cotton stainer damaged a crop of about 1000 bales of Sea Island cotton to the extent that 200 bales were classed as stained.

The Southwestern cotton stainers were not present in injurious numbers in any part of the Salt River Valley during 1917 and 1918. They may be expected to vary greatly in numbers from year to year. They should be recognized by all cotton growers as being capable of causing considerable damage. Whenever any are found they should be watched carefully and whatever steps may be necessary should be taken to prevent breeding on weeds or other plants in the neighborhood of cotton fields, while in the cotton fields the stainers should be collected and destroyed whenever they appear in threatening numbers. The bugs have a habit of congregating in large numbers on the bolls, and their conspicuous color makes it easy to destroy them by knocking them by hand into a bucket or other convenient vessel containing water with a small amount of coal oil on the surface.

THE BROWN COTTON BUG

A third species of plant bug which has caused noticeable damage to cotton in Arizona is known as the brown cotton bug *(Euschistus impictiventris* Stal.) This is very closely related to the brown cotton bug which is known as a cotton pest in Texas and other states of the cotton belt. This insect belongs to the group commonly known as "stink bugs". The adult is broad and flattened, a little over half an inch in length, has rather sharp shoulders and is yellowish below and marked with dark brown or black punctures above. The brown cotton bug injures the crop by sucking the juices from the bolls. The thread-like mouth organs are used to penetrate through to the interior of the developing seed. The effect is similar to that produced by the cotton stainer. The brown cotton bug is found in nearly all cotton fields in Arizona, sometimes in considerable numbers. No excessive damage, however, has thus far been observed. The importance of this pest consists in its general occurrence in nearly all cotton fields rather than occasional serious outbreaks, such as observed in the case of the cotton stainer. The brown cotton bug here referred to does not seem to breed to

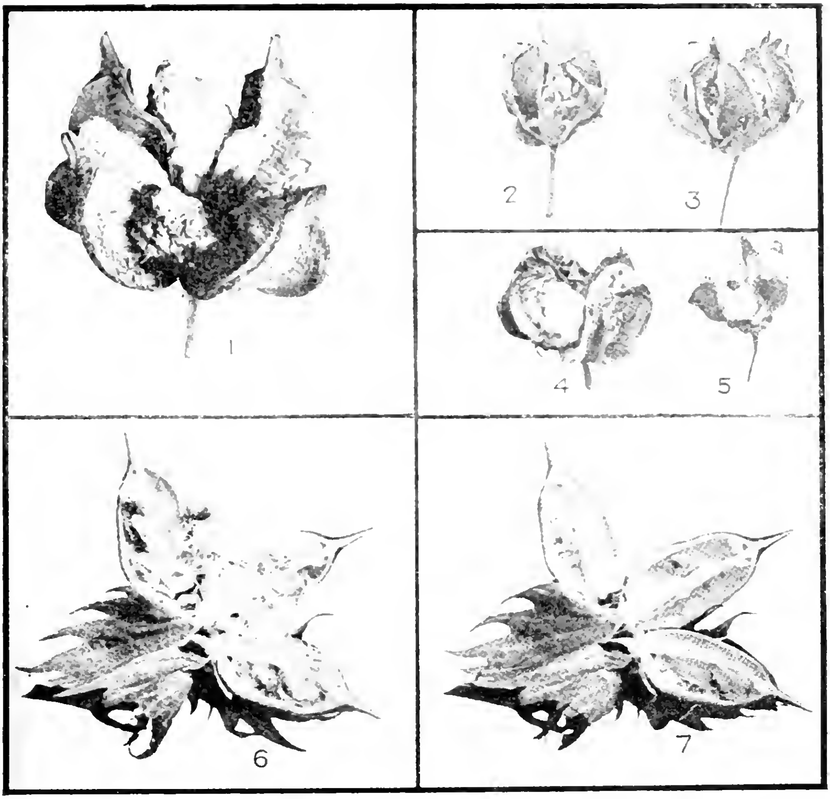

Fig. 19—Effects of plant bug attack on cotton bolls. 1, Boll with shrivelled lock. 2, 3, 4 and 5, Small bolls, stunted and decayed as a result of plant bug attack. 6, Immature cotton boll broken open to show decayed condition of locks as result of plant bug attack. 7, Same with lint and seeds removed to show proliferation or abnormal wartlike growth on insides of carpels produced by plant bug punctures.

any extent upon the cotton plants. It is quite likely that it multiplies principally on wild food plants and migrates to the cotton plants when these wild food plants become overstocked with the insects or, in the case of annuals, reach maturity and die. The brown cotton bug is rarely found in sufficient numbers to require treatment except in small areas. Judging from observations made on related species each adult of the brown cotton bug is capable of destroying a large number of bolls. An average of one of these bugs to a plant should be considered as threatening very noticeable damage. The only remedies which can be suggested consist in making observations to determine where the insects are breeding and in destroying them by spraying with coal oil or by burning whenever they are found concentrated in considerable numbers. If they have appeared in the cotton fields the only remedy available consists in hand picking. Each adult of this species is capable of destroying from two to five cents worth of cotton lint and it is unquestionably very profitable to collect them by hand when this work can be done at a slight cost, as for instance 10 or 15 cents a hundred.

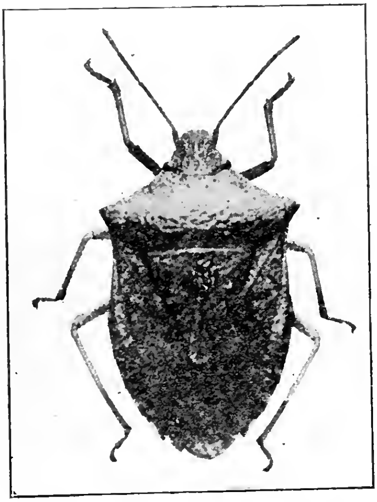

Fig. 20.—The brown cotton bug.

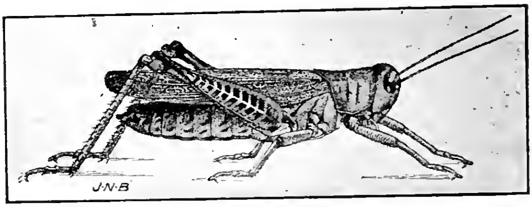

Fig. 21—The differential grasshopper. (About natural size.)

GRASSHOPPERS

Three species of grasshoppers have been observed doing damage to cotton in Arizona. The attacks of these insects in large numbers may result in the complete destruction of the crop. In several instances noted the plants have not only been completely stripped of all leaves but the green bark has been gnawed from the main stem and branches. Grasshoppers in cotton growing sections breed principally in alfalfa fields and are very apt to migrate from the alfalfa to cotton immediately after a heavily infested crop of alfalfa is cut for hay and removed from the field, particularly when the cutting and raking is started on the side away from the cotton and these and other cotton pests are virtually driven out. The principal grasshopper damage to cotton in Arizona is by a species known as the differential grasshopper (*Melanoplus differentialis* Thos.) This insect is light brownish in color with black markings. The adult females are over an inch and a half in length. The voracity of these insects is indicated by a calculation made by the writer showing that when the adults average about 16 to a square yard they may consume the equivalent of a ton of hay a day in a forty acre alfalfa field. The number mentioned represents only a moderate infestation.

The other two species of grasshoppers destructive to cotton in Arizona are closely related *(Schistocerca shoshone* and *S. vega.)* They are nearly twice as large as the differential grasshopper. One is brown in color and the other is green. So far they have been excessively numerous in only one instance, where they completely defoliated a small field of cotton.

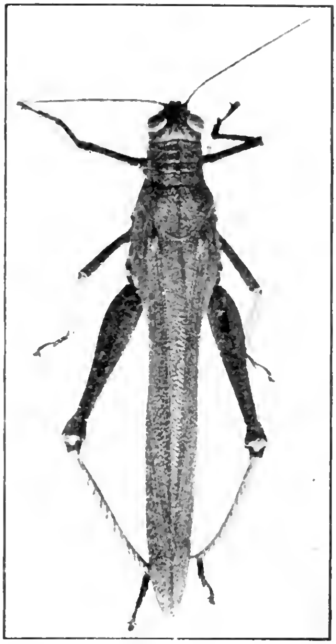

Fig. 22 —The large cotton grasshopper, *Shistocerca shoshone* (natural size).

Grasshoppers may be destroyed in cotton fields with comparatively slight expense. The method consists in spreading broadcast a poisoned bait. The standard grasshopper bait consists of bran, molasses, Paris green, finely chopped lemons or oranges and water. Experiments by the writer during 1917 and 1918 have shown that a half and half mixture of bran and sawdust is as effective as the bran alone. Ground canteloupe (culls) have been found as effective as lemons or oranges. The evidence so far favors the conclusion that the addition of molasses to the bait does not increase its attractiveness to the grasshoppers. The proportions of the materials in a bait successfully used in Arizona are as follows:

Bran, 12½-15 pounds.
Sawdust, 12½ pounds.
Paris green, 1 pound.
Canteloupe, 1 pound. (Use 5 lemons or oranges if canteloupes are not available.)
Water, enough to make a crumbly mixture.

The Paris green should be mixed with the dry sawdust and bran. This may be done by placing the bran, sawdust and Paris green in a barrel, tub or special mixing vat, and using a hoe. A wet sponge or a gauze mask should be used to protect the operator against breathing the Paris green dust. The finely ground canteloupe, lemons or oranges should be mixed with about a gallon of water and this mixture then thoroly stirred into the bran-sawdust-Paris green combination. More water is added as needed to make a moist crumbly mixture. This mixture should be sown broadcast in the infested cotton fields. Observations on the habits of the differential grasshopper have shown that late afternoon is not a favorable time for spreading the bait in cotton growing sections of Arizona.

Fig. 23.—Cotton plants in foreground stripped of leaves by differential grasshoppers which migrated from adjoining alfalfa field.

The advantages of concentrating grasshoppers and cotton square daubers in the center of alfalfa fields rather than driving them out with mowers and rakes, as is sometimes done with disastrous results to adjoining cotton, has been discussed under the subject of the control of the cotton square daubers. Heavy applications of poisoned baits in proportion to the abundance of the insects in the uncut area, or the use of the hopper dozer, are the best available methods of disposing of the grasshoppers after they have been concentrated.

THE COTTON APHIS

During the first two or three weeks in the spring after the young cotton plants come through the ground cotton growers are frequently alarmed by the attack of small greenish or greenish black insects known as the cotton aphis *(Aphis gossypii* Glov.) The same species attacks and sometimes destroys melon vines and is perhaps better known as the melon aphis. It occurs everywhere in the United States where cotton is grown, but is not ordinarily of much importance as a cotton pest on account of the effectiveness of its natural enemies, particularly a black wasp-like parasite.

There are two forms of the adult, winged and wingless females. Males are not known. The body of one of the full grown insects is about a fifteenth of an inch long. The folded wings in the case of the winged form extend approximately another fifteenth inch

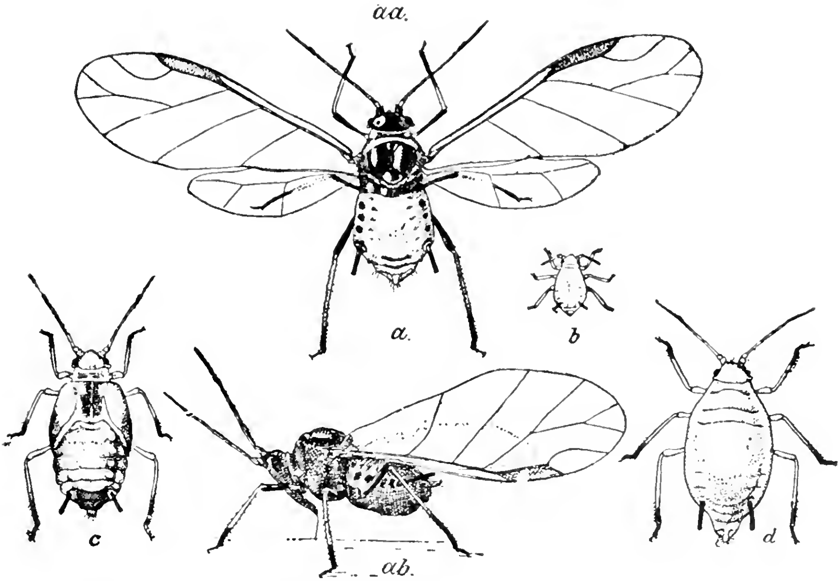

Fig. 24—The cotton aphis.

beyond the end of the body. The migrating or winged adults spread into the cotton fields from mallow and other weeds which have remained infested throughout the winter. Eggs are laid on the young cotton plants soon after they come through the ground. These soon hatch and the nymphs in the course of a few days develop into wingless adults. These are each capable of giving birth to six to ten young per day. As these in turn become full grown in less than a week and are ready to reproduce it is apparent that no crop could long survive if such an increase were unchecked.

Fortunately, wasp-like or hymenopterous parasites, principally *Aphidius testaceipes* Cress, lady birds, principally *Hippodamia convergens* Guerin., lace wing flies or chrysopas and predaceous flies known as syrphus flies, are very effective as a rule in preventing undue multiplication. Before the death of the parasitized aphis occurs the body of the insect turns light brown in color and becomes almost globular in form. The insect before dying attaches itself rigidly to the leaf on which it was feeding. These parasitized insects and the empty shells which remain after the adult parasite emerges are very conspicuous and a farmer should learn to recognize them. Each adult female of the parasites is capable of destroying around two hundred aphis individuals. That is, each adult parasite will parasitize or deposit an egg in the body of each of two hundred or more specimens as long as the supply of aphis holds out.

The effectiveness of parasites, lady birds and other natural ene-

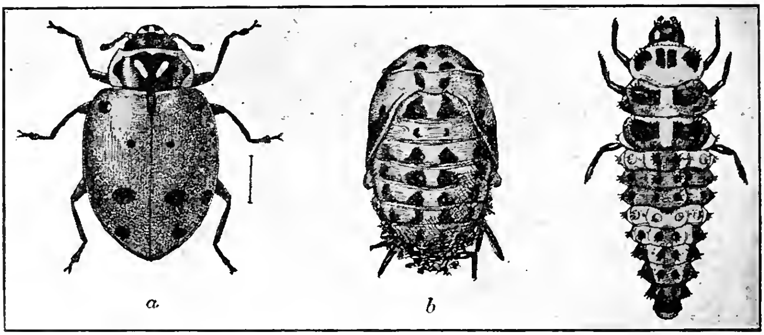

Fig. 25—The convergent lady bird, an enemy of the cotton aphis. a, Adult. b, Pupa. c, Full grown larva. (All greatly enlarged.)

mies of aphis, is dependent on the weather. Cold weather during the crop growing season is unfavorable for the natural enemies and therefore favorable for the aphis. During warm or hot weather the parasites are capable of multiplying so much faster than the aphis that the latter are relatively unimportant among cotton pests. The natural enemies of this species of aphis for some reason are much more reliable in the control of the pest on cotton than on melons and other crops. Owing to this indirect relation of the weather to the effectiveness of the parasites it is a common belief among farmers and gardeners that the hot weather destroys the aphis. As a matter of fact the aphis will thrive in our hottest midsummer weather and do much damage if for any reason the parasites and other natural enemies are not active.

In 1914 and again in 1918 the cotton aphis was notably destructive in the Yuma Valley. In July, 1918, the attack was especially severe and for a time threatened the complete destruction of the crop. Soon after the first of August, however, hymenopterous parasites increased sufficiently to control the pest. Lady birds, which are more conspicuous and therefore better known as enemies of this aphis, were of no practical importance during the 1918 midsummer outbreak according to the observations of Mr. J. L. E. Lauderdale. Similar observations in regard to lady birds were made by the writer in 1914. The following account[1] of the ineffectiveness of

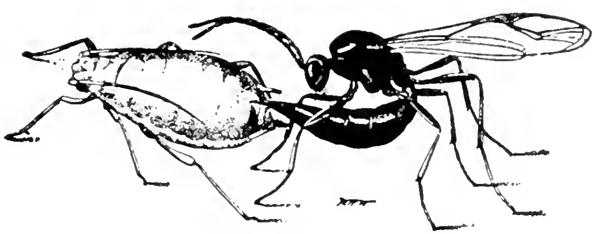

Fig. 26—Hymenopterous parasite attacking an aphis.

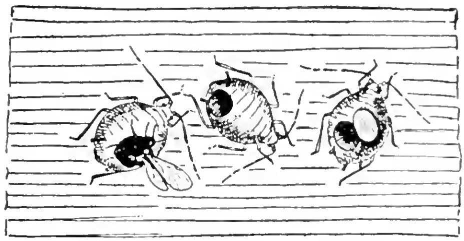

Fig. 27—Parasitized specimens of aphis.

the lady birds at the time of the first serious outbreak is quoted to emphasize the impracticability of relying upon these natural enemies for the control of the cotton aphis in midsummer:

"On August 19-20, 1914, a visit by the State Entomologist to numerous cotton fields on both the California and Arizona side of the Colorado River near Yuma disclosed the fact that all kinds of natural enemies were scarce, particularly the lady-bird noted above. In some fields there had been a decrease in the number of aphis due to internal parasites. In several infested fields large numbers of convergent lady-birds had been liberated some weeks previously. Wherever this had been followed by a decrease in the amount of aphis the introduction of the natural enemies was generally credited with the supposed benefits. A close examination, however, showed that these introductions could have had no beneficial effects whatever since the lady-birds in any stage were as scarce in these fields, which had been stocked with the beneficial insects, as in fields which had not been so supplied. Furthermore, an examination of the plants failed to disclose any evidence of the lady-birds having bred in the fields. Such evidence would have been easily found in the presence of large numbers of pupae or empty pupal

[1]Sixth Annual Report Ariz. Comm. Agr. & Hort., pp. 37-38, 1914.

skins attached to the cotton stalks if they had been breeding in numbers capable of accomplishing results."

The feasibility of spraying for the control of the cotton aphis on plants from 3 to 3½ feet high was demonstrated at Yuma by Mr. Lauderdale with an improvised power sprayer and spray boom arranged for spraying 5 rows of cotton at a time. He found that about thirty acres of cotton could be sprayed in a day by two men at a cost of about $1.25 per acre for materials. The total cost per acre should be less than $1.90. The insecticide used was nicotine sulfate (Black Leaf 40) and soap. The sprayer used by Mr. Lauderdale is shown in the frontispiece.

THE COTTON THRIPS

The cotton thrips *(Thrips arizonensis* n. sp. Morgan) is a slender yellowish insect which when full grown is scarcely over a fifth of an inch in length. It attacks young seedling cotton plants and is capable of doing much damage. Characteristic effects upon the

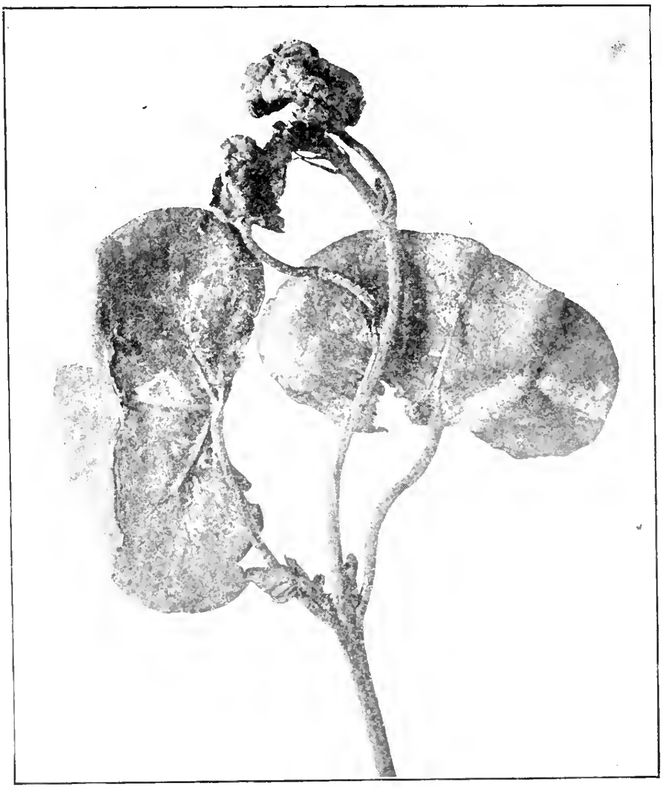

Fig. 28—Work of cotton thrips on seedling cotton plant.

plants are shown in Fig. 28. The insects work on the under surfaces of the primary leaves and on young leaves of later growth which are soon crinkled by their attacks. It is probable that this insect infests certain weeds and other vegetation in and near cotton fields and that clean culture will act as a preventive of injurious attacks. When the young plants are seriously infested spraying is the only available remedy. For this purpose nicotine sulfate—soap solution is probably the best insecticide. This should be used at the rate of six ounces of nicotine sulfate (Black leaf 40) and two and one-quarter pounds of whale oil or fish oil soap in fifty gallons of water. The spray should be applied with as strong pressure as can be used without injury to the plants. A right angle nozzle or a combination of angle nozzle and elbow joint giving a ninety degree spray is needed in order to reach the under surfaces of the leaves and to drive the spray into the crinkled leaves from all sides. Fortunately the cotton thrips, so far as observed, is destructive only when the plants are small, and the early injury is usually outgrown by otherwise thrifty plants.

THE RED SPIDER

During the past few years the two-spotted red spider (*Tetranychus bimaculatus* Harvey) has become quite prominent among the cotton pests of the Southeastern United States. This same species is of common occurrence in the Salt River Valley where it attacks violets, climbing roses (Dorothy Perkins), strawberries, blackberries, and beans. So far, however, it has not been observed on cotton plants in Arizona. It seems very likely that sooner or later this insect will be found doing damage to cotton in the fields, altho, apparently, conditions for the infestation of cotton are not as favorable here in Arizona as they are in the Southeastern states.

The red spider is a true mite rather than an insect, having eight legs instead of six in the adult stage, lacking antennae and otherwise differing from true insects. The adult female is only one-fiftieth of an inch in length and the adult male is only about half as large as the female. Infested cotton leaves turn deep red on the upper surface, producing a condition sometimes called "rust". An examination of the under surfaces of the leaves, however, reveals the presence of the minute red mites. Badly infested leaves become distorted and finally drop. The pest develops very rapidly, producing in a single season as many as seventeen generations. It is of special interest in the arid Southwest on account of belonging to a group notoriously favored by hot, dry weather. In the Southeastern states the influence of weather on breeding activity was found to be very noticeable. Hot, dry conditions favored rapid development while cool, wet weather retarded it, the rate of egg laying varying from none to twenty per day according to temperature.

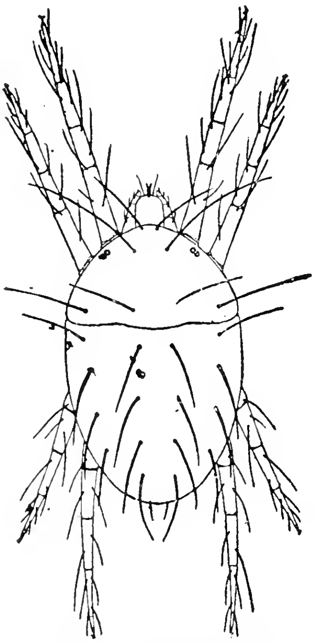

Fig. 29—The two spotted red spider (greatly enlarged).

In view of the possibility of this spider appearing in Arizona cotton fields sooner or later, preventive measures should be closely observed. Violet and strawberry plants and the Dorothy Perkins rose are food plants which are very likely to be a means of spreading and maintaining the pest. Not all beds or specimens of these food plants in the Salt River Valley are infested with the red spider. It is also probably true that there are many other kinds of plants which are subject to infestation and more or less dangerous. It is advisable, however, for cotton growers either not to permit the plants named to grow near cotton fields, or to examine them carefully from time to time to detect the first infestation should the red spider appear. Weeds or other plants supposed to be infested with the red spider should be submitted to the Office of the State Entomologist, Phoenix, or the Department of Entomology, College of Agriculture, Tucson, for examination. When preventive measures have not been given proper attention or have failed to protect the cotton field, spraying with potassium sulphide, lime sulfur solution, kerosene emulsion, or flour paste solution is recommended. Flowers of sulfur and "Atomic Sulfur", which are effective against most species of red spider, have not proved effective against this one.

OTHER COTTON PESTS

Of the pests discussed in the foregoing pages all except the Mexican cotton boll weevil and the pink bollworm occur in Arizona. A very close relative of the Mexican boll weevil, however, is found in certain mountain ranges of the Southern part of the State. In addition there are over twenty other species of insects known to feed upon the cotton plant in Arizona. Their numbers have been insignificant so far as observed, or injurious attacks have been confined to very small tracts. Such pests include certain cutworms and other moth caterpillars, a white ant or termite, several sucking plant bugs related to those herein mentioned, and two beetles, *Myochrous longulus* Lec. and *Blapstinus pimalis* Casey, which attack cotton seedlings sometimes necessitating replanting. The cotton fields should be closely watched by the grower from the time the seed sprouts, and specimens of any unrecognized pests should be sent at once to an entomologist for examination.

COTTON SEED AND SEED COTTON QUARANTINE

For the protection of the Arizona cotton growing industry against pests likely to be transported with cotton seed and seed cotton the Arizona Commission of Agriculture and Horticulture has placed in effect the following Quarantine Order and Inspection and Quarantine Regulation:

QUARANTINE ORDER NO. 15

Seed Cotton and Cotton Seed

In order to prevent the introduction and dissemination of the cotton boll weevil (*Anthonomus grandis*) and the pink bollworm (*Pectinophora gossypiella*) into and within the State of Arizona, it is hereby ordered:

(a) That the introduction of cotton seed and seed cotton into the State of Arizona from any other state or territory of the United States or from any foreign country, except as herein provided, is hereafter prohibited.

(b) That the transportation of cotton seed and seed cotton from any county in the State of Arizona into any other county in the State of Arizona is hereafter prohibited except under special authorization from the State Entomologist.

(c) That paragraph (a) of this quarantine order shall not apply to seed cotton or cotton seed grown in that part of the State of California adjoining the Colorado River and included in the Yuma Reclamation Project, and paragraphs (a) and (b) shall not apply to cotton seed for experimental purposes shipped by the U. S. Department of Agriculture or the Arizona Agricultural Experiment Station under special authorization from the State Entomologist

(d) That all persons, firms or corporations in the State of Arizona are prohibited from having possession of, transporting, selling or giving away any seed cotton or cotton seed introduced into the state or transported within the state in violation of this order.

(e) That Quarantine Orders Nos. 5 and 9 are hereby rescinded.

Adopted November 16, 1917.

REGULATION NO. 3

Car-lot Shipments Emigrants' Goods From Cotton Growing States and Counties and Alfalfa Weevil Infested States and Counties

In order to make more effective the provisions of Quarantine No. 1 against the alfalfa weevil and of Quarantine No. 15 against cotton pests, it is hereby ordered:

(a) That upon arrival at any common carrier station in the State of Arizona of any carlot shipment of emigrants' goods from the states of Utah, Idaho, Wyoming, Colorado, Virginia, North Carolina, South Carolina, Georgia, Florida, Tennessee, Alabama, Mississippi, Arkansas, Louisiana, Oklahoma, Texas, Missouri, the counties of Graves and Fulton in the State of Kentucky, of Montgomery in the State of Kansas, and of Imperial and Riverside in the State of California, such shipment shall be held intact and not delivered to consignee until notice has been given to and certificates of release received from the State Entomologist, Assistant Entomologist or a Crop Pest Inspector.

(b) That the unloading or unnecessary moving, by any person or persons, of carlot shipments of emigrants' goods from any of the states mentioned in the foregoing paragraph before a proper certificate of release has been received is prohibited.

(c) That where there is no local inspector designated to attend to inspections for the Commission of Agriculture and Horticulture notice of the arrival of the shipment may be sent to the State Entomologist in Phoenix by wire, the expense to be borne by the State, and a telegraphic message from the State Entomologist, or officer acting in charge, authorizing the release of the shipment may be accepted and filed by the common carrier agent in lieu of the customary certificate of release.

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Farmers Bulletin 890—How Insects Affect the Cotton Plant and Methods of Combatting Them (W. D. Pierce).

For Sale by Superintendent of Documents, Government Printing Office, Washington, D. C.

Bulletin 86, Bureau of Entomology, U. S. Department of Agriculture. Plant Bugs Injurious to Cotton Bolls (A. W. Morrill). Price 20 cents.

Bulletin 723, U. S. Department of Agriculture. The Pink Bollworm with Special Reference to Steps Taken by the U. S. Department of Agriculture to Prevent Its Establishment in the United States (W. D. Hunter). Price 5 cents.

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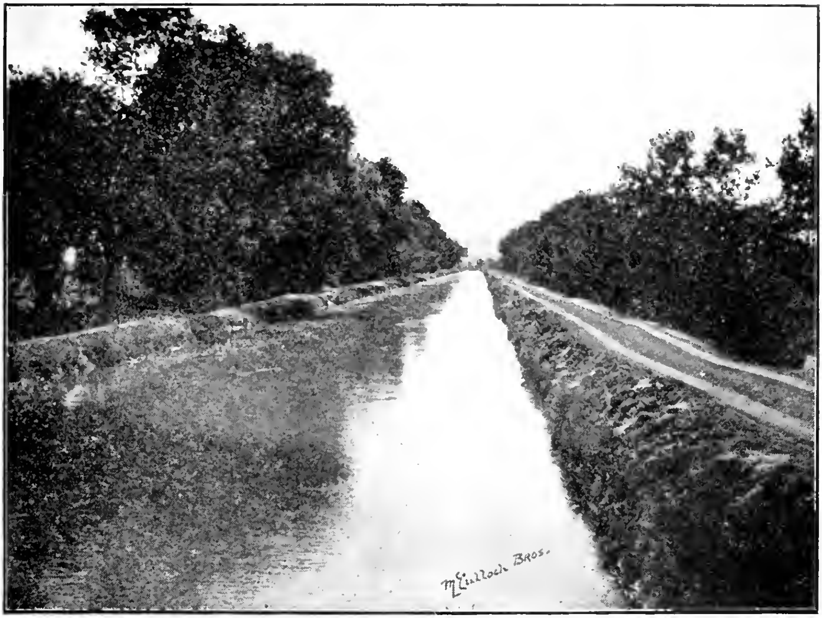
The University of Arizona
College of Agriculture

Agricultural Experiment Station

Bulletin No. 88



An irrigation canal near Tempe.

USE AND WASTE OF IRRIGATION WATER

By G. E. P. Smith

Tucson, Arizona, May 15, 1919

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D. C. AEPLI, Foreman	Date Palm Orchard, Yuma
T. L. STAPLEY, Foreman	Date Palm Orchard, Tempe
T. F. WILLCOX, Foreman	Prescott Dry-Farm, Prescott
F. H. SIMMONS, Foreman	Sulphur Spring Valley Dry-Farm, Cochise

The Experiment Station offices and laboratories are an integral part of the College of Agriculture of the University at Tucson. The Salt River Valley Experiment Farm is situated one mile west of Mesa, Arizona. The date palm orchards are three miles south of Tempe (co-operative U. S. Department of Agriculture) and one mile southwest of Yuma, Arizona, respectively. The experimental dry-farms are near Cochise and Prescott, Arizona.

Visitors are cordially invited and correspondence receives careful attention.

*On leave.

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ILLUSTRATIONS

Irrigation by flooding in borders from a cement-lined ditch on ranch of B. A. Fowler near Phoenix. The "head" of water is divided evenly into three "lands." There is no seepage loss from the ditch, no ditch cleaning, and the water is easily controlled.

USE AND WASTE OF IRRIGATION WATER

By G. E. P. Smith

What becomes of the irrigation water? The irrigator knows that in a general way the water is beneficial, in fact, is necessary; he does not know just where the water goes after it sinks into the ground, nor does he know just how much of the water applied to the land actually does useful service and how much of it is wasted. In the early days of irrigation in any country, the chief interest and energy are exerted in developing the water. But when the water supplies are so fully developed as they are in Arizona at the present time, then farmers and others interested in agriculture must study the efficiency of irrigation in order that waste of water may be reduced and the water supplies may be made to serve as large an acreage as possible. It must be confessed that in some communities the various losses of irrigation water aggregate as high as 80 percent of the total quantity of water diverted from the stream. If the losses in such a community can be cut down to 60 percent, the remaining useful portion is increased from 20 percent to 40 percent, that is, it is increased two-fold. There are, indeed, inviting possibilities of doubling the irrigated area in certain Arizona valleys where already the entire water resources are thought to be fully developed.

A survey of the water supplies of the State at the present time indicates a shortage in the supply for this year on many streams, and the Roosevelt Reservoir contains less than one-half of its full capacity. Reservoir supplies must be conserved as far as possible, in the fear that the present dry year may be followed by another equally dry. It is very pertinent, therefore, that this year the farmers should make a special study of their methods of irrigation in the effort to conserve the water supplies to the utmost.

TRANSPIRATION

Plants, like animals, breathe. The surfaces of leaves, and to a less extent of stems, are covered with innumerable minute breathing pores. Thru these small openings carbonic acid gas is taken in from the atmosphere and moisture is given out. It is a vital function of all plants to gather moisture thru their roots and to expire the moisture thru the minute stomatal pores into the air.

Plant growth is dependent in large measure upon the presence of an abundant supply of soil moisture. Surely the irrigating water which actually passes thru the plant in this way does a most useful service; all that portion of the irrigating water which does not pass thru the plant is wasted, so far as crop production is concerned.

The transpiration rate, even for the same plants, varies greatly according to climatic conditions, being least in humid countries and increasing greatly with aridity. The rate must be high in Arizona. Like the evaporation rate, it depends upon the temperature, the wind movement, and the relative humidity. The characteristic of high transpiration rate in this State must be acknowledged.

Many investigators have measured the quantity of water transpired by various plants. The U. S. Department of Agriculture* conducted extensive tests of this kind in northeastern Colorado. Some of their results are given in the following list, in which the transpiration is stated as the number of pounds of water required to produce a pound of dry matter, sometimes called the transpiration ratio. The soil used was "rich, dark loam."

WATER ABSORBED BY PLANT ROOTS DURING GROWTH
(Based on total dry matter produced)

Crop	Pounds of water per pound of dry matter
Alfalfa	1068
Barley, average of 4 varieties	539
Wheat, average of 5 varieties	507
Potato	448
Corn, average of 3 varieties	369
Sorghum, average of 5 varieties	306

When the production of grain alone was considered, the water requirement of wheat was found to be 1357 pounds of water per pound of dry matter, and of sorghum 790 pounds of water. The sorghum family of plants is specially adapted to arid climates and in particular to those localities where the limitations of water supply are felt seriously. It is evident, too, that alfalfa is the water gourmand, suggesting therefore that farmers, especially those under pumping plants with high lifts, should restrict their alfalfa to the amount needed for feeding their own necessary stock.

Most investigators believe that the texture and tilth of the soil, and the fertility, have a pronounced effect on the transpiration ratio. Thus, on clayey soils and very sandy soils plants transpire more water per unit of crop produced than on good loam; and compara-

*U. S. Dept. Agri., Bureau of Plant Industry, Bull. No. 284, 1913.

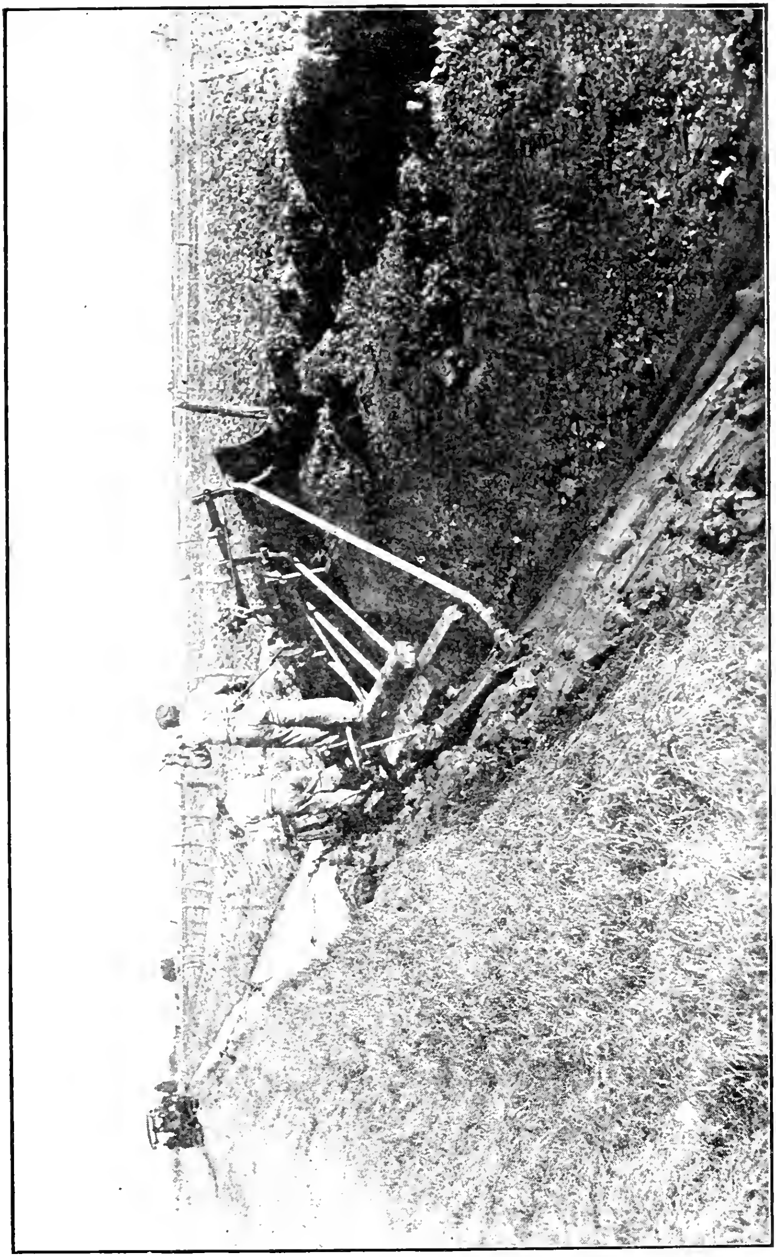

Fig. 2.—Cleaning a lateral canal in the Yuma Valley by means of a "Vee" drawn by two 75-horsepower tractors. In a few months the earth canal becomes foul with silt deposits and the growth of vegetation.

tive tests have shown the water requirement on sand and clay to be reduced more than fifty percent by the addition of fertilizers. On rich loams, however, the addition of fertilizer appears to have little effect upon the ratio of water transpired to crop produced.

It is not likely that the actual transpiration ratio in broad fields is so high as given in the table. Nevertheless, the table indicates the relative rates of different crops and the possibility of tremendous demands for water by plants under adverse soil and climatic conditions.

The water requirements of crops in Arizona have not been determined in an adequate manner. Observations and meager records indicate that, for the Salt River Valley, alfalfa that is grown continuously through the summer should have about eight 6-inch irrigations per year on medium loam soil, and about twelve 4-inch or 5-inch irrigations on sandy soils. Cotton requires from two acre-feet per acre on fertile loam soil to three acre-feet on light sandy soil and new desert soil, and milo maize about one and a half or two. The yield of alfalfa increases almost in proportion to the amount of water applied, at the rate of one ton of hay per acre-foot of water, even up to seven or eight acre-feet per acre; but with grain and other crops the yield is reduced by applying more than the optimum amount. The duty of water is higher in some cases due to subirrigation.

There is one school of irrigators in the Valley who do not irrigate alfalfa during part of July and through August. Allowing the alfalfa to rest during this period tends to keep out water grasses and tends to avoid damage by insects. Under this system the water requirements are less than the amount stated above, and the total yield also is reduced.

WATER LOSSES

The water transpired by plants constitutes, ordinarily, but a small part of the total water diverted for irrigation. Beginning at the point of diversion, the supply stream suffers continuous losses. The sequence of these losses is as follows: seepage (and evaporation) from canals; seepage from the field laterals; evaporation upward from the irrigated fields; seepage downward from the fields; and wilful or careless waste. These losses will be discussed separately and suggestions will be offered as to how they can be reduced.

LOSSES FROM CANALS AND FIELD LATERALS

Earth canals are more or less porous; new canals in sandy soils are sometimes little better than sieves. Fortunately, most of the irrigating supplies taken from streams in Arizona carry considerable fine silt; and this silt, settling in the canals, forms a blanket and reduces to some extent the excessive losses which occur in new canals. Since the construction of the Roosevelt Reservoir the proportion of clear water carried in the canals of Maricopa County has increased greatly and the loss by seepage from the canals has increased correspondingly.

Measurements of seepage losses on scores of ditches and canals in the Western states have been compiled and published.* The results are startling. Losses of over 10 percent per mile are not infrequent, and it is concluded that "a large percentage of the water, estimated at 40 percent of the amount taken in at the heads of the main canals, is lost by absorption and percolation along the routes." The records of the U. S. Reclamation Service in the Salt River Valley† state that during the past six years the canal losses between the Granite Reef and Joint Head diversion dams and the points where water is delivered to the water users have been from 40 to 45 percent of the total amount diverted. While the losses as given in the records may be overstated somewhat, it is certain that at least one-third of the water diverted is lost in the canals. The loss from the Avondale Canal is 40 percent in the first four miles.

Practically all of the loss in canals is by seepage, for the loss by evaporation is small. The evaporation from a free water surface during the summer months at Tucson averages 10 inches per month in depth. On that basis a canal with a water surface 10 feet wide and carrying 25 second-feet of water would lose just one acre-foot per month per mile by evaporation while the total discharge in the same time would be 1500 acre-feet.

An excessive seepage loss can be reduced somewhat by puddling the canal with clay. This method, however, is not recommended for general practice, for it is a temporary half-way measure, and the puddling must be repeatedly injured by ditch cleaning. Oil lining has been tried to some extent in California and is said to reduce the seepage about 50 percent, but it does not prevent the growth of weeds and ditch cleaning becomes more difficult. The best method is to line the canal with concrete, or, in the case of

*U. S. Dept. Agri., Bull. No. 126, 1914. This bulletin, designed for irrigation engineers and superintendents, contains descriptions of many concrete linings.

†Reclamation Record, 9, 11, Nov., 1918, p. 532.

small ditches, as from pumping plants, to convey the water in cement pipe lines. Concrete linings are coming into use widely, and they will be employed more extensively as projects become thickly settled and the value of the water increases. The Tucson Farms Company has lined 2½ miles of its canals with 3-inch reinforced concrete. The cost of this lining was about $18,000, while the value of the water saved is at least $40,000. An excellent example of concrete lining for field laterals is to be found on the ranch of B. A. Fowler near Phoenix, as shown in the frontispiece. The Agricultural Products Corporation has used cement pipe lines

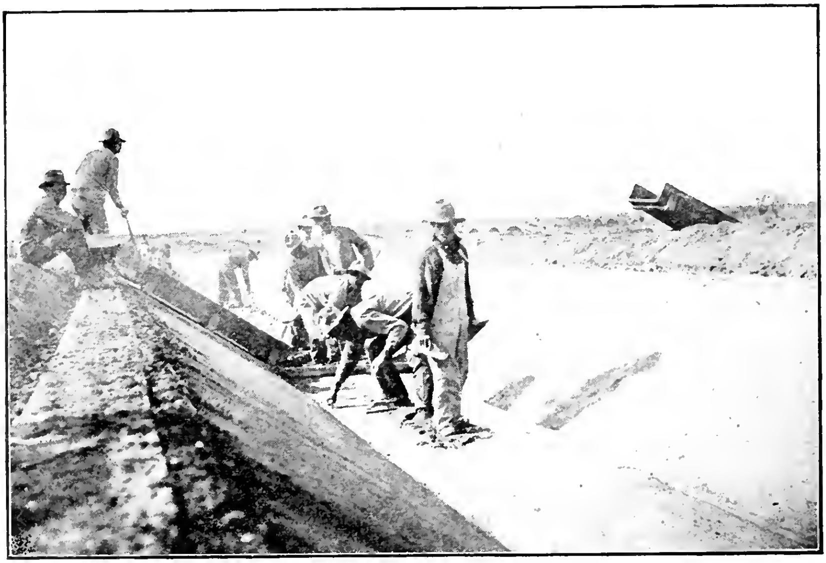

Fig. 3.—Lining earth canals with a 2-inch lining of concrete at Litchfield, Arizona. The total cost of this work in 1918 averaged 11 cents per square foot.

thruout for its distribution system, twenty-six miles in all. The Southwest Cotton Company uses both canal linings and cement pipe lines and ultimately will carry all irrigation water in concrete. Concrete linings and pipe lines have additional advantages: ditch cleaning is nearly or quite eliminated; breaks, especially those caused by the gopher holes, cannot occur; and the labor cost of irrigating is reduced.

EVAPORATION FROM IRRIGATED FIELDS

The direct evaporation of water from the ground surface may account for from 10 to 40 percent of the water applied. This loss

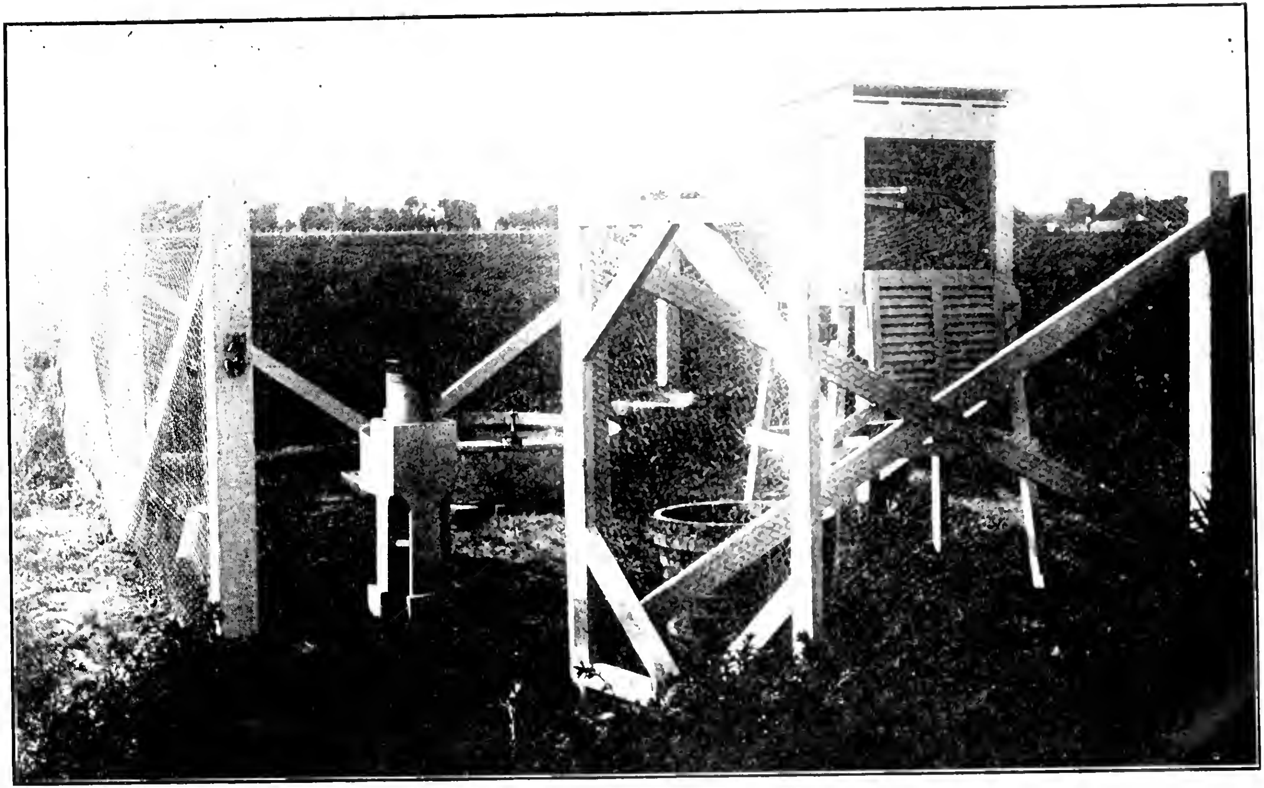

Fig. 4.—Evaporation station on Experiment Station Farm at Mesa, Arizona. The evaporation from the 18-inch circular pan is about nine inches per month thru the summer. It has been found that where the soil is kept saturated nearly to the surface, the combined transpiration and evaporation loss is greater than from the free water surface of a tank set in the soil.

is much larger on heavy loams and adobe soil than on sandy soil. It is greatest, of course, during and just after each irrigation and decreases gradually until the next irrigation. In the case of alfalfa it is comparatively high after each cutting and decreases as the plants grow again and shade the ground. It is greater on an open wind-swept area than on one protected by windbreaks.

Many methods for reducing the evaporation loss are available to the farmer. They are:

1. Deep plowing. A shallow seed bed underlain by packed soil tends to cause a high evaporation loss. From seven to nine inches of soil should be turned over by the plow.

2. Cultivation. In the case of crops planted in rows, such as corn, the ground between the rows should be cultivated as soon as possible after each irrigation. In the case of orchards, the ground should be furrowed just before irrigating and cultivated just afterward. If the furrows are 6 inches in depth, one may expect to save 60 percent or more of the loss which would occur without the mulch. Even alfalfa needs cultivation at least twice a year, and particularly after the soil has been packed by winter pasturing.

3. Increase in soil fertility. It is difficult to make a mulch when humus is lacking. A fertile soil takes water readily and, if cultivated, retains it with comparatively little loss by evaporation. Straw should be spread on the ground and plowed in. Weeds, trash, and perhaps a green manure crop can be utilized to improve the fertility. All stable manure should be spread and plowed into the soil.

4. More thoro and less frequent irrigation. This practice, besides saving water, tends to establish deep root feeding, while frequent light irrigations encourage shallow roots. For alfalfa one irrigation per cutting is ample except for sandy soils, where two lighter irrigations are preferable.

5. Irrigation at the right time. Irrigate heavily before planting, and withhold water after the planting for a considerable time. In the case of alfalfa, irrigate about a week before cutting. This will supply the water when it is most demanded for plant growth, and after cutting, the ground being still moist, the new crop will spring up quickly and shade the ground. Wheat should be planted in thoroly irrigated ground, and, with the aid of good winter rains, no irrigation is needed until the boot or flower stage. Cotton should be irrigated sparingly in the early stages of growth.

6. Irrigation at night. Evaporation is much restricted in the

night compared with the day time. It is a great mistake to shut down pumping plants each evening.

7. Elimination of weeds. The waste of water to raise weeds should be included with evaporation losses. Weed farming is unprofitable.

8. Windbreaks. They should be planted along the ditch banks and the road sides. Every farmer should raise his own fence posts and fire wood. Wind movement in the Salt River Valley is greatly reduced by the long rows of magnificent cottonwoods with which the landscape is checkered. The nearby fringes of fields require additional fertilization, but the net result of the windbreaks is beneficial.

SEEPAGE LOSS FROM IRRIGATED FIELDS

As a rule, this loss is even greater than the preceding one. It is particularly severe on light soils. It could be avoided to a large extent if no more water were applied at each irrigation than the amount that can be held by the soil within reach of the plant roots.

An ideal irrigation consists in applying the right amount of water, evenly distributed over the field. Thruout the central and southern portion of Arizona the practice for field crops is to lay out the field in long strips or "lands" In many observed cases the water, turned in at one end, requires from one to three hours to traverse a land to its lower end. As soon as the water reaches the lower end the ditch water is turned to another land. For one or two hours, then, the head end of a land gets water, part of which soaks downward beyond the reach of, and beyond the needs of, the plant roots, while at the far end the land receives water for fifteen to forty minutes. Surely, this is not an ideal irrigation. In 1913 the author made several tests of the evenness of distribution of the water. In one case, on heavy loam, it was found that the percentage of soil moisture at the head of a land, for six feet depth, was increased from 24.1 to 26.3 percent by a 4-inch average irrigation, while at the tail end the soil moisture was increased from 15.4 to 18.2 percent. In another case on sandy loam the soil moisture at the head end was increased from 14.3 to 21.1 percent and at the tail end from 8.3 to 12.2 percent. In both cases, therefore, the head end had more soil moisture before irrigating than the tail end had after irrigating—a preposterous condition. Inasmuch as the alfalfa near the foot of each land was making excellent growth it follows that the head ends of the land were getting unnecessarily large, wasteful amounts of water. On one of the fields thus tested the average depth of water applied in 1914 was 108.2 inches. Unquestionably, 50 percent of the water thus applied sank to the water table and was wasted. Many similar cases have been observed in alfalfa irrigation and in furrow orchard irrigation, where the quantity of water absorbed at the head ends of the furrows was found to be excessive and wasteful. When these conditions exist, the remedy is less water more rapidly applied, by means of a larger head, or shorter runs, or steeper slopes.

As a result of the downward percolation of irrigation water from canals and from fields, nearly all irrigation projects are encountering difficulties due to waterlogged or seeped lands or to the consequent rise of the alkali. The rising water table is disastrous to crops, causing the death of orchards and alfalfa. On several projects of the U. S. Reclamation Service the necessity for drainage works became urgent before the irrigation systems were fully completed. On one of the projects the water table over nearly 30,000 acres rose from 90 feet average depth to less than five feet depth in six years, and about 6000 acres of the land became a marsh. Over 15 percent of the total area in the arid region irrigated by individuals and corporations in the past has been abandoned on account of waterlogging. Already there are four important sections of the Salt River Valley which need drainage, and an extensive project for lowering the groundwater table over a large area has been financed by a bond issue and has been begun. An important area in the Upper Gila Valley is being reclaimed by a system of clay tile drains. At a school house near Pima the water table has risen to the surface of the ground and the alkali has crept upward in the brick work to the top of the door. Extensive drainage works are being constructed in the Yuma Valley.

Although in general the head ends of the fields are given too much water, yet there are exceptions to this rule. Thus, on clay loam and heavy adobe soils, if the lands have considerable fall, the irrigating water runs quickly to the lower ends of the lands without soaking into the ground more than a few inches. A similar effect is produced by very silty water, such as that of the Gila and Colorado rivers; a silt-blanket is formed at the upper end of the lands and becomes almost impervious. In such cases the remedy is either to divide the head of water over more lands, or to use a flatter gradient, and silt-blankets must be broken up and mulched.

The frequently discussed problems of what slope to give the lands and what head of water is best are interrelated, and involve also a discussion of the length and width of lands, and the character

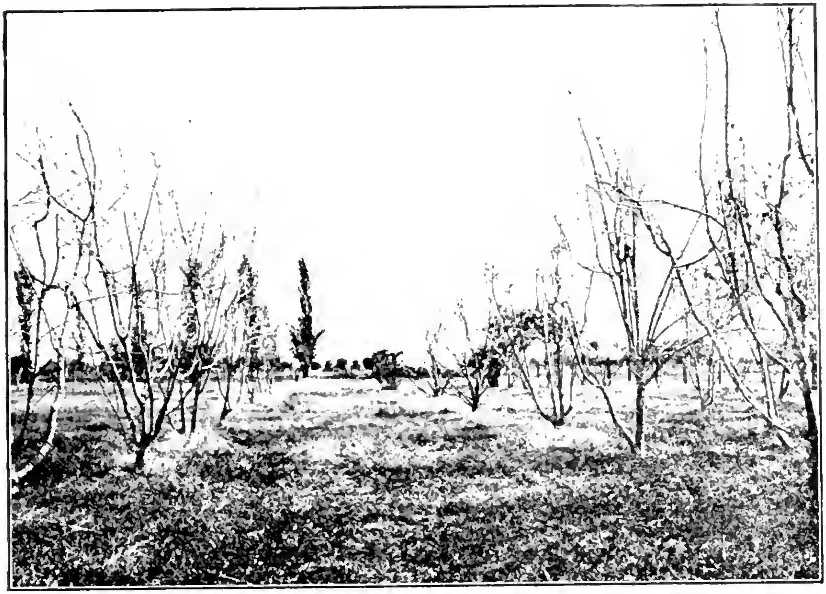

Fig. 5.—A peach orchard in Salt River Valley killed by the rise of the water table. Alfalfa likewise is subject to root rot, due to a rising, or fluctuating shallow, water table.

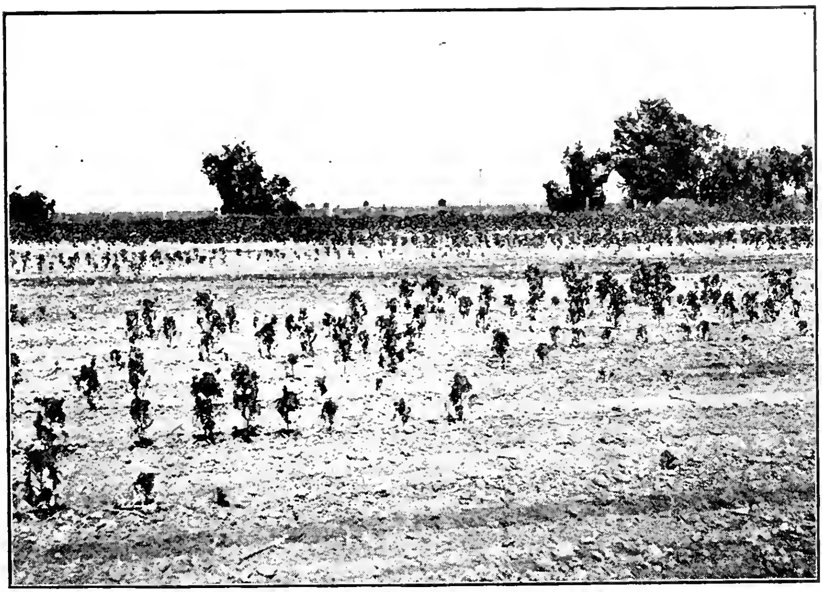

Fig. 6.—A large area in a cotton field, where the seed did not germinate, due to the shallow water table.

of the soil. Any one of these five factors can be taken as a function of the other four factors. The problem is complex and should be solved separately for each crop and for each locality. In some communities the lands are graded level or on a very slight gradient at an additional expense of $20 to $40 per acre. This outlay is of doubtful utility. The lands should be graded down the natural slope or approximately so. Surely any lands with slope from 3 to 40 feet per mile can be laid out and irrigated without material change in the general direction of the slope. The other factors, then, can be determined so as to give the most uniform distribution of water. Thus, on light soil with a grade of 20 feet per mile, where a large head of water is available, perhaps the lands can be laid out 50 feet wide and 880 feet long. If the head of water is small, as from a No. 5 centrifugal pump, then the lands should be not over 30 feet wide and 440 feet long. If, however, the grade is only 10 feet per mile, the lands, perhaps, should be 660 feet long for the large head and 330 feet long for the small head. These values are intended to be suggestive; on shallow soils underlain by caliche the lands can be longer; in some cases lands 1300 feet long are irrigated successfully. For heavy loams the lands can be considerably longer than for sandy soil, and in general the flatter the grade, the shorter should be the runs and the larger should be the head of water.

The final adjustment to obtain an even distribution should be made by varying the head of water in each land or in each furrow. This adjustment should be made last because it is the easiest to make. Recently an irrigator near Mesa complained that the stand of alfalfa was better in the lower part of his field than in the upper part. He wished to regrade the field so as to reduce the fall. But the remedy was much simpler than that. His head of water delivered by the Reclamation Service was 300 miner's inches. By changing his order and obtaining 275 miner's inches he would get a uniform irrigation and uniform crop. Many irrigators have difficulty in getting the water across their land. They require a larger unit head. They should order more water, or concentrate it in fewer lands or furrows, or if this cannot be done without increasing the unit head to a point where it will erode the soil, then the length of run should be reduced.

In cases where the distances between head ditches, especially cement pipe lines, prove to be too great, special methods of irrigating can be used. One method is to open an intermediate head ditch midway between the permanent ditches. The intermediate ditch can be used for the preliminary irrigation and possibly for the first irrigation after planting, after which the ground will become settled and packed and the ditch can be leveled off and planted also. In the case of furrow irrigation, double heads can be run in alternate furrows and subdivided about two-thirds of the way down the field. Later, the intervening furrows can be treated the same way, and thus the proportion of water received by the lower end is increased. Another practice is to turn a large head down each furrow at first, and, when the water reaches the lower end, to re-

Fig. 7.—An alfalfa field in Navajo County, irrigated by the corrugation method. The corrugations are about three inches deep, are spaced at intervals of about thirty inches, and run down the steepest slope. This method is advantageous particularly where the soil is heavy and tends to bake on the surface if flooded.

duce the head to such an amount as will continue just to reach the lower end.

Good control over the division of the stream of water into furrow streams or into separate heads for the lands is essential. Sometimes it is well to divide the stream into two, three, or more parts by means of a division box. Then each part can be more readily divided into furrow-heads. Spiles, made of laths or of narrow boards, are effective in the final distribution. The spiles are set in the ditch bank at the natural ground surface. Sometimes the water is let into forebays and then distributed thru spiles. Wooden spiles are much used in the Northwest; in Arizona, however, spiles should be of some other material than wood, which cannot long withstand the alternate wetting and drying in this climate. Galvanized iron, or clay, or cement tile would be preferable. The division of water from cement pipe lines can be made with ease and accuracy, an important argument for their use.

Frequency of irrigation is a related subject. The smaller the application at each irrigation, the more often the field must be irrigated. Investigations along this line have not been conclusive except for the peculiar set of conditions under which the tests were made. Many a test has been terminated by the untimely death of the young plants when the irrigations were too infrequent. Sandy soils or other soils that are shallow and underdrained by gravel need frequent applications, while a deep, rich loam, with its large capillary storage capacity, will require much fewer applications. Heavy clay soils, in some places, require frequent irrigations because it is impossible to make them take much water at an application, either because of their physical condition or because they are shallow and are underlain by hardpan that is nearly impervious.

There is much diversity in Arizona in methods of laying out fields and irrigating. Farmers in the Yuma Valley prefer to grade the lands level from end to end. Elsewhere in southern Arizona, the general custom is to run water down the slope parallel to the steeper side of the field, the lands varying from 30 to 100 feet in width, and the lengths of runs depending on the slope, soil, crop and the available head of water. In northeastern Arizona the corrugation method is used without borders and the water is run down the steepest slopes. In Yavapai County the Colorado system of flooding from field laterals is used for alfalfa and grain.

Most Arizona soils take water readily. Uniformity of distribution is possible, but requires thought and skill on the part of the irrigator. The use of the proper unit head in each land or in each furrow will prevent waste of water in the upper or lower end of the field and will give an even appearance to the field of grain or other crop.

WILFUL OR CARELESS WASTE

This loss includes allowing excess water from the lower end of a field to run onto unused land or, as sometimes happens, into the highways. It is due sometimes to the absence of a good tail border, sometimes to gopher holes, sometimes to a sleepy or forgetful irrigator. On some irrigation projects the loss has been proved to exceed 10 percent of the water applied. In Arizona, however, and especially in the Salt River Valley, there is a strong public sentiment against wilful or careless waste, and the total loss of this character is comparatively small. The method of measuring the water to each user and charging him for just what he uses has made the water user more diligent in distributing the water over his own fields and somewhat loath to turn it back into the system or to let it run to waste. Would that he might take an equal interest in preventing the water from escaping downward beyond his control, or upward by evaporation from a crusted soil.

In the grading of a field the lower 40 or 50 feet should be graded

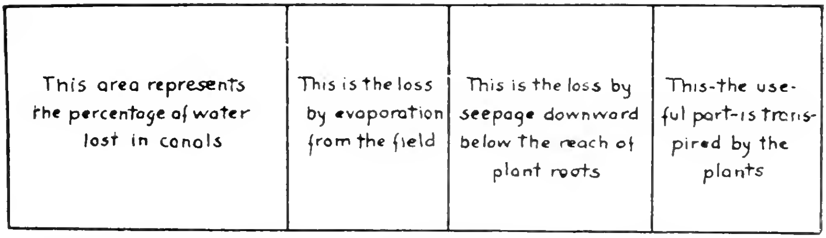

Fig. 8.—What becomes of the irrigating water supplies diverted from the streams is shown by the diagram. The area of each rectangle is proportional approximately to the percentage of the total water supply lost or utilized as indicated.

level in the direction of the irrigation. The lands should terminate in one common land running at right angles across the field, or the furrows should be connected so that the furrow streams will be equalized at their lower ends. Very few irrigators are able to gauge the irrigation and shut off the water from each land at just the right time; invariably some lands receive too much and frequently the water overflows the levee at the lower end of the land. A common crosswise land prevents this loss and usually will have the heaviest alfalfa.

EFFICIENCY OF IRRIGATION

Every progressive farmer can easily investigate the general efficiency of his irrigation system. In the first place, he should set a weir or other measuring device and keep a record of the amount of water applied to each field. His records will serve as a basis for comparisons. There are several simple means by which he can ascertain the nature and extent of his water losses. Some of the most useful are the following.

1. He can note with a watch the number of minutes during which the head end and the center and the tail end of the lands or furrows get water.

2. Pits dug to a depth of six feet with a posthole digger at different points in a field will show whether or not the irrigation is uniform, and whether the soil is wet amply or too much. The pits should be dug about 12 hours after the irrigation. In lieu of the pits, a sharp stick can be thrust into the ground at various points and much can be learned thereby of the penetration of the water. The Southwest Cotton Company uses a pointed metal rod with a groove one foot long in the side near the point. By driving the rod to any depth, rotating it there, and then withdrawing it, a sample of the soil at that depth is obtained. A soil augur is a convenient and useful tool; every farmer can well afford to own one.

3. Observation of the water level in nearby wells may indicate whether the groundwater plane is rising due to over-irrigation.

4. Does the soil surface bake? If so, there must be a heavy loss of water by evaporation. A farmer can easily demonstrate to his own satisfaction how far evaporation losses can be reduced by cultivation.

Ditch losses are best measured by setting weir boards and measuring the quantity of water at two points.

The efficiency of irrigation can be defined as the ratio of that portion of the water actually utilized by the crop to the total quantity applied to the land. It is the farmer's province to endeavor to make this ratio as high as possible, and thus to decrease the amount of water needed for his ranch.

The courts of Arizona have excellent opportunities in their decisions in cases establishing water rights to limit the diversion and applications of irrigating water to the real needs of crops, plus a reasonable allowance for water losses which it is impractical to prevent. Usually the courts have established the duty of water much lower than it should be. The Kent decree in Maricopa County and the Lockwood decree in Pinal County fix the limit of application at 5.5 acre-feet per acre annually, the water to be measured at the land. The records of the Salt River Valley Water Users Association show that the average amount of water bought and paid for by farmers during the past six years has varied from 2.36 acre-feet per acre to 3.67 acre-feet. The decree of 1905, adjudicating water rights of Graham County, fixes the duty of water at "one-half miner's inches continuous flow to the acre." This is equivalent to 9 acre-feet per acre annually. Under the license of

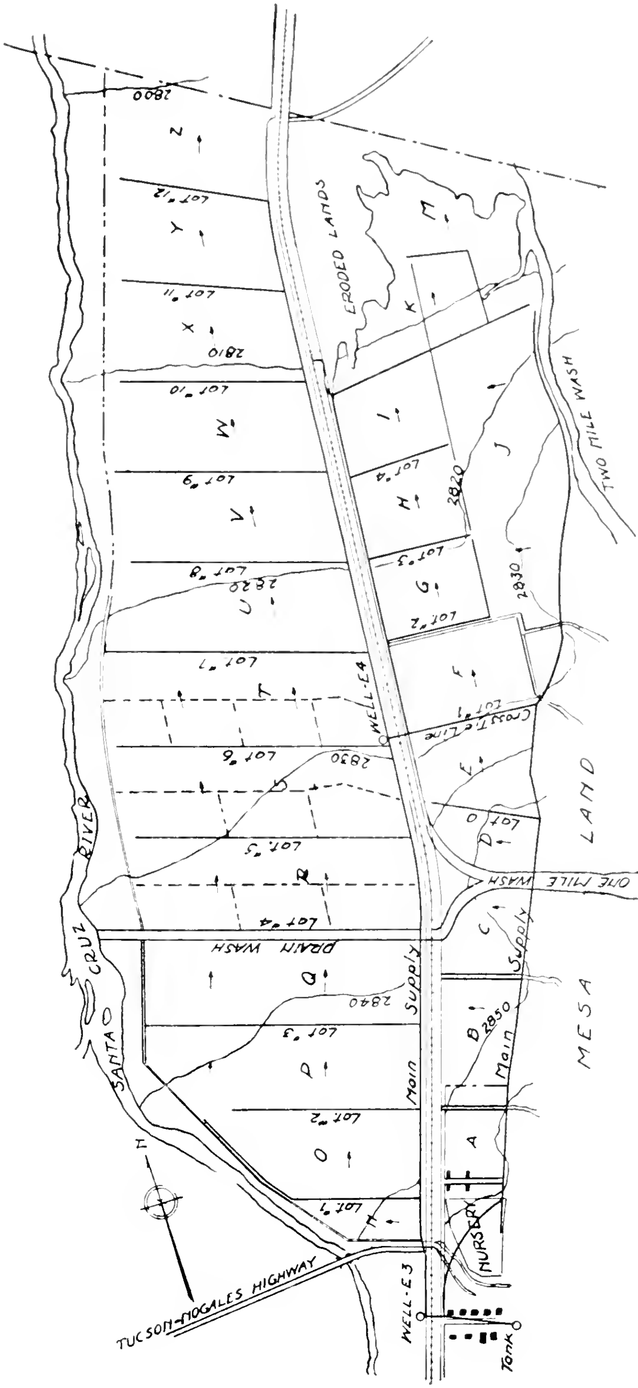

Fig. 9.—Layout of cement-pipe distribution system for the northeast unit of Agricultural Products Corporation ranch near Tucson. The pipe sizes are 12, 14, and 16-inch. The total length of pipe lines in this unit is 8.35 miles and the area irrigated 994 acres. The contours show elevations above sea level. The dotted lines show temporary ditches for use on a newly-graded field. With this layout the cost of grading was reduced to a minimum and the irrigation is made very efficient.

the decree, many farmers have over-irrigated their lands and some localities have become water-logged and alkalied. A temporary decree in Apache County in 1917 established the duty of water at St. Johns at one cubic foot per second for 75 acres, at Eagar at one second-foot for 100 acres, and at Greer at one second-foot for 150 acres. The distinction between the conditions at different altitudes is logical and is an important step forward. In 1918 the decree was changed so as to allow one second-foot per 90 acres at St. Johns, 110 acres at Eager and 180 acres at Greer. Inasmuch as rotation of water is practiced thruout Arizona, the duty of water should be stated in acre-feet per acre per year or a monthly schedule can be decreed for the limiting use of water.

Irrigation districts and cooperative companies can influence the use and waste of water under their canals by their method of charging for water. The old flat rate, a fixed amount per acre per year, was a constant challenge to each irrigator to use as much water as he could obtain. It was as unreasonable as a proposition to buy the family flour supply at a fixed sum per annum. The water should be measured to each water user and each user should pay on the basis of the amount which he uses. In the Salt River Valley the change from the old flat rate to the new basis in 1912 resulted immediately in a decreased use of water; what remains to be done is the installation of weirs or other measuring devices so that the measurements can be made more accurately than they are at present.

With the exception of some projects which will require Federal aid, surface water supplies in Arizona are quite thoroly appropriated, and the limit of development of groundwater supplies will be reached in a few years. But the water supplies must be made to serve more land and this must be brought about thru a reduction of the water losses. No longer is it considered justifiable for appropriators to divert and use excessive amounts of water even tho they may have been doing so for many years. The modern viewpoint of courts in the other arid states is that no man has a right to take more water than he can put to beneficial use together with a reasonable allowance for conveyance and other losses. But each appropriator is expected to make such expenditures on his ditches and in the preparation of his land and in his care of the land that his losses will be small and the general water supply thereby conserved. As Judge J. H. Kibbey said in his decree covering water rights in the Salt River Valley, "No man has a right to waste a drop of water."

The University of Arizona

College of Agriculture

Agricultural Experiment Station

Bulletin No. 89

The Gateway to the Yuma Mesa

THE YUMA MESA

By A. E. Vinson, F. J. Crider and
G. E. Thompson

Tucson, Arizona, August 15, 1919

Agricultural Experiment Station

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ILLUSTRATIONS

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Three-year-old Washington Navel orange at Mulford Winsor's residence on the Yuma Mesa

THE YUMA MESA

By A. E. Vinson, F. J. Crider, and G. E. Thompson

GENERAL INFORMATION

For many years the irrigation of the Yuma Mesa with the water of the Colorado River has been discussed. Various attempts by individuals and companies to accomplish this end have been undertaken with more or less success; and investigations made by engineers of the U. S. Reclamation Service have shown the reclamation of large tracts on the Mesa to be possible at reasonable cost. It has been realized, however, that the determining factor in the establishment of a permanent project of this nature has been whether or not the agricultural possibilities are such as to warrant the necessary investment. As early as 1891 Mr. C. B. Collingwood, at the request of Mr. H. W. Blaisdell, investigated the character of the soil of this Mesa and made a special study of the amount and composition of the silt carried by the Colorado River. These results were published as Bulletin No. 6 of the Arizona Agricultural Experiment Station. Aside from the general soil survey of the Yuma district by J. Garnet Holmes, of the U. S. Department of Agriculture, Bureau of Soils, in 1903, and minor observations made in reports of the Reclamation Service engineers, nothing further bearing on this phase of the project has been attempted. At the request of the Reclamation Service, this commission was appointed by Dr. R. B. von KleinSmid, President of the University of Arizona, to make such investigation and report upon the agricultural possibilities of the Yuma Mesa with special reference to the production of citrus and other commercial fruit crops. This commission was composed of the agricultural chemist, the horticulturist, and the agronomist of the University of Arizona, College of Agriculture, who were already more or less conversant with conditions on the Mesa, having made previous observations there in connection with their regular work.

After thoro consideration of all available information the commission visited the tract again early in November, 1918, to make further investigations. In this work they were generously assisted by Mr. W. W. Schlecht, Project Manager of the Yuma Reclamation Project; Mr. J. W. Longstreth, Agricultural Agent of Yuma County; Mr Geo. M. Hill, a citrus grower, and other persons having knowledge of conditions on the Mesa. Careful studies were made of the citrus plantings and of other crops and vegetation now growing there, and inquiries were made concerning the past history of these crops, particularly the old citrus grove known as the Blaisdell Orchard. Units A and B of the project, as surveyed by the Reclamation Service, were inspected by several automobile and foot trips. Soil samples representative of the different soil phases were taken for chemical and mechanical analysis, and for physical tests and pot cultures. Fruit samples were obtained for physical and chemical analysis, and for comparison with similar fruits from Florida and California.

TOPOGRAPHY OF THE YUMA MESA

The Yuma Mesa rises abruptly about 100 feet above the valley of the Colorado River and stretches to the mountains on the east, sloping gently southward into Mexico. Depressions, commonly spoken of as pot holes, are found at a few places. The entire region, probably, was once the floor of the upper end of the Gulf of California, which accounts for the prevalence of sands. Frequent draws lead from the mesa to the valley below making the margin quite rough. The great body of the Mesa, however, is level and may be brought under cultivation with little expense for grading creosote bushes. A few dunes, too large for leveling, occur, but other than the leveling of small sand dunes, collected about the

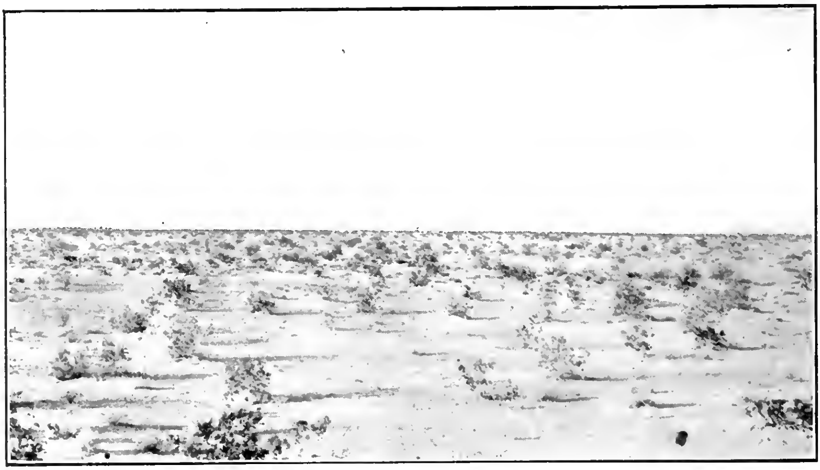


Fig. 2.—General view on the Yuma Mesa

these are not extensive and, judging from the old shrubbery on their tops, show little evidence of shifting. While much of the tract is not easily accessible on account of sands, good road building material is easily available. The northern point of the Mesa extends well into the city of Yuma and is the site of many well-kept suburban homes, which have afforded additional evidence of the capacity of the soil to support a good growth when water is applied.

The city of Yuma, situated at the northern end of the project, is on the main line of the Southern Pacific Railroad, insuring prompt shipment, quick delivery, and lessened expense in marketing crops produced. When it is considered that many commercial fruit districts are located on branch roads, this advantage becomes apparent.

CLIMATE OF THE YUMA MESA

Climate more than anything else has been the determining factor in the location and development of the citrus districts of the world. The physical nature of the soil may be modified, plant food supplied, and water problems solved, but unless a region has the natural and fundamental requisites of climate, it cannot become a commercial citrus producing center. In this particular the Yuma Mesa qualifies preeminently. Its climate is unique among the citrus districts of the country in that no other area in North America has occuring together the smallest rainfall, lowest relative humidity, and greatest percentage of sunshine—a combination which makes possible the production of fruit of the finest quality, the highest color, and with the earliest ripening period. A product with this distinctive excellence wins favor, extra high prices, and a permanent place in the market. Furthermore, the fruit can be allowed to remain on the trees until it attains maturity without fear of competition. The history of plantings on the Mesa shows that the Navel crop can be placed on the market in November and December, and at this time is of such perfect quality as to command a price far in excess of oranges from any other district. Grapefruit at this time also has extremely superior quality over that found on the market from other citrus districts, which insures the highest selling price.

Another climatic feature of paramount importance found on the Yuma Mesa is immunity from injurious frost. The tract is composed for the most part of a broad table land with a gentle slope towards the edge of the Mesa, which breaks up into numerous wide draws, affording excellent air drainage to the valley below. Coupled with this ideal topography there is an almost constant circulation of air. Observations on the Mesa covering a period of twenty-six years (the age of the oldest citrus planting in this district) with accurate weather records covering the greater portion of this time, show no serious injury from cold. In the disastrous freeze of 1913 when the temperature in the Southwest was lower than had been known for a period of sixty years, lemon trees on the Mesa were only slightly affected, the thermometer registering from three to eight degrees higher than in the citrus districts of California. It can, therefore, be stated most positively that the frost hazard, a matter which should receive first consideration in the selection of a location for citrus growing, is a negligible factor

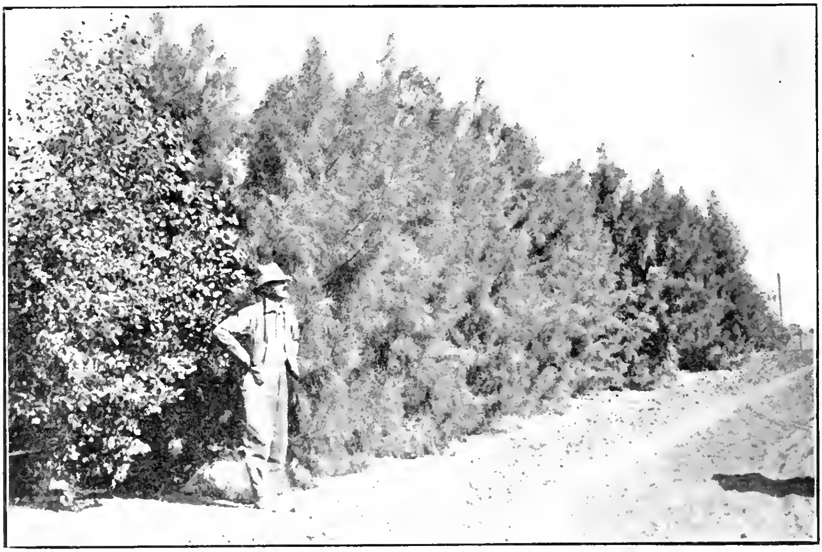


Fig. 3.—Windbreak of evergreen tamarisk on the Yuma Mesa, 18 months from planting

in this district, and should give the prospective citrus grower no concern. In view of the great expense involved in the use of smudge pots, as practiced in some of our older citrus regions, immunity from frost injury is an item of extreme economic importance.

Weather records kept at the Blaisdell Orchard from October, 1893, to June. 1987, are given in Bulletin 58 of the Arizona Agricultural Experiment Station and are reproduced here in Table I.

TABLE I—WEEKLY MAXIMUM AND MINIMUM TEMPERATURES TAKEN AT THE BLAISDELL ORCHARD

1893	Max.	Min.
Oct. 30	80	50
Nov. 6	91	48
Nov. 13	85	45
Nov. 20	79	40
Nov. 27	73	34
Dec. 4	79	41
Dec. 11	83	44
Dec. 18	81	44
Dec. 25	76	42
1894		
Jan. 1	74	38
Jan. 8	69	32
Jan. 15	65	30
Jan. 22	71	33
Jan. 29	73	30
Feb. 5	74	37
Feb. 12	71	32
Feb. 19	72	29
Feb. 26	76	31
Mar. 5	82	33
Mar. 12	78	36
Mar. 19	95	46
Mar. 26	84	34
Apr. 2	96	49
Apr. 9	95	50
Apr. 16	95	54
Apr. 23	96	45
Apr. 30	101	55
May 7	95	45
May 14	105	57
May 21	100	52
May 28	100	57
June 4	100	59
June 11	96	53
June 17	101	60
June 25	102	61
July 2	105	61
July 9	115	67
July 16	112	78
July 23	107	71
July 30	115	76
Aug. 6	111	77
Aug. 13	101	70
Aug. 20	107	68
Aug. 27	109	75
Sept. 3	106	69
Sept. 10	98	64
Sept. 17	103	60
Sept. 24	108	68
Oct. 1	110	68
Oct. 8	101	58
Oct. 15	99	62
Oct. 22	99	58
Oct. 28	91	50
Nov. 5	91	53
Nov. 12	91	46
Nov. 19	84	42
Nov. 27	85	47
Dec. 3	82	36
Dec. 10	72	37
Dec. 17	65	37
Dec. 24	71	41
Dec. 31	66	46
1895		
Jan. 6	72	31
Jan. 13	81	38
Jan. 21	73	41
Jan. 28	65	33
Feb. 4	71	35
Feb. 11	77	39
Feb. 18	76	36
Feb. 25	84	44
Mar. 4	86	44
Mar. 11	85	45
Mar. 18	79	38
Mar. 25	90	41
Apr. 1	97	42
Apr. 8	90	41
Apr. 15	101	47
Apr. 22	96	50
Apr. 29	94	51
May 6	100	50
May 13	108	62
May 20	102	58
May 27	98	55
June 3	95	49
June 10	104	60
June 17	105	60
June 24	109	60
July 1	110	65
July 8	107	65
July 15	107	67
July 22	111	67
July 29	108	70
Aug. 5	113	68
Aug. 12	112	71
Aug. 19	110	73
Aug. 26	106	73
Sept. 2	103	60
Sept. 9	105	59
Sept. 16	106	64
Sept. 23	104	54
Sept. 30	104	58
Oct. 7	96	54
Oct. 14	97	56
Oct. 21	93	52
Oct. 28	86	49
Nov. 4	93	48
Nov. 11	79	40
Nov. 18	87	40
Nov. 23	87	32
Dec. 2	77	37

TABLE I—WEEKLY MAXIMUM AND MINIMUM TEMPERATURES TAKEN AT THE BLAISDELL ORCHARD—*Continued*

1895	Max.	Min.
Dec. 9	76	39
Dec. 16	82	43
Dec. 23	65	33
Dec. 30	65	26
1896		
. . . .		
. . . .		
Feb. 10	68	38
Feb. 17	72	37
Feb. 24	85	42
Mar. 2	83	44
Mar. 9	92	45
Mar. 16	80	35
Mar. 23	88	48
Mar. 30	93	50
Apr. 6	101	47
Apr. 13	87	47
Apr. 20	90	40
Apr. 27	87	42
May 4	87	47
May 11	91	46
May 18	92	50
May 25	97	58
June 8	105	57
June 14	100	61
June 22	115	67
June 29	116	63
July 6	105	64
July 13	104	53
July 20	108	80
July 27	103	73
Aug. 4	102	69
Aug. 11	102	67
Aug. 17	105	69
Aug. 24	111	72
Aug. 31	101	71
Sept. 7	107	69
Sept. 14	104	70
Sept. 21	99	68
Sept. 28	105	58

1896	Max.	Min.
Oct. 5	100	52
Oct. 12	98	54
Oct. 19	99	59
Oct. 26	90	57
Nov. 2	88	54
Nov. 9	80	45
Nov. 16	76	38
Nov. 23	82	52
Nov. 30	84	45
Dec. 7	70	36
Dec. 14	77	38
Dec. 21	75	40
Dec. 28	71	40
1897		
Jan. 4	74	41
Jan. 11	61	38
Jan. 18	70	40
Jan. 25	60	38
Feb. 1	72	40
Feb. 8	70	42
Feb. 15	72	42
Feb. 22	69	37
May 1	73	36
May 8	80	35
May 13	72	35
May 20	72	37
May 27	82	43
Apr. 3	97	47
Apr. 10	94	56
Apr. 17	82	44
Apr. 24	92	47
May 1	97	50
May 8	97	49
May 15	94	54
May 22	101	58
May 29	99	53
June 5	109	62
June 11	106	60
June 18	105	56

From May, 1916, to the present time detailed weather records have been kept on the Mesa by Mrs. Geo. M. Hill. A summary of these records is given in Table II.

The effects of summer heat and strong winds are items that should receive consideration in establishing a citrus planting; but they are not matters that would prove detrimental to citrus growing in this particular locality. While the heat is quite intense during portions of the summer, proper methods of pruning obviate any serious difficulty from this quarter. Injury from winds has been observed to occur only on the outer edges of the orchards on

TABLE II—MAXIMUM, MINIMUM AND AVERAGE MONTHLY TEMPERATURE AT THE GEO. M. HILL ORCHARD

Month	5 A. M.		Noon		3 P. M.		6 P. M.		5 A.M.	Noon	3 P.M.	6 P.M.
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Avg.	Avg.	Avg.	Avg.
1916—May	92	55	98	70	102	74	98	70	67	90	93	89
June	82	65	108	88	116	92	112	84	71	100	104	95
July	88	72	106	93	112	82	106	84	81	102	104	99
Aug.	88	70	107	94	108	98	103	90	80	100	103	97
Sept.	84	62	106	88	108	88	102	82	73	96	99	90
Oct.	66	50	94	72	94	74	84	70	57	80	83	72
Nov.	56	38	86	53	90	55	79	48	49	70	76	65
Dec.	52	28	73	50	76	52	68	43	39	62	65	54
Year	76	55	97	67	101	77	94	71	65	88	91	83
1917—Jan.	53	32	76	44	78	44	59	44	40	61	62	51
Feb.	58	36	84	60	86	62	67	52	47	74	75	61
Mar.	76	36	92	60	102	63	76	52	45	74	74	62
Apr.	70	40	95	53	93	70	90	58	53	81	88	72
May	68	52	95	70	98	74	90	68	60	84	90	79
June	84	62	110	91	120	96	110	88	76	103	107	103
July	90	80	110	82	113	96	108	84	85	101	104	98
Aug.	88	68	106	94	110	100	104	94	81	102	105	98
Sept.	86	62	104	88	108	88	100	80	78	99	101	92
Oct.	76	54	103	80	108	80	94	76	66	92	94	86
Nov.	60	40	86	74	92	76	75	60	52	80	82	68
Dec.	58	36	84	64	84	68	68	52	44	75	76	69
Year	72	50	95	65	99	76	87	67	61	87	88	78
1918—Jan.	50	33	82	60	84	56	62	50	41	71	70	59
Feb.	58	32	82	62	92	62	66	52	44	71	74	60
Mar.	62	42	90	66	93	66	84	60	53	80	80	73
Apr.	68	44	100	74	108	78	93	70	54	90	99	79
May	72	49	101	74	105	78	82	70	57	93	96	78
June	86	60	110	100	122	102	100	84	75	105	102	94
July	86	70	110	94	112	98	100	90	81	103	106	95
Aug.	86	66	113	88	118	86	104	76	77	98	101	88
Sept.	83	60	103	88	106	95	96	78	73	97	100	87
Oct.	78	46	97	80	100	78	88	60	62	88	90	72
Nov.	55	44			82	56	64	52	45		72	63
Dec.	66	38	75	68	78	68	52	50	46	71	73	51
Year	71	49	97	78	100	70	81	66	59	88	90	75

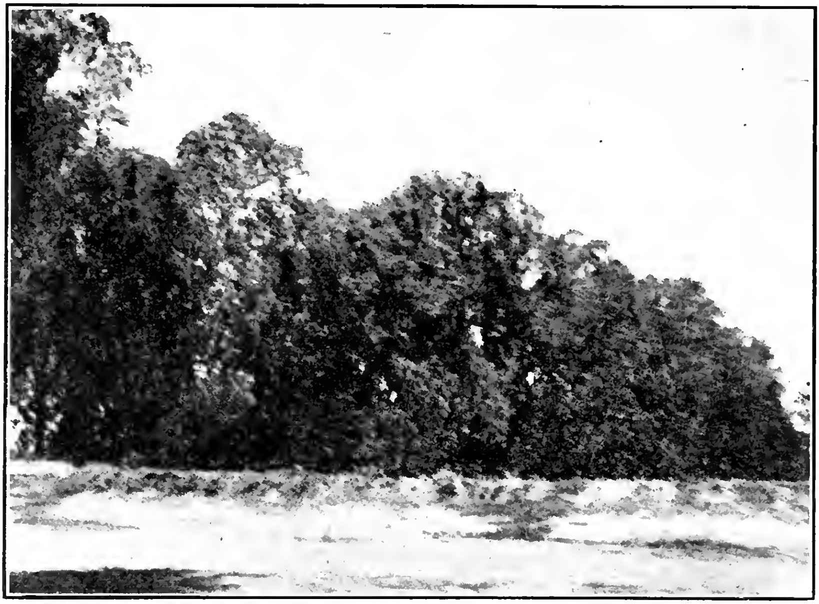


Fig. 4.—Windbreak of Eucalyptus on the Blaisdell citrus orchard, 26 years from planting

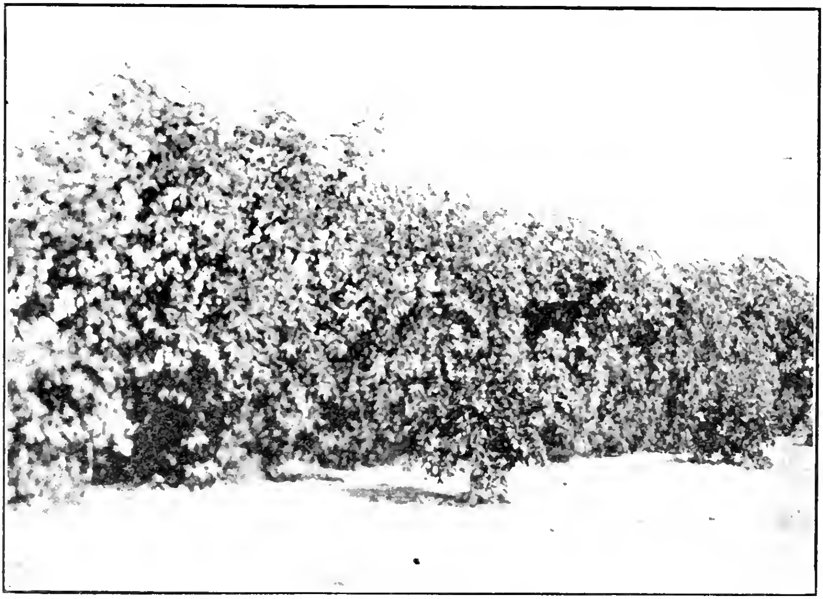


Fig. 5.—Castor beans used as a temporary windbreak in a young citrus orchard on the Yuma Mesa

the north and west sides, and is easily remedied by planting windbreaks. Two plants that have been found particularly well adapted to this section for the purpose of windbreaks are eucalyptus *(Eucalyptus rudis)* and the evergreen species of tamarisk *(Tamarisk articulata)*. The latter is very ornamental and if generally used would form a most attractive landscape feature of the district. Furthermore, it is easily propagated from cuttings, and on the Yuma Mesa has made a growth of 25 feet in 18 months, becoming sufficiently large to serve as a windbreak in less than two years from the time of planting. See Figure 3.

SOIL OF THE YUMA MESA

The soil of the Yuma Mesa has been classified by the U. S. Department of Agriculture Bureau of Soils as Yuma Sand. It is probably of marine origin and consequently is quite uniform over a large area. In common with marine soils it does not contain a large total amount of plant food elements. The abrupt edges of the Mesa left by the erosion of the river valley show some stratification. Bands of shale-like clay of varying thickness may be seen where vertical sections are exposed. It is not definitely established to what extent these clay bands reach out under the Mesa. At several points clay strata reach the surface, but dip off rapidly again beyond the reach of an ordinary spade. Drilled wells have encountered clay in several locations. The clay strata are often strongly alkiline. With the exception of these bands, the sands are deep and well drained.

The most striking character of the Yuma Sand is its highly calcareous nature; even the drifting sands and dune sands effervesce strongly with acid. The lime does not exist as grains of calcium carbonate, excepting to a small extent in the silt and clay separates, but as a more or less uniform incrustation on all the soil particles. This incrustation remains on the particles thru the process of separation in mechanical analysis, and all separates from the finest to the coarsest effervesce with acids. The incrusted particles give the soil a characteristic appearance, which at once suggests the name "tarnished sand." The lime content varies in the vertical section, and usually a band of cemented soil a foot or more in thickness is found at or near the surface. The surface appearance of the Yuma Mesa is that of gravelly and sandy streaks and patches alternating. By following the gravelly areas a light automobile can be driven over the Mesa. Investigation shows that the gravelly areas in a general way mark the places where the lime cemented strata come near the surface. A vertical section thru one of these lime cemented strata shows a mottled or marble-like appearance, due to the cutting of limy concretions varying in size from a wheat grain to a walnut. In places the lime becomes so dominant as to form semi-chalky layers. These are hard when dry, but soft as clay when wet. An explanation of the surprising fertility of these seemingly barren sands may be found in the distribution of the calcareous incrustation over the surface of the soil grains. This probably averages 8 or 10 percent of the total weight of the soil. Associated with the calcareous incrustation occurs a considerable part of the phosphorus and potassium found in the soil, which would account for the ready availability of the mineral plant foods present.

CHEMICAL COMPOSITION OF THE YUMA SAND

In Bulletin No. 6 of the Arizona Agricultural Experiment Station, Collingwood reports the analysis of a sample of this soil taken from Blaisdell Heights and compares it with an analysis of a sample from the Fruitdale Tract, Fresno, California, made by Dr. Hilgard. The analyses are comparable, having been made from the same portion of the soil by the same methods of analysis. In each case the "fine earth" passing 0.5 m. m. sieve was used, and solution was effected by the same strength (1.115-sp. gr.) hydrochloric acid. Analyses are given in Table III.

TABLE III—ANALYSIS OF FRESNO AND YUMA HEIGHTS SOIL

	Fruitvale Tract Fresno, Cal.	Blaisdell Heights Yuma, Ariz.
	%	%
Insoluble matter	78.91	84.30
Potash	0.82	0.64
Soda	0.29	0.32
Lime	1.14	4.57
Magnesia	1.58	0.51
Oxide of iron	7.51	1.07
Alumina	6.30	3.28
Phosphoric acid	0.07	0.07
Sulphuric acid	0.01	0.01
Carbonic acid		3.73
Water and organic matter	3.28	1.50

The Fruitdale soil showed more acid soluble constituents, due, however, to large amounts of iron and alumina; whereas the Yuma Mesa soil showed very much more calcium carbonate. In the Yuma soil the sum of the lime and carbonic acid corresponds almost exactly to the theoretical amount of calcium carbonate corresponding to the carbonic acid. This indicates that practically all the lime found in the acid soluble portion of the soil existed as calcium carbonate. The acid soluble phosphoric acid content of the two soils was identical, and the potash content corresponded quite closely. The inference would be that the Yuma soil was the equal if not the superior of the Fresno soil due to the association of its plant food elements with well distributed calcium carbonate rather than with iron and alumina.

For the investigation which forms the basis of this report two series of samples were taken: one set of ten for chemical analysis and another of eight large samples for pot cultures and physical tests. A few other samples for special determinations were also taken. The chemical analysis was restricted to the determination of acid insoluble material, of total potassium and phosphorus, and 1.115 sp. gr. hydrochloric acid and 2 percent citric acid soluble potassium and phosphorus. The results are reported in Table IV.

6915. Small area of shale-like clay soil adjoining Hill's nursery; possibly the same as the clay strata seen on the edge of the mesa.

6917. Surface foot of sandy soil from center of Sec. 9; this layer did not show lime concretions.

6917a. Second foot in same hole containing abundant lime concretions.

6918. Average of first three feet avoiding surface six inches of wind blown sand; soil homogeneous to bottom of hole; south side of N. W. corner of Sec. 15 near the edge of a pot hole; Project A.

6919. Tarnished sand from south of center of east of S. W. ¼ of Sec. 4 at depth of three feet. Surface was calcareous cemented sand; typical of the tarnished sands that make up the greater part of the Mesa soil.

6920. Surface cemented sand from same hole as 6919. Fifty feet away this same cemented sand occurred at depth of two feet; sometimes spoken of as hardpan, but disintegrates immediately when moistened.

6922. First foot from a little N. W. of the S. E. corner of the proposed experiment station tract. A small amount of lime was seen near bottom of the hole at about three feet depth.

6923. Third foot from south of middle of Sec. 7, Project B. The sand at this depth appeared slightly less tarnished than the first foot, which was the typical tarnished sand of the Mesa.

6924. Second foot from same hole, containing some lime concretions.

6925. First foot same hole; typical of a large tract which shows less variation than the north end of the Mesa in Project A.

The material represented in 6915 is not important, since it was noted at or near the surface in very small areas. It is a highly calcareous alkaline clay which accounts for the low content of insoluble matter. It is probably the most abundantly supplied with mineral plant food of any soil on the Mesa, and when sufficient water is available can be leached free from injurious amounts of alkali. It is omitted in averaging the composition of the Mesa soils.

TABLE IV—COMPOSITION OF YUMA MESA SOIL—ANALYSIS BY C. N. CATLIN

Sample	Acid insoluble	Total K_2O	1.115 sp. gr. HCl soluble K_2O		Citric acid soluble K_2O	Total P_2O_5	1.115 HCl soluble P_2O_5		Citric acid soluble P_2O_5
	%	%	%	*Lb. K in 2,000,000*	%	%	%	*Lb. P in 2,000,000*	%
6915	57.105	1.68	.589	9780	.0155	.185	.115	1004	.051
6917	84.31	1.78	.166	2760	.0096	.062	.049	419	.018
6917a	86.16	1.82	.178	2960	.0054	.108	.086	751	.022
6918	98.98	1.66	.168	2870	.0093	.108	.086	751	.026
6919	81.08	1.28	.213	3540	.0051	.170	.104	908	.024
6920	79.12	1.71	.266	4420	.0101	.170	.088	768	.017
6922	92.46	1.63	.135	2240	.0103	.092	.07	611	.023
6923	91.16	1.65	.282	4680	.0074	.092	.07	611	.029
6924	88.63	1.55	.116	1920	.0076	.108	.17	699	.030
6925	90.70	1.44	.119	1918	.0107	.185	.07	611	.031

The remaining samples, which are all tarnished sands varying chiefly in their content of calcium carbonate, compare favorably with the medium and less fertile soils of the United States with regard to phosphorus, but are very deficient in potash—a matter that need give little concern since the Colorado water, as will be shown, carries large amounts of water soluble potash. The average acid soluble phosphorus in 2,000,000 pounds of the Mesa tarnished sand as shown by nine analyses is 681 pounds, as compared with 875 pounds shown by 262 samples of surface soils of California according to Hilgard (Hopkins' Soil Fertility, p. 102). The average of the Yuma Mesa set is lowered much by a single sample (6917) which contains only 419 pounds. The richest sand from the Mesa contained 908 pounds. While the acid soluble phosphorus content is not high, the citric acid soluble phosphorus shows a large part of it readily available. An average of nearly one-third of the strong hydrochloric acid soluble phosphorus is also soluble in 2 percent citric acid, whereas it has been estimated roughly that in humid regions usually only one percent annually of the total phosphorus could be rendered available by practical cultural means. In a few cases only about one-half of the total phosphorus dissolved in 1.115 sp. gr. hydrochloric acid. The high apparent availability of the phosphorus agrees with the rapid growth made by vegetation when sufficient water is supplied. This condition would be expected in an almost rainless region where slow weathering has gone on for ages with no leaching.

For comparison the average composition of the very sandy orange soils of Florida is given in Table V.

TABLE V.—AVERAGE COMPOSITION OF FLORIDA SANDY ORANGE SOILS

	Percent	Percent of the element	Elements in 2,000,000 lb. soil
			Pounds
Silica	93.82		
Phosphoric acid	.085	.037	740
Potash	.039	.032	640
Soda	.107		
Lime	.295		
Magnesia	.129		
Iron and Alumina	.760		
Nitrogen	.054		
Humus	.64		
Loss on ignition	3.11		

While the Yuma Mesa sand is quite similar to the Florida sand with regard to phosphorus, it probably has a decided advantage with regard to easy availability of the phosphorus, since the Florida soil occurs in a region of abundant rainfall, and the easily available phosphorus would be leached out. The potash content of the Yuma sand is several times that of the Florida sand.

FERTILITY OF THE YUMA SAND

The average plant food content of citrus fruits is nitrogen .118 percent, phosphoric acid .054 percent, and potash .293 percent. If we take 400 boxes of about 70 pounds each as a large yield per acre, there will be required for the annual crop 33 pounds of nitrogen, 6.7 pounds of phosphorus and 68.1 pounds of potassium. A report by G. Harold Powell, Secretary of the Citrus Protective League of California, based on the practice of 271 ranches containing 8095.9 acres, showed the expenditure of $44.20 per acre annually for chemical fertilizers and barnyard manure. Florida growers also find heavy fertilization profitable. The waters of the Colorado will in large part furnish the fertilizers which prove so expensive in other citrus districts.

Table VI, showing the plant food carried in the waters of the Colorado during 1900, has been compiled from Bulletin 44 of the Arizona Agricultural Experiment Station, The River-Irrigating Water of Arizona, by R. H. Forbes.

TABLE VI—COMPOSITION OF THE WATER OF THE COLORADO RIVER

	Parts per 100,000	Pounds per acre-foot
Nitrogen in silt and water	Average .274	7.45
Nitrogen as nitrates	Average .079	2.15
Potassium soluble	Average 1.51	41.07
Phosphorus in sediment		5.56

Since not less than 2½ acre-feet of water would be applied annually, the minimum amount of plant food added from this source would be: Total nitrogen 18.6 pounds, of which 5.4 pounds would be nitrate nitrogen; potassium 102.7 pounds, phosphorus 12.9 pounds. A comparison of the crop composition with the plant food content of the irrigating water shows the potassium requirement to be supplied in excess. The nitrogen requirement is about one-half covered, but it should be mentioned in this connection that much nitrogen would be supplied by leguminous cover crops which should be grown to raise the humus content of the soil and improve its physical condition. The phosphorus requirement appears to be more than covered by that carried in the silt but this figure is somewhat uncertain for these reasons. The analysis

Fig. 6.—Alfalfa used as a cover crop in the Blaisdell citrus orchard

Fig. 7.—Cover crop of cow peas planted in rows in Hill's citrus orchard on Yuma Mesa. The land between the trees had received no water or cultivation up to the time the trees were planted

shows the silt in the river water itself and not the residue delivered to the land; this amount is extremely variable thru the year and the average found might vary widely from that actually delivered. The phosphorus content of the sediment would probably be very slowly available. Based on these considerations, fertilizer needs on the Mesa would probably be found covered best by light applications of acid phosphate, stable manure and leguminous cover crops—a relatively inexpensive practice when compared with that in use in other citrus districts. See Figure 6 and 7 for cover crop.

ALKALI

Small areas of alkali occur in the Yuma Mesa, but are neither so extensive nor will they be so difficult to handle as in the valley. These areas are not readily detected due to the shifting surface sands, but it is said they may be traced immediately after a rain. Where alkali does occur it is probably related to the heavier soil phases, such as the clay bands. Collingwood found the following amounts of alkali in the clay seams exposed in the railroad cut at Yuma:

TABLE VII—ALKALI IN CLAY SEAMS UNDER YUMA MESA

Sample	Soluble solids	Sodium chloride	Sodium sulphate	Sodium carbonate
	%	%	%	%
4 ft. beneath surface...........	0.25	0.15	0.10	trace
8 ft. beneath surface...........	0.75	0.60	0.15	trace

The analyses given in Table VIII show the nature and amount of alkali in a few spots that show surface indications of alkali.

TABLE VIII—ALKALI IN ALKALI SPOTS ON YUMA MESA

Sample	Water soluble solids	Sodium chloride	Calcium sulphate or equivalent	Sodium carbonate
	%	%	%	%
No. 1	0.232	.004		.119
No. 2	0.952	.032	.370	
No. 3	2.452	.400	.631	
6915	1.412	.840	.087	
6926	1.784	.572	.762	
6927	5.600	4.200	22.241	

Sample 6915 was the alkaline calcareous clay described elsewhere; 6926 and 6927 were taken from strong alkali spots that had developed after irrigation on the same tract from which Nos. 1, 2 and 3 were taken before irrigation. Further analysis showed 6927 to contain much calcium chloride.

Altho alkali spots do occur, the tarnished sands which make up the greater portion of the Mesa soil are free from injurious amounts of water soluble salts as shown by the analyses in Table IX.

TABLE IX—ALKALI IN TARNISHED SANDS ON YUMA MESA

	Water soluble solids	Sodium chloride	Calcium sulphate or equivalent	Sodium carbonate
	%	%	%	
6917	0.120	0.020	0.054	
6917a	0.200	0.052	0.087	
6918	0.092	0.008	0.004	
6919	0.664	0.276	0.087	
6920	0.196	0.052	0.044	
6922	0.124	0.016	0.044	
6923	0.148	0.020	0.065	
6924	0.140	0.016	0.087	
6925	0.128	0.016	0.065	

The results indicate the absence of injurious amounts of soluble salts and the entire absence of sodium carbonate or black alkali in the sands. Some apprehension has been expressed that black alkali would develop from the action of irrigating water on the calcium carbonate which occurs so abundantly on all parts of the Mesa. The fact that almost without exception the soils tested had the capacity to neutralize considerable black alkali, and that the Colorado River water has a high permanent hardness thruout the year, should remove any danger from this source. Sodium chloride is also much in excess of sodium sulphate in the river water and this has been shown to inhibit largely the reverse reaction between sodium sulphate and calcium carbonate which gives rise to black alkali. Some white alkali may rise from frequent shallow irrigation, but can be leached back easily into the deeper subsoil. Analyses show the alkali found in the valley to carry 1 part of potassium to 4.3 parts of sodium and the year's average of the river flow to be 1 part of potassium to 9 parts of sodium, with a much higher ratio of potassium during flood periods. White alkali then becomes an important source of readily available potash in these soils.

PHYSICAL CHARACTERS OF THE YUMA MESA SAND

The soil of the Yuma Mesa when dry is for the most part loose easily shifted sand, but when wet it resembles a sandy loam. The dry appearance and the mechanical analysis are both somewhat misleading, due to the calcareous incrustations on the soil grains. This incrustation and the fine silt and clay particles which are often cemented are not broken down entirely by shaking with ammonia. Under the microscope the sand grains have a roughened appearance and as mentioned elsewhere, even the coarsest separates effervesce strongly with acid. The roughened surface of the sand grains probably accounts for the relatively high water holding capacity of this sand. The mechanical analysis of a few typical samples of the tarnished sand are given in Table X.

TABLE X—MECHANICAL ANALYSIS OF YUMA MESA SOIL

Sample	Gravel over 2.0 m. m. in diam.	Fine soil						
		Fine gravel	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt	Clay
	%	%	%	%	%	%	%	%
6942...	3.8	2.3	3.5	7.7	13.7	30.3	29.5	12.9
6943...	13.3	8.3	15.7	24.7	25.3	11.2	8.4	5.1
6944...	4.4	7.1	19.6	33.0	29.2	6.9	3.3	0.2
6945...	none	2.2	3.8	4.5	26.2	42.5	13.9	6.7
6947...	12.9	2.3	4.7	10.0	34.9	31.4	9.7	6.4
6949...	none	1.6	5.5	24.5	47.7	17.2	1.9	1.4
6922...	....	3.7	14.6	20.8	36.3	19.3	3.1	1.9
6923...	....	1.6	13.7	22.3	50.7	7.9	2.5	0.9
6924...	....	1.6	9.1	18.8	45.8	17.6	5.8	1.3
6925...	....	2.8	12.1	16.0	41.5	21.4	4.0	1.8

Nos. 6922, 6923, 6924 and 6925 are the same soils described under chemical composition.

No. 6942. Top foot of silt from the Colorado River water mixed with sand as it occurs on the old Blaisdell Orchard. Cover crops had been plowed under, but no recent manure had been applied. Orange roots were abundant in this layer half way between the tree rows.

No. 6943. So-called hardpan of gravelly sand with some lime concretions; about one foot thick, occuring as sub-soil beneath 6942.

No. 6944. Clean tarnished sand beneath 6943; containing few orange roots probably due to insufficient irrigation to penetrate the third foot.

No. 6945. Virgin tarnished sand between the old Blaisdell Orchard and Hill's Orchard. A little lime was noticeable.

No. 6946. Indurated sand with much lime from just outside S. W. corner of Hill's Orchard.

No. 6947. Surface from gravelly area between the Hill and Hibbard places; immediately overlying the excessively limy sample 6948.

No. 6948. Very limy material beneath 6947.

No. 6949. Blown sand from beneath creosote bushes; found on the surface on all parts of the Mesa and appears less tarnished than the bedded sands.

The moisture equivalent and wilting percentage as determined by C. A. Jensen of the Bureau of Plant Industry and given in the engineer's report on the Yuma Mesa Project are repeated in Table XI. The following quotation is from Mr. Jensen's report to the project manager:

"The moisture equivalent represents approximately the amount of moisture the soil will hold 24 hours after irrigation, and is probably about the optimum. Some of these soils have the lowest wilting percentage of any that I have ever seen. The difference between the moisture equivalent and wilting percentage represents approximately the amount of available moisture, that is, about the percentage that a plant can get after an irrigation less the amount lost by evaporation."

TABLE XI—MOISTURE EQUIVALENT AND WILTING POINT YUMA MESA SOILS—BY C. A. JENSEN

Sample	Depth below surface	Moisture equivalent	Wilting percentage
		%	%
1..........	4 in.	23.9	13.0
2..........	18 in.	7.0	3.8
3..........	3 ft.	8.3	4.5
4..........	4 ft.	8.4	4.6
11..........	Surface	9.8	5.3
12..........	12 in.	4.2	2.3
13..........	2 ft.	2.5	1.35
14..........	3 ft.	1.54	0.85
15..........	4 ft.	1.75	0.95

No. 1, 2, 3, 4 are from the old Blaisdell Orchard in N. E. ¼, N. W. ¼ S. 33, T. 8 S., R. 23 W.

No. 11, 12, 13, 14 and 15 are from 300 feet S. W. of N. E. corner N. W. ¼ N. E. ¼ S. 4, T. 9 S., R. 23 W. Of 6 samples taken at different points of the Mesa, this sample was found to be, by mechanical analysis, the coarsest; i. e. it contained the lowest amount of fine material.

Table XII gives the moisture holding capacity of the same series of soil as was used for the mechanical analysis reported in Table X. Only the soil passing a 2.0 m. m. sieve was used, and the determinations were made with the soil packed in brass tubes on the iron compactor in the usual way. From 2 or 3 to 24 hours were required for water to rise thru the soil when the tubes were placed under a water head equal to their height, about 10 inches.

Very little water drained off the tubes under the force of gravity during the first 24 hours, and after that time almost none. If the depth of water equivalent to that retained after 24 hours be computed, it is seen that approximately 4 inches of water is retained per foot of soil. The silty surface soil in the old orchard shows a much higher water holding capacity. It would thus appear that under ordinary irrigation, especially with a scant supply, the soil would not be wet very deeply, even though it appears to be sandy. The relatively high water holding capacity of these sands must be attributed to the roughness of the soil particles, which in turn is caused by the calcareous incrustation.

TABLE XII—PHYSICAL PROPERTIES OF YUMA MESA SOILS

Sample	Apparent sp. gr. of fine soil	Wt. per acre ft.	Water when saturated	Water retained after 24 hours	Water retained per acre ft. soil	Depth of water retained in one acre ft. soil
		Pounds	*%*	*%*	*Pounds*	*Inches*
6942...	1.380	3,758,050	28.2	37.5	1,033,363	4.6
6943...	1.497	4,075,582	23.1	22.7	924,157	4.1
6944...	1.540	4,192,650	22.7	22.3	934,960	4.1
6945...	1.405	3,825,112	28.1	27.1	1,036,505	4.6
6946...	1.412	3,844,170	20.2	19.9	764,989	3.4
6947...	1.398	3,806,055	25.1	24.4	928,677	4.1
6948...	1.351	3,678,097	26.7	26.2	963,661	4.2
6949...	1.582	4,306,995	20.5	20.3	874,318	3.9

The belief has been expressed that great difficulty would be experienced in getting water to penetrate the silt that would be deposited on the surface from the Colorado water, and, when once through the surface blanket, water would sink very rapidly beyond the reach of crops. In the light of data recorded in Table XII, and the incrusted nature of the said, these fears seem without foundation. The soil, which in its virgin state shows good water holding capacity, will be improved by the Colorado silt. Silt will probably be deposited at the rate of about .034 inches a year, or 1 inch in 30 years. For many years this silt can be broken and incorporated with the sand by ordinary tillage implements, and for many additional years there will be the possibility of bringing sand to the surface with power subsoiling tools.

FRUIT CROPS ON THE YUMA MESA

FIRST CITRUS PLANTINGS

Too much credit can not be given the pioneer citrus grower of the Yuma Mesa, Mr. H. W. Blaisdell, who had the foresight to realize something of the possibilities of this district for citrus production and established here in 1892 an orchard of twenty acres, and eight years later another orchard of forty acres. Considered in the light of actual returns, it can not be said that the orchards have proven a financial success, but the plantings are of extreme value and importance in that they have furnished sufficient evidence to show that orchards operated under more favorable circumstances would be profitable.

Fig. 8.—View in ten-acre block of Valencia oranges in Blaisdell orchard on the Yuma Mesa

A review of the methods employed in the handling of these orchards shows that crops requiring clean cultivation were grown between the rows while the trees were young. In later years the practice generally followed was to allow sour clover, together with a natural growth of weeds and grass, to cover the entire area during summer. This was turned under in the fall or winter. The present appearance of the orchard would indicate that Bermuda grass and sand burrs have been allowed to encroach severely upon the trees, in some instances entirely choking them out. When the orchards were set about a pound of bone phosphate was applied in each tree hole. This was supplemented by liberal applications of stable manure to crops planted between the rows of trees. Furrow irrigation was practiced, but very frequently the trees suffered from a lack of water. During several summers they were injured to such an extent as to cause their leaves to drop.

From a careful study of the orchards, and from information secured from past as well as present owners and managers, it appears that the failure of these plantings to yield profitable returns was largely due to the following causes:

1. High cost of water, with consequent lack of sufficient irrigation.
2. The absence of methods of culture tending to improve the soil, particularly the growing of leguminous cover crops between the rows of trees.
3. Absentee control, with frequent changes of managers.
4. Orchard trees being planted wider apart than necessary with numerous vacancies being allowed to exist.
5. The use of too large a number of varieties rather than a few standards.
6. General neglect, particularly during later years, in matters of cultivation, pruning, and irrigation.

RECENT CITRUS PLANTINGS

In addition to the old citrus grove of sixty acres there are at the present time on the Mesa eighty-eight acres of young orchards, set in the spring of 1916. As evidenced by Figures, 11, 12 and 13, the trees have made a very substantial growth. By actual measurement the growth per season has averaged from two to four feet, which compares very favorably with the growth made by young trees in older citrus regions. The methods employed in the handling of these orchards are extremely simple and such as would make practical the development of large areas. The trees have been fertilized in some cases with stable manure, but no soil-building crops have been grown, owing to the added expense of supplying them with water. If water is furnished in abundance at reasonable cost such crops can be planted between the rows of trees, in which case a better growth of tree will result and the matter of handling the orchards will be still further stimulated.

In order to determine the possibility of growing cover crops on the Yuma Mesa, Mr. George M. Hill planted a small area of his

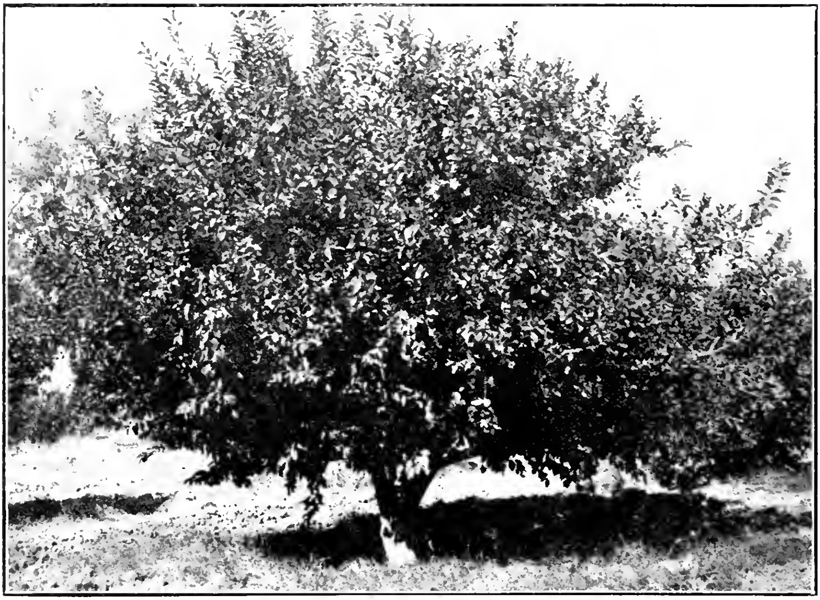


Fig. 9.—Individual lemon tree on the Yuma Mesa

Fig. 10.—Individual Marsh grapefruit tree on the Yuma Mesa

orchard to cowpeas, tepary beans, and peanuts, all of which made a very substantial growth, see Figure 7.

INSECT AND PLANT DISEASE PROBLEMS ON THE MESA

A feature of the Mesa as a citrus district not to be overlooked is its freedom from injurious insect and plant diseases. In the large citrus regions of both California and Florida, the cost to the growers in the control of these pests is a heavy expense—materially cutting down profits—which serves to emphasize the very great economic advantage of a district where these control measures are unnecessary. It cannot be hoped that the Yuma Mesa will always be entirely free from such infestation, but with the rigid quarantine against foreign importations that is now being maintained in the State of Arizona, it should be a long time before any serious difficulty of this sort arises.

CHARACTERISTICS OF FRUIT GROWN ON YUMA MESA

While it is commonly known that citrus fruits attain the very highest quality in an arid soil and climate, special effort has been made to determine if this in reality applies to the fruit produced on the Yuma Mesa, and if so in what way and to what extent. Repre-

Fig. 11.—Citrus orchard of George M. Hill on the Yuma Mesa, 8 months from planting

Fig. 12.—The same orchard as shown in Figure 11, one year later

Fig. 13.—The same orchard as shown in Figure 11, two years later

TABLE XIII—PHYSICAL ANALYSES OF YUMA CITRUS FRUITS

Variety	Date of harvest	Total weight	Color of rind	Thickness of rind	Rind	Pulp	Juice
		Grams		M. M.	%	%	%
Washington Navel orange	Nov. 15	331.8	Rich yellow	4.6	21.9	26.4	51.7
Valencia orange	Nov. 15	188.4	Greenish yellow	5.3	18.4	25.2	56.4
Mediterranean Sweet orange	Nov. 15	147.4	Greenish yellow	4.6	24.9	26.1	49.0
Marsh grapefruit	Nov. 15	323.4	Light yellow	6.0	26.6	24.2	49.2
Eureka lemon	Nov. 15	134.8	Yellow	1.8	19.3	23.3	57.4
Lisbon lemon	Nov. 15	137.2	Yellow	2.0	17.7	26.5	55.8

TABLE XIV—PHYSICAL ANALYSIS OF CALIFORNIA WASHINGTON NAVEL ORANGES

Place of production	Total weight	Rind	Pulp pressed	Juice
	Grams	%	%	%
Northern Calif. District	255	27.3	23.1	49.6
San Joaquin	231	27.6	24.2	47.2
Southern Calif. District	176	29.4	23.3	47.3
Total average for the three districts	221	28.1	23.5	48.0

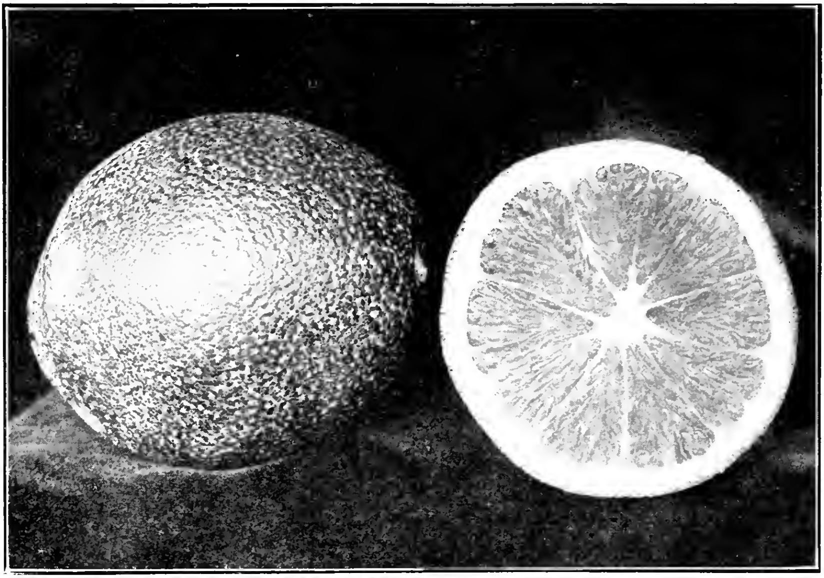


Fig. 14.—Washington Navel orange produced on the Yuma Mesa. (Thickness of rind due to pulling before fully ripe.)

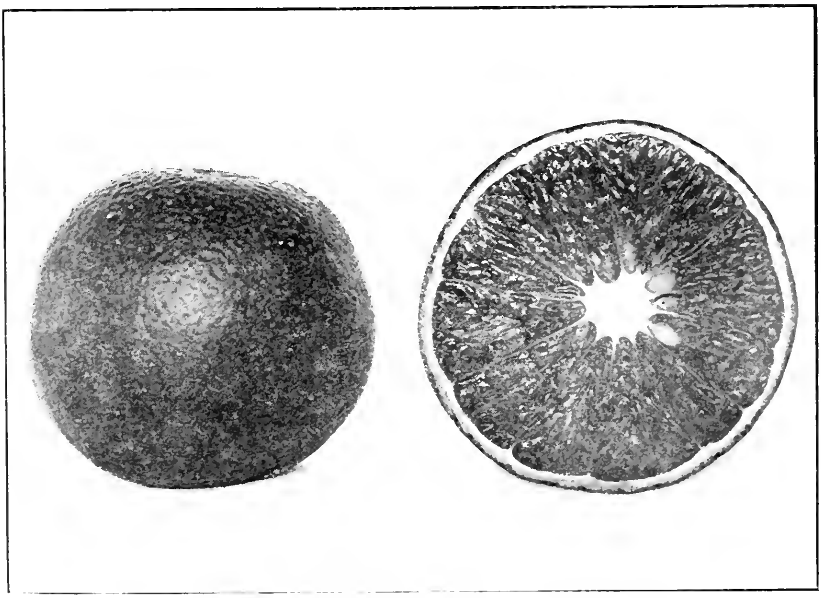


Fig. 15.—Valencia orange produced on the Yuma Mesa

sentative samples of the leading varieties now growing in this district were closely studied and compared with similar varieties of other commercial citrus growing regions—particularly California and Florida. Table XIII is a summary of the physical analyses of Yuma fruits.

For comparison with the fruit of the older citrus regions the physical analysis of the California Washington Navel, as given in the California Experiment Station report of 1902, is given in Table XIV. The figures represent the average of a number of samples collected from the leading citrus districts of California. They were taken during the latter part of November—one or two weeks later than the Yuma Mesa samples.

It will be observed that in percentages of rind and juice content, the Yuma Navels are superior at this season to the California Navels.

Table XV gives the composition of the fruit on the Yuma Mesa as relates to sugar and acid content. This analysis represents the average of two determinations; samples taken November 15.

TABLE XV—CHEMICAL COMPOSITION OF YUMA MESA CITRUS FRUITS

Variety	Total weight	Apparent sugar	Citric acid	Cane sugar	Invert sugar	Total sugars
	[illegible]	*Degrees*		%	%	%
Washington Navel orange	337.2	12.22	.57	5.99	4.16	10.15
Valencia orange	187.1	11.88	1.12	4.22	4.38	8.60
Mediterranean Sweet orange	143.6	12.02	1.88	3.75	3.66	7.41
Marsh Seedless grapefruit	323.4	11.34	2.00	3.68	4.18	7.86
Eureka lemon	147.3	10.17	7.04			
Lisbon lemon	143.8	10.19	7.05			

This analysis shows that the Washington Navel variety of orange has attained by the middle of November a degree of ripeness or of total sugar content of 10.15 percent, which, according to Wickson, is .16 percent in excess of a fully ripe Southern California Navel and exceeds by 2.70 percent the Navel as produced in Florida. The percentage of citric acid in fully ripe Southern California Navels, as given by Wickson, is 1.45 percent and that of Florida Navels .95 percent, whereas, the samples from the Yuma Mesa orchard show only .57 percent. This low acid content, together with the high sugar content, establishes a record for sweetness in the Navel variety of orange that is unsurpassed. The Valencia, Mediterranean Sweet, and Marsh Seedless are not expected to approach this variety in sweetness during fall; however, they show a remarkably high percentage of sugar for the season. The acidity and juice content of the Eureka and Lisbon varieties of lemon are both high—as much so as could be desired in this fruit.

In summing up the results of both the physical and chemical analyses of the fruits in question it can be said that the excellent flavor, abundant juice, fine texture of flesh, thinness of rind, high color, earliness of maturity and freedom from blemishes combine to give it a distinctive and unparalleled quality, presenting most clearly a unique and enviable advantage which the Yuma Mesa possesses as a commercial citrus district.

GENERAL ADAPTATION OF VARIETIES OF CITRUS TO THE YUMA MESA

While there is much room for experimentation in the matter of varieties of citrus best suited to the Yuma Mesa, several of the standard varieties have been grown for a number of years and have already demonstrated their adaptability to the conditions found in this district. Outstanding facts regarding these varieties are as follows:

ORANGES

The Washington Navel, Valencia, and Mediterranean varieties have all produced satisfactory crops on the Mesa and could be relied upon under proper methods of culture and irrigation to give good returns; but of the three the Washington Navel appears to offer the greatest promise to the commercial grower. Its early shipping season, beginning in the first part of November, allows this variety to be placed on the market in advance of fruit from other citrus districts. The bulk of the crop could be marketed just previous to the holiday season when citrus fruits are in greatest demand. These facts, together with the high quality and general popularity of the Navel, furnish the grower the very best advantages of market, and consequently insure for him the very highest prices. This variety has been known to produce an average of from five to nine boxes per tree in the old orchard, and during the present season there are a number of individual trees that are giving equally good yields. Another advantage of the Navel is its early bearing habit, as much as 16 finely formed fruit having been produced on two-year-old trees on the Mesa. See Frontispiece. The Valencia variety in the old orchard is carrying a crop this year that will average from 6 to 8 boxes per tree for a ten-acre block. Although excellent in quality and a good yielder, this variety does not appear to lend itself quite so well to commercial planting from the fact that it comes in later in the season when the California crop is being placed on the market in great quantity. The Mediterranean Sweet has given good results in the old orchard, and its season being only a little later than the Navel should make it a very satisfactory variety.

GRAPEFRUIT

The Marsh Seedless grapefruit, universally considered the leading commercial variety, has given a good account of itself on the Mesa, and promises to become a very profitable crop for this district. It is highly enough colored and sufficiently sweet to be placed on the market in November, but as there is no special advantage in seeking out an early market for this fruit, it might be allowed to remain on the tree until in absolutely prime condition, (climate offering no obstacles), at which time it is of most superior quality and commands a fancy price. The latter fact is illustrated by the Los Angeles market report as printed in a February issue of the Los Angeles Times in 1912 as follows:

Marsh Seedless grapefruit, local or Southern California, $1.75 to $2.25 per box.

Marsh Seedless grapefruit, Northern California, $2.25 to $2.75 per box.

Marsh Seedless grapefruit, Yuma Mesa, $5.00 to $5.50 per box.

LEMONS

Both the Eureka and Lisbon varieties of lemon have given splendid yields on the Mesa, and the fruit has all the requisites of a good commercial product, being particularly high in juice content and having a very thin rind. An outstanding feature of this fruit as grown on the Mesa, is its freedom from discoloration, which makes washing unnecessary. It has been noted that the lemon as grown in this locality tends to produce the greater portion of its crop in the fall—a time when the market demand is rather low. However, there should be no difficulty in holding the crop in storage thru the winter, as is practiced in many of the older lemon districts, until early summer when it could be marketed to advantage.

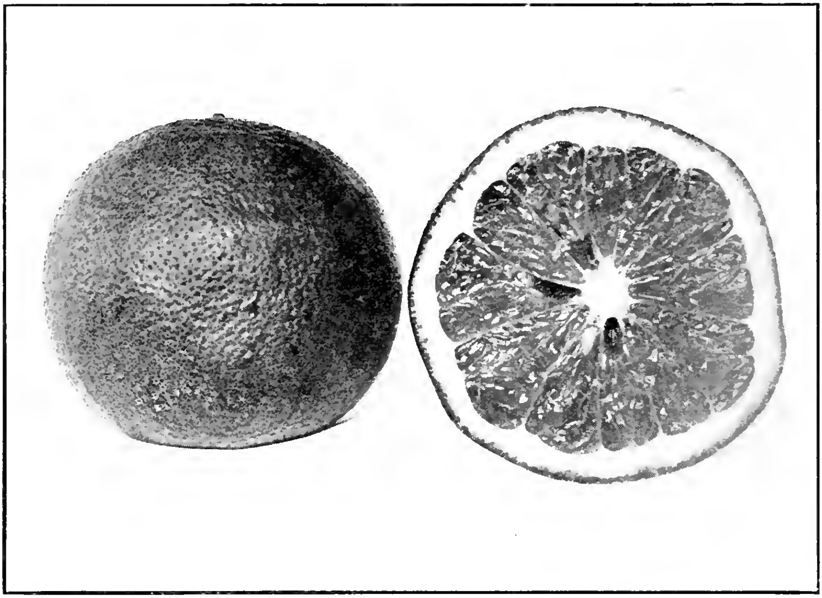


Fig. 16.—Grapefruit produced on the Yuma Mesa

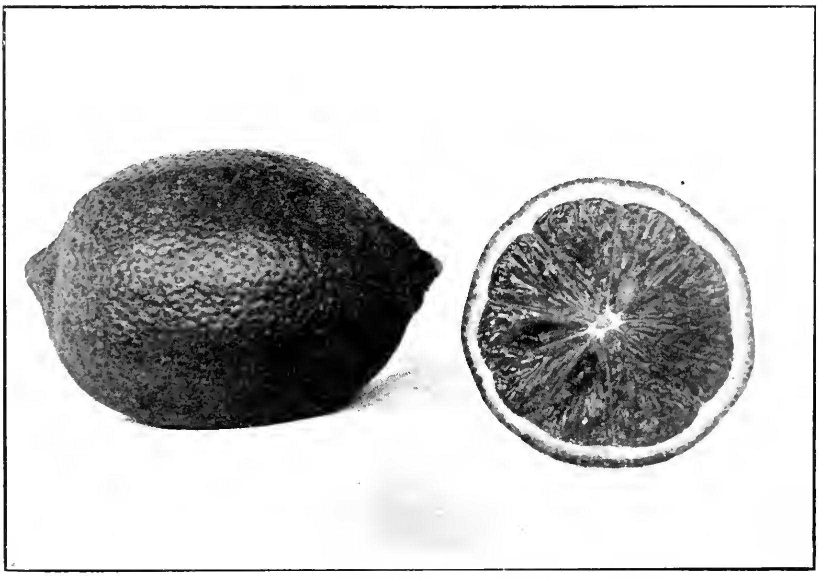


Fig. 17.—Lisbon lemon produced on the Yuma Mesa

In general, the varieties in the old orchard have given a good account of themselves, when the adverse circumstances under which they have been handled are considered. They give genuine evidence of profitable yields that could be increased and made constant with proper methods of culture and irrigation. In speaking of this orchard the present manager, Mr. R. M. Moore, states: "We own two orange groves in California and earnestly believe that the Yuma Mesa is the best location for an orange, lemon, or grapefruit grove of any place in the United States, as samples of fruit have shown us that there is none better grown."

OTHER FRUITS ADAPTED TO THE MESA

In addition to or in combination with citrus fruits the Yuma Mesa offers most ideal conditions for the commercial production of a number of other fruits, among the most important of which are dates, olives, grapes, and figs. Also there are a number of truck crops that could be produced with profit.

DATES

While the lower altitudes of the greater portion of southern Arizona are well adapted to date culture, the Yuma Mesa presents special advantages in the growing of this fruit, particularly such varieties as the Deglet Noor that matures late in the season. With practical immunity from frost, together with relatively low humidity during harvest (under which conditions the date palm ripens its fruit to best advantage), afforded by this district, the Deglet Noor and kindred varieties could be allowed to remain on the trees until fully mature, becoming enriched to the highest degree in flavor and sugar content. The knowledge that this world-famous variety can be profitably produced only in specially favored regions lends interest to the fact that the Yuma Mesa appears to possess the proper requisites for its successful culture. While the Deglet Noor variety is emphasized, this does not preclude the fact that many other varieties would succeed admirably well here. As proof sufficient that the date would thrive on the Mesa there are at present a number of old, neglected seedling trees along the roadside on the Blaisdell Orchard that bear heavy crops. At the low estimate of ten cents per pound (fresh dates are now selling at from twenty-five cents to one dollar per pound) it is easily possible for the grower to make enormous net profits per acre.

OLIVES

The olive, like the date, is peculiarly adapted to arid conditions such as are found in the Southwest, and should receive favorable consideration as an adjunct planting on the Mesa. Its value for both pickles and oil has become so fully established that the demand for these products is permanently assured. With proper handling this fruit should yield very profitable returns.

GRAPES

It is believed that the grape would give quicker returns on the Yuma Mesa than any of the fruits, paying crops being produced the second year from planting. Furthermore, the grape can be

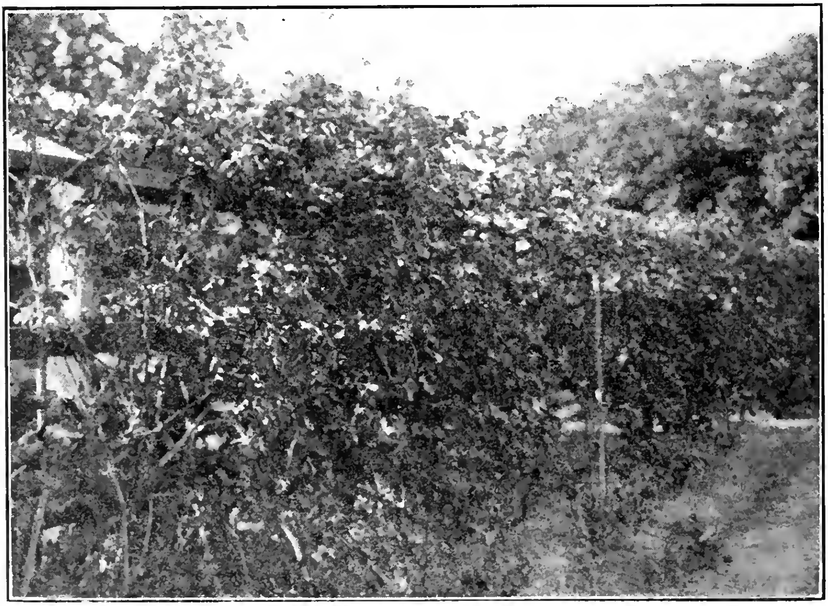


Fig. 18.—Two-year-old grape vines on the Yuma Mesa

relied upon to bear every year. Both the soil and climate are conducive to the production of the highest quality European grapes, unequaled in point of earliness by any other section of the United States. By planting early maturing varieties, such as the Thompson Seedless, table grapes could be grown and placed on the market in advance of the bulk of the grape crop from the older commercial grape growing centers, and as a consequence command the best prices. It is not only true that table grapes could be profitably grown here to advantage, but very excellent raisins could also be produced, as the absence of rain during the harvest season affords excellent opportunity for curing the raisin crop. Grapes have already been grown in a small way in this district, sufficiently to demonstrate beyond question that the Mesa land will produce a vigorous growth of vine and heavy yields. See Figure 18. The grape could be interplanted between rows of citrus with good results, but it is believed that it is of sufficient importance to warrant the making of special plantings.

FIGS

The Mesa is particularly adapted to the production of the Smyrna or dried fig of commerce. To produce this fig of the

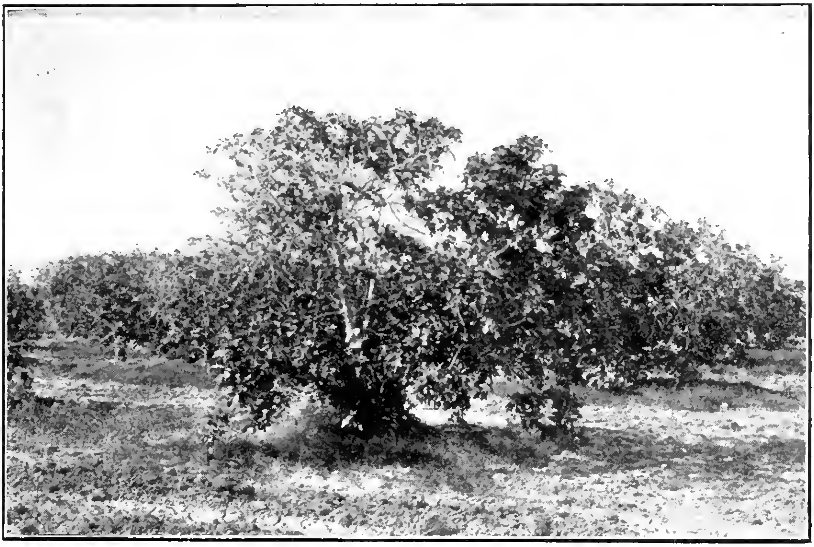


Fig. 19.—Three-acre fig orchard on the Yuma Mesa

finest quality, thinnest skin, and richest sugar content requires a warm, dry climate, such as is afforded by this region. Moreover, the climate is such that the little wasp *(Blastophaga grossorum)* necessary for the pollination of this type of fig could be colonized permanently. Like the grape, the fig can be depended upon absolutely to produce a crop every year, and the fact that our importations of Smyrnas are constantly increasing, the annual amount averaging not far from 13,000 tons, is in itself sufficient indication of the possibilities of a great industry under the favorable conditions presented by this section. To successfully produce the dried fig it is not only necessary that a warm, practically frost free climate be had, but there must be an absence of rain during harvest in order that the crop may be dried successfully, which condition is found here.

Evidence of the thrifty growth of figs on the Mesa is shown by the condition of the three-acre orchard of Adriatic figs now growing on the old Blaisdell ranch. Figure 19 shows a picture of this orchard as it now stands.

TRUCK CROPS

The mild climate of the Yuma Mesa affords an opportunity for the successful production of a number of the truck crops, particularly cantaloupes, tomatoes, and sweet potatoes. These crops are well adapted to growing between the rows of citrus trees while the orchards are young, and the fact that they could be produced exceptionally early gives them a distinct market advantage. It might be mentioned that in the early years of the old citrus orchard on the Mesa cantaloupes were grown between the rows of trees and were found quite profitable.

While the crops mentioned above appear to have an outstanding value as regards profitable production on the Mesa, there are doubtless others that individual growers would find equally satisfactory.

FIELD CROPS ON THE YUMA MESA

Field crops growing under virgin soil conditions were compared with crops growing on land that has been under cultivation for upwards of twenty years. All improved farms of the Mesa were visited, and their condition noted. The native vegetation of the Yuma Mesa also was observed and examined as an indication of the natural productiveness of the soil. Much information regarding the results secured in the growing of field crops upon the Mesa was secured from old residents of the vicinity.

The chemical and mechanical analysis of the Mesa soils are reported upon in another section of this report, and will not be discussed here. It is sufficient to say that the total amount of plant food is relatively low, but the available amount relatively high, consequently when water is supplied in sufficient quantities, crops adapted to the climate of the Yuma Mesa may be expected to grow and produce in a satisfactory manner. The soil is deficient in organic matter, and also in nitrogen. As stated elsewhere in this report, the irrigation water from the Colorado River carries considerable nitrogen and a very heavy deposit of silt. For this reason irrigation will build up these soils and the longer they are held under cultivation and irrigated with water from the Colorado River, the more productive they should become, provided green manure crops are sufficiently utilized and a well regulated cropping system followed.

On the Mesa lands near the Blaisdell Orchard in 1918 there was a field of cotton of approximately 10 acres, on land said to be, and appearing to be, virgin soil. This field was not uniform in growth, but taken on the average it was a very creditable field and was estimated by competent parties to yield approximately one-half bale of short staple cotton per acre. Examination of the field showed that it had not been supplied with sufficient water, as the portions of the field along the irrigation ditches, and the portions toward the lower side of the field, showed a more rank growth of cotton stalk and a greater quantity of lint. See Figure 20.

In another field near this same orchard, milo was grown in 1918 on soil that had previously grown one other crop. This field likewise suffered from lack of water, and the stand was very thick, but even with these handicaps, the milo made a creditable forage growth. The yield of grain was light.

Reliable parties report that in previous times barley, oats, and wheat have been grown with more or less success, but, mainly due to the high irrigating costs, they were seldom profitable. It is reasonable to suppose from the character of the soil that a considerable number of truck crops could be profitably handled, and probably peanuts and certain of the vetches could be made to yield moderate crops.

There is no question but that Sudan grass sufficiently irrigated would return large yields of hay, or would supply a considerable amount of pasture. Many of the common varieties of sorghum can also be grown to advantage.

An engineer's report on this Mesa project, issued some months ago, indicates that it probably would cost in the neighborhood of $7.00 per acre foot to deliver irrigating water to this land. Considering the fact that this land is comparatively porous and open, and the climate dry and hot, it will doubtless require large amounts of irrigation to give relatively satisfactory results with common

Fig. 20.—Cotton on Yuma Mesa on land under second year's cultivation.

field crops. It is very questionable whether any of the field crops previously mentioned can be made profitable from the market standpoint. They can, however, be grown by the farmer who is living upon his land and developing a citrus orchard. Properly handled they will be sufficiently productive to enable him to live upon his own farm without being forced to buy expensive feeds through the local markets, and by the use of these crops and the use of alfalfa and various beans and pea crops, the farmer will be able gradually to improve the fertility and the texture of the Mesa soils.

In proof of the above statement, examination of the older portion of the Blaisdell Orchard shows that the sandy Mesa soil has been so thoroly changed by irrigation, deposits of silt, and the decay of crops grown that the surface 18 inches to 2 feet now appears to be, and is often called, a heavy adobe soil. Alfalfa planted as a cover crop in this old orchard has done very well indeed, as is shown by one of the pictures accompanying this report. Likewise cow peas have made an excellent growth. Sesbania, a rank growing legume, has been used on the Mesa for green manuring purposes and it promises to be very satisfactory.

SUMMARY

The climate of the Yuma Mesa combines the smallest rainfall, the lowest relative humidity, and the greatest percentage of sunshine of any citrus region in North America. This combination and its freedom from injurious frost make the Mesa a most promising region for citrus culture.

The fruit grown on the Yuma Mesa is unexcelled in color, quality, early maturity and freedom from blemishes.

The Mesa is now and probably can be kept free from injurious citrus pests.

The Mesa is particularly well adapted to growing such other crops as dates, olives, grapes, figs and early truck.

The Yuma Mesa, joining the main line of the Southern Pacific at Yuma, is insured efficient shipping facilities.

While ordinary field crops probably cannot compete with similar crops grown in the valley, they can be produced in quantities sufficient for home needs.

The total plant food in the soil of the Mesa is relatively low, but its availability is high. Chemical analyses show it to compare favorably with soils from the citrus districts of California and Florida.

The irrigating waters of the Colorado River will in large part supply the fertilizing elements which prove so expensive in many citrus sections.

Cover crops which have been found desirable in the handling of all orchards can be grown successfully on the Mesa.

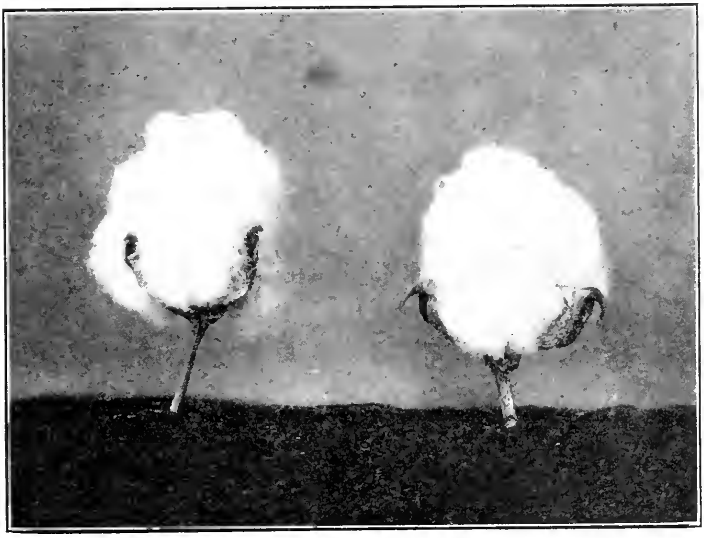
In view of the findings set forth in this report this commission hereby recommends that the Yuma Mesa be brought under irrigation according to the plans proposed by the engineers of the Reclamation Service, and developed by the growing of citrus and other sub-tropical fruits.

The University of Arizona

College of Agriculture

Agricultural Experiment Station

Bulletin No. 90



Arizona grown long-staple cotton

Growing Cotton in Arizona

By G. E. Thompson and C. J. Wood

Tucson, Arizona, December, 1919

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ILLUSTRATIONS

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Cotton should be cultivated as soon as the plants are through the ground well enough to make the row

GROWING COTTON IN ARIZONA

By G. E. Thompson and C. J. Wood

TYPES OF COTTON

At the present time two general types of cotton are grown in Arizona—the American Egyptian, represented by the Pima variety, and the short staple, represented by the variety called Mebane's Triumph or Mebane and others more or less similar.

American Egyptian is so called because the original stock, from which our present strains were secured, came from Egypt. We are indebted wholly to the United States Department of Agriculture for the selection and development of the varieties now used in Arizona. Fiber of this cotton is longer and stronger than the fiber of the varieties commonly called short-staple cotton. The bolls are smaller, usually having three locks or parts instead of five, as is the case with short-staple cotton. In general the plants are larger and coarser, and the shape of the leaf is different, making it very easy to distinguish the two general classes under field conditions. The Salt River Valley and the Santa Cruz Valley are growing but one variety of cotton—the Pima variety of American Egyptian. The Yuma Valley and the Upper Gila Valley are growing principally short-staple varieties—Mebane's Triumph being the most important one at the present time.

The discussions of this bulletin refer primarily to American Egyptian cotton. At the end of the bulletin those particulars in which short-staple cotton differs from long staple are given special mention.

SEED

Great pains to secure the best possible seed should be exercised by all who grow cotton. Seed of an inferior strain will result in a decreased yield and a poor quality of fiber. It is advisable for farmers to buy seed for planting purposes from responsible cotton growers' associations. At least one of these associations at the present time (and others are preparing to do the same) make it a business through their cotton experts to produce and sell high-quality seed to members of the association. One of the associations now maintains, and the other associations should maintain, a separate gin for handling this cotton. Cotton seed that goes through the regular commercial gins is certain

Acknowledgment: The authors of this bulletin wish to express grateful appreciation to H. C. Heard, J. W. Longstreth, C. K. Wildermuth, and others for reading the manuscript and offering many helpful suggestions.

to be mixed more or less with inferior seed, and its use will in time result in decreased yields.

Those who have the time and who are especially interested in cotton breeding may find it worth while to grow a separate small field of cotton from which seed is selected for the following year's planting. On this special field great care should be taken to rogue out and destroy all plants of undesirable or inferior type and all plants that fail to produce a reasonable number of matured bolls. In addition to this general precaution, the fiber itself should be examined; and if any of the plants have produced fiber that is short and weak, they should be discarded. The seed that is to be used for planting purposes should be fully matured before the first freeze of consequence in the fall. Because early setting and maturing of bolls is very desirable in American Egyptian cotton, it is advisable to select seed from plants that show this character.

The average farmer in Arizona uses twenty-five to thirty-five pounds of seed per acre when planting cotton. Although one-half of this amount will give a sufficient stand if seed is good and soil and weather conditions are ideal, still it is advisable to use the amount indicated and later thin to the proper stand.

LAND ADAPTED TO GROWING COTTON

A rich sandy loam soil, well supplied with humus, is ideal for the growing of cotton. Very light sandy soils as a rule do not produce heavy crops of cotton. Heavy adobe soils are unsatisfactory because of the trouble experienced in securing a good stand, and because of the difficulty of irrigating properly. However, with good care, cotton can be produced upon practically any soil that is suitable for general farming.

PREPARATION OF LAND FOR PLANTING

Thorough preparation of the land for cotton pays, and pays well. Cotton is a cash crop. A good quality of clean, strong fiber brings a better price than fiber that is weak, dirty, or inferior for any other reason. Well-prepared land will produce more fiber, longer fiber, and stronger fiber than poorly prepared land. Cotton from a field that produces a heavy crop is easier to pick and keep clean and free from dirt and trash than cotton with small, poorly opened bolls. If land is to be properly prepared for cotton, the preparation should begin several months before the planting season. Coarse trash or other material on the ground must be chopped fine and plowed under or otherwise

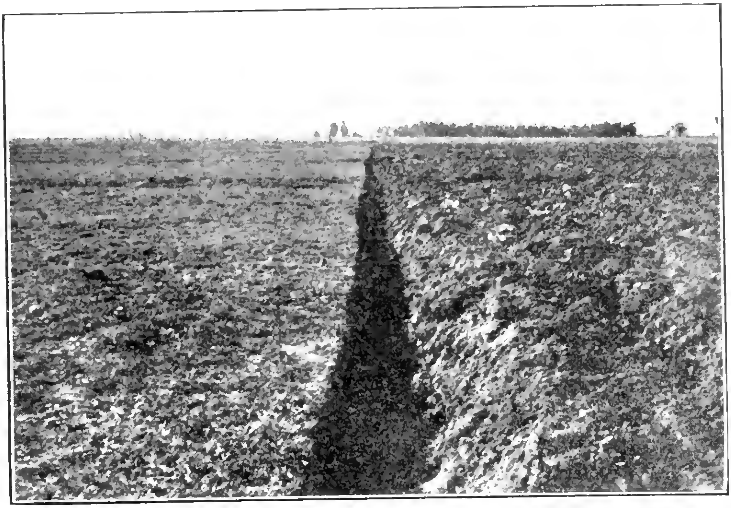

Fig.2—Good plowing—the first step in preparing a satisfactory seed-bed

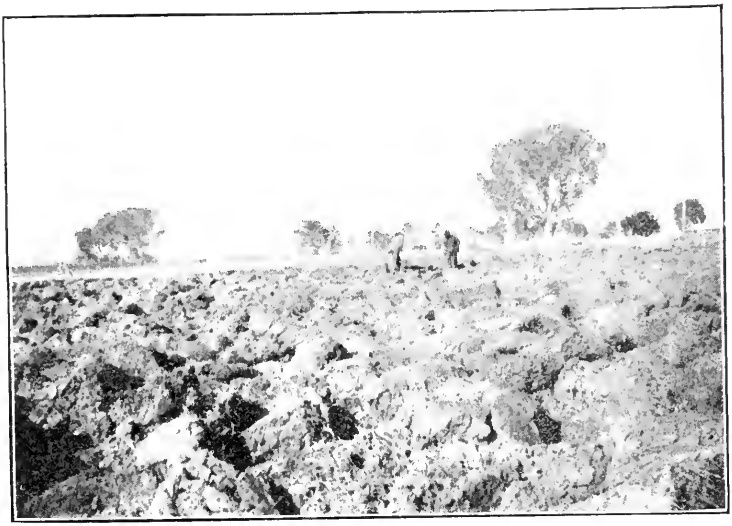

Fig. 3—Poor plowing—with such plowing as this it is impossible to prepare a satisfactory seed-bed

put in such shape that it will not interfere with the cultivation of the cotton plants. The ground should be plowed rather deep (7 to 8 inches) as early as possible and allowed to weather till planting time. From five to ten days before planting, the ground should be thoroughly irrigated. This time should be just sufficient to allow the ground to dry out properly and be worked to a good seed-bed. Many farmers make a mistake in the preparation of their cotton land by not having sufficient moisture in the ground before planting. Water should be held on the land long enough to insure its being wet to a depth of four to five feet. Land left rough after plowing takes water better than land that has been disked and harrowed to a smooth surface. Land that has been irrigated when rough, particularly if it is of a heavy adobe type, should be harrowed with a spike-tooth harrow as soon as dry enough to permit of this treatment. This harrowing will save considerable moisture, knock off the tops of large clods, and fill the small depressions. The disk, followed by the spike-tooth harrow when necessary, can be used to work up a satisfactory seed-bed. An ideal seed-bed consists of about two and one-half inches of finely mulched surface soil with a firm and moist soil beneath. It is not advisable to plant cotton and "irrigate it up" because of the difficulty often encountered with the baking of the ground over the sprouting cotton seeds.

PLANTING

The time of planting cotton will vary somewhat with the kind of soil and with the locality of the State in which the planting is made. Recommendations differ greatly in this regard, but the consensus of opinion of the practical cotton growers is that the best time for planting in an average season is during the last ten days of March and the first ten days of April. Farmers handling sandy types of soil can plant one to two weeks earlier than those handling heavy or adobe types of soil. It pays to plant as soon as the ground is sufficiently warm to insure good germination and thrifty plants. Early plantings when the ground is cold often result in a thin stand and weakened plants; likewise early planting in cold ground, particularly if the days are warm and the nights cold, favors the development of the disease called "sore shin." Late plantings do not allow sufficient time for the plants to set and mature a large crop. The sooner the cotton can be planted after the ground is well warmed and danger of frost is past, the better the average results that will be secured. Cotton should be planted as shallow as possible and still get the seed deep enough into moist ground to insure good germination.

THINNING

The thinning of cotton is a question on which the best cotton growers hold widely differing opinions. We believe that the distance to which cotton plants are to be thinned should be governed largely by the soil. Heavy, rich land will stand thick plantings of cotton. Thin, light land should have cotton spaced relatively far apart. This thin planting, however, should not be carried to such an extreme that the land will not be utilized to its full capacity to produce. With heavy rich ground some cotton growers prefer that the plants be from six to ten inches apart. A few growers will prefer even less space than this. The average cotton grower with typical cotton land of the Salt River Valley will space his cotton from 12 to 18 inches apart in the row, with rows $3\frac{1}{2}$ feet apart. On thin poor land it may be advisable to increase the spacing to 24 or 30 inches. The purpose of thinning cotton is so to space the plants that they may have light, air, moisture, and plant food in such proportions that they will produce the maximum number of matured bolls per acre. Cotton given too much space is very likely to produce a large, coarse plant, from which the branches may be broken in the fall by heavy winds. Cotton given a reasonable spacing can stand more drying or more severe conditions and still recover than cotton closely spaced. American Egyptian long-staple cotton should be thinned on the sandy light soils when the plants are from four to eight inches high, and on the heavy rich soils when the plants are from eight to twelve inches high. On the extremely rich soils thinning can be delayed till the plants are fourteen to sixteen inches high.

Time of thinning has a great deal to do with the control of vegetative branches. The development of vegetative branches is undesirable in American Egyptian cotton. Early thinning encourages their development while late thinning discourages their development.

CULTIVATION

The cultivation of cotton should begin as soon as the plants are through the ground well enough to mark the row, and be continued every 10 to 15 days till the plants are too large to permit the use of a regular cultivator. Sometimes the cultivation can be continued by the use of a one-horse cultivator, especially in the wider spaced rows and on heavy soils that tend to bake. Early cultivation checks evaporation, warms the soil, and will kill weeds and grass at the stage at which they are most easily destroyed. It will also eliminate much hand work or hoeing. For the most part the early cultivations may be comparatively deep and reasonably close to the plant. Late cultivations must be shallow in order to avoid cutting and breaking numerous cotton roots.

IRRIGATION OF COTTON

The proper irrigation of cotton is the most important single item in the profitable growing of the crop. Even though all other conditions are right, if the irrigation is wrong the yields will not be satisfactory. Over-irrigation stimulates plant growth, and to a certain extent prevents the forming of cotton squares and the setting of bolls; while light irrigation encourages the setting of fruit and the dwarfing of the plant, which are highly desirable especially in the earlier stages of growth of American Egyptian cotton. However, this dwarfing of the plant is neither necessary nor desirable on light desert soils deficient in both nitrogen and humus. When a plentiful supply of water is suddenly applied, following a period when the plant has been suffering for water, it will cause a quick stimulation of growth and the plant will shed or drop much of the young fruit already set. It is best to withhold irrigation after planting as long as possible and still keep the plants in a growing condition. Cotton will not be injured by wilting slightly in the middle of the day, provided it fully recovers its fresh appearance by late afternoon or early evening, and provided there is enough moisture deep in the soil to encourage deep root penetration. As long as there is sufficient moisture in the ground to permit transpiration to maintain the leaves in a cool condition during the heat of the day, the plant is not suffering, but when the leaf feels warm to the hand irrigation must be immediately supplied. After cotton begins to bloom the moisture supply should be kept as uniform as possible. Cotton should be kept growing steadily, but excessive growth should be prevented. If examination during the blooming stages shows that the vegetative growth has practically stopped and the cotton is blooming to the top of the plant, water has been withheld too long. In other words, the terminal bud should be kept growing slightly in the lead of the flowers on the fruiting branches.

Prior to fruiting the desirable method is to give as little water as possible, forcing roots to penetrate deeply for soil moisture stored prior to planting. The system changes after the fruiting begins, and the purpose then is to maintain a thrifty and uniform though not rank growth.

PICKING

In Arizona, cotton picking is usually begun during the last half of September. It does not pay to begin picking until sufficient cotton is open to allow the gathering of 500 to 700 pounds of seed cotton per acre at the first picking. In nearly all cases it will be advisable to pick the fields two or three times before the gathering of the crop is complete. Care should be taken in picking to see that no dirt, leaves, sticks, or other trash gets mixed with the fiber. It is extremely difficult to separate the dirt from the fiber in a roller gin, and dirty cotton always brings a low price. With short-staple cotton, leaves and other trash can be separated to a considerable extent. Saw gins are used with short-staple cotton.

VOLUNTEERING OR RATOONING

The volunteering or ratooning of cotton for two or three years in succession from the same planting was practiced in Egypt a good many years ago, but has been abandoned there. It has been tried in this

Fig. 4—Volunteer cotton (the 1919 crop from 1917 planting). Volunteering cotton does not pay

State with varying results. The practice is to be condemned for several reasons. In many seasons the volunteer stand of cotton is insufficient to produce a maximum yield. Usually the fiber produced from volunteer cotton is shorter and weaker than the fiber produced from cotton planted each year. In addition to these difficulties, the practice of volunteering cotton favors the increase of injurious insect pests and the development of troublesome cotton diseases. The practice has much to condemn it and very little to favor it. It is only under the most extreme or unusual conditions that the volunteering of cotton will pay.

TOPPING

The topping of cotton, or the pinching or cutting off the terminal buds, has been advocated and practiced by many as a means of preventing excessive plant growth and as a means of stimulating the formation of bolls. The results secured from this practice have been conflicting. In some cases, particularly on heavy rich ground, reports state that the practice has been profitable. Up to the present time no reports have been received showing that the practice is profitable on medium or thin lands. Properly grown cotton plants should not require topping. Uncontrollable conditions, such as a high water table or excessive rains, may make topping desirable. If topping is to be practiced at all, it is recommended that it be delayed until about the middle of August. Early topping, instead of checking plant growth, may stimulate the production of vegetative branches if growing conditions are favorable, while late topping ought to further the development of bolls already set.

FERTILIZING COTTON

Considerable interest has developed in the last two years in the fertilizing of cotton. For the most part the desert soils in Arizona are deficient in nitrogen, and it is possible that on such soils nitrogen fertilizers may prove beneficial. Experience indicates that desert land that has been plowed and irrigated a number of times and brought into a condition of good tilth will produce better cotton than similar land that has received but little cultivation. This is shown by the fact that the second crop of cotton on desert soil is often better than the first crop. On old lands that have grown legumes for a number of years, if any fertilizer proves profitable, it will be one containing phosphorus. Nitrogen fertilizers probably will not pay on such lands. It is not advised that farmers buy phosphorus fertilizers or any other fertilizers on an extensive scale until they have first tried them on small plots in their own fields. Applications of 200 to 500 pounds of acid phosphate per acre at the time the cotton is planted promise to give beneficial results; yet several farmers who have made small tests failed to note appreciable benefits, and tests on the Salt River Valley Experiment Station have so far failed to give increases in yield.

During the last year many questions have been asked regarding the advisability of planting cowpeas in the growing cotton for the purpose of increasing the available nitrogen. This recommendation has usually been to the effect that the cowpeas should be planted about thirty days after the cotton is planted, and then destroyed about the time the cowpeas are coming into full bloom. A more practical method is to plant the cowpeas at the time the cotton is planted, as this avoids the necessity of special irrigation to bring up the cowpeas. It is claimed that the planting of cowpeas in this way has a beneficial effect upon the growing cotton. In handling the cowpeas in this manner, it has been customary to plant two rows of cotton and the third row of cowpeas. We do not have accurate or conclusive information regarding the benefit of planting cowpeas with cotton. There is considerable evidence to prove that a legume crop may have beneficial effects upon a companion crop, but whether it will pay in the case of cotton remains to be proven. If cotton is planted in this manner, it should be considered an experiment and an accurate comparison should be made with the common methods of planting.

ANGULAR LEAF SPOT

Fortunately there are not many cotton diseases of serious consequence in Arizona at the present time. Probably the disease that has caused heaviest losses is one that farmers have observed but little, even though it may be present to a considerable degree. This is a disease called Angular Leaf Spot or Black Arm Disease of cotton. This disease attacks the plant in all stages of its growth, appearing on the younger plants as small dark angular spots on the leaves. Later the disease attacks the stems and fruit, showing as darkened, shrunken spots. Control measures are still in the experimental stage, but there is evidence that control, at least in the seedling stage, can be effected by careful treatment of the seed before planting. If treatment of seed to control this disease is attempted, the following is recommended.

BICHLORIDE OF MERCURY TREATMENT FOR ANGULAR LEAF SPOT

Dissolve one ounce of bichloride of mercury in a small quantity of hot water, then mix into seven and one-half gallons of water. Dip the seed into this solution, stirring to make sure that it is thoroughly wet and allow to soak for one hour. Spread the seed out and dry thoroughly before putting into sacks.

Do not dip more than three lots of seed into the same solution, as each lot of seed weakens the solution.

Bichloride of mercury is a poison, and the solution should be destroyed in order that people or animals may not drink it by mistake.

Bichloride of mercury corrodes metal and solutions of it must not be placed in metal utensils. Wooden or earthenware vessels should be used.

COTTON ANTHRACNOSE

Cotton Anthracnose is a disease that has caused great loss in the south, but little if any in Arizona. Importation of cotton seed should be avoided, as this disease is carried on or within the seeds. No satisfactory methods of controlling this disease are known.

ROOT ROT

Root rot of cotton is a disease and lives over in the ground from year to year. The only practical known method of control on infected soil is to grow for at least two years in succession some crop not affected by root rot. Such crops are corn, the various varieties of sorghum, and the small grains, such as wheat, barley, etc. Alfalfa and certain other tap-rooted plants are subject to root rot and must not be grown when attempting to rid the ground of this disease. Since certain weeds may be affected by root rot, deep plowing and clean cultivation are recommended as control measures.

INSECT PESTS

Due largely to the strict quarantine that has been maintained, cotton boll weevil, pink boll worms, and many other troublesome insect pests of cotton have been kept out of Arizona. It is urged that every farmer within the State use his influence to help enforce this quarantine. If insect troubles of any kind are encountered, notify at once the Experiment Station at Tucson, or the State Entomologist's office at Phoenix. A complete discussion of cotton insect pests will be found in Bulletin 87 of this Station, which may be had on application.

COTTON IN ARIZONA AGRICULTURE

At the present time (1919) cotton is the most important cash crop in Arizona. It is unlikely that the present high price of cotton will be maintained indefinitely and farmers should bear in mind that any system of agriculture that is to be permanently successful must be well balanced. Cotton should not be grown to such an extent that other crops or livestock are reduced below a safe amount or number. It should be the aim of every good farmer to maintain the soil at all times in a high state of fertility and to this end an intelligently planned crop rotation must be followed.

SHORT-STAPLE COTTON

Short-staple cotton will mature in a shorter growing season than

American Egyptian cotton and therefore can be grown further north and at higher elevations. The soil requirements and the preparation of the seed-bed should be the same for the two classes of cotton.

Because of its shorter growing season short-staple cotton can be planted one to three weeks later than American Egyptian. A smaller amount of seed is required per acre—fifteen to twenty-five pounds being sufficient.

The thinning of short-staple cotton should be done when the plants are four to six inches high, and the plants are usually spaced from sixteen to twenty-four inches in the row, with rows three and one-half feet apart. With very rich soils, both the spacing between the plants in the row and the distance between rows is increased.

The general principles applying to the irrigation and cultivation of American Egyptian cotton apply to short-staple cotton.

SUMMARY

In growing cotton, good seed is extremely important.

A rich sandy loam soil, well supplied with humus, is ideal.

Early, deep plowing and thorough preparation of the land are necessary.

The seed-bed should be wet to a depth of four to five feet.

Plant early, but not until the ground is sufficiently warm to insure good germination and thrifty plants.

The character of the land should govern the rate of thinning.

Cultivation should begin as soon as the plants are through the ground well enough to mark the row.

Proper irrigation is the most important single item in the growing of cotton.

After planting, withhold irrigation as long as possible.

Prevent excessive growth.

The terminal bud should be kept growing slightly in the lead of the flowers on the fruiting branches.

In picking, keep the cotton clean.

Volunteering cotton does not pay.

Report trouble with disease or insect pests to the Agricultural Experiment Station, or the State Entomologist.

Do not allow the soil to become depleted; practice crop rotation; maintain a balanced agriculture.

University of Arizona College of Agriculture

Agricultural Experiment Station

Twenty-Ninth Annual Report

For the Year Ending June 30, 1918

(With subsequent items)

Consisting of reports relating to

Administration,

Agronomy, Botany, Horticulture,

Plant Breeding, Animal Husbandry,

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Tucson, Arizona, December 31, 1918.

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Tucson, Arizona, December 31, 1918

GOVERNING BOARD

(Regents of the University)

Ex-Officio

His Excellency, The Governor of Arizona

The State Superintendent of Public Instruction

Appointed by the Governor of the State

John T. Hughes	Chancellor
William J. Bryan, Jr., A.B.	Treasurer
William Scarlett, A.B., B.D.	Regent
Mrs. Madge Roberts	Regent
Mrs. Bettie White	Regent
H. S. McCluskey	Regent
Mrs. Louise Foucar Marshall	Secretary
J. W. Chapman	Regent

Agricultural Staff

Rufus B. von KleinSmid, A.M., Sc.D.	President of the University; Director
Estes P. Taylor, B.S.A.	Assistant Dean, College of Agriculture
Robert H. Forbes, Ph.D.	Research Specialist
John J. Thornber, A.M.	Botanist
Albert E. Vinson, Ph.D.	Biochemist
George E. P. Smith, B.S., C.E.	Irrigation Engineer
Richard H. Williams, Ph.D.	Animal Husbandman
Walter S. Cunningham, B.S.	Dairy Husbandman
Charles T. Vorhies, Ph.D.	Entomologist
G. E. Thompson, B.S.A.	Agronomist
F. J. Crider, M.S.	Horticulturist
Clifford N. Catlin, A.M.	Assistant Chemist
*Arthur L. Enger, B.S., C.E.	Assistant Irrigation Engineer
Walker E. Bryan, M.S.	Assistant Plant Breeder
C. O. Bond, B.S.A.	Assistant Plant Breeder
W. E. Code, B.S.	Assistant Irrigation Engineer
A. F. Kinnison, B.S.A.	Assistant Horticulturist
R. S. Hawkins, B.S.A.	Assistant Agronomist
Austin W. Morrill, Ph.D.	Consulting Entomologist
D. C. George	Consulting Plant Pathologist
Leland S. Parke, B.S.	State Leader Boys' and Girls' Clubs
Mary Pritner Lockwood, B.S.	State Leader Home Demonstration Agents
W. M. Cook, A.B.	State Leader County Agricultural Agents
A. B. Ballantyne, B.S.	County Agent, Graham-Greenlee Counties
C. R. Fillerup	County Agent, Navajo-Apache Counties
De Lore Nichols, B.S.	County Agent, Coconino County
J. R. Sandige, B.S.	County Agent, Gila County
C. R. Adamson, B.S.A.	County Agent, Cochise County
H. C. Heard, B.S.	County Agent, Maricopa County
J. W. Longstreth	County Agent, Yuma County
Leo L. Laythe, B.S.	County Agent, Pima-Pinal Corнties
Agnes A. Hunt	Assistant State Leader Boys' and Girls' Clubs
Edward B. Oxley, B.S.	County Club Leader, Maricopa County
Hazel Zimmerman	Home Demonstration Agent, Pima-Pinal Counties
Florence D. Sandige, B.S.	Home Demonstration Agent, Gila County
Amy L. Dinsmore, B.S.	Home Demonstration Agent, Maricopa County
Flossie D. Wills, B.S.	Home Dem. Agent, Graham-Greenlee Counties
Grace I. Tufts	Home Demonstration Agent, Yuma-Yavapai Counties
Louise Sporleder	Home Demonstration Agent, Cochise County
Nora Lamoreaux	Home Demonstration Agent, Apache County

The Experiment Station offices and laboratories are an integral part of the University at Tucson. The Salt River Valley Experiment Station Farm is situated one mile west of Mesa, Arizona. The date palm orchards are three miles south of Tempe (co-operative U. S. D. A.) and one mile southwest of Yuma, Arizona, respectively. The experimental dry-farms are near Cochise and Prescott, Arizona.

Visitors are cordially invited, and correspondence receives careful attention.

*On leave.

LETTER OF TRANSMITTAL

To His Excellency, The Governor of Arizona,
Executive Department, Phoenix, Arizona.

SIR: I have the honor herewith to transmit to you the Twenty-ninth Annual Report of the Arizona Agricultural Experiment Station, of the College of Agriculture, University of Arizona, for the fiscal year ending June 30, 1918.

This report is made in accordance with the Act of Congress, approved March 2, 1887, establishing Agricultural Experiment Stations, and the Act of Congress, approved March 16, 1906, known as the Adams Act.

Faithfully yours,
R. B. VON KLEINSMID,
President.

CONTENTS

ILLUSTRATIONS

ROBERT HUMPHREY FORBES

Chemist of Experiment Station, September 1, 1894 to May 6, 1899; Director May 6, 1899 to February 15, 1918; Research Specialist, on leave, February 15, 1918,—

Twenty-ninth Annual Report

ADMINISTRATION

The period covered by this report is one of particular interest from an agricultural standpoint for it was during this time that our country was engaged in the war.

Never before were farmers and stockmen of Arizona spurred on for increased production as during this time. The dire need of food and supplies for domestic consumption, for our troops abroad and for our Allies, made agricultural effort a pleasure from a patriotic standpoint. Prices of agricultural products have never been better.

A rapid adaptation to the needs of the war period was effected by those engaged in agricultural production in Arizona. The very definite program of production outlined and advised as a result of the Agricultural Mobilization Conference called by the College of Agriculture of the University of Arizona, and held at Tucson on April 20 and 21, proved to be the guiding plan of the farmers, stockmen, and housewives during the year following.

Arizona farmers first set about the production of crops to support local mining industries which were producing war materials. Agricultural and livestock products were also adopted which were in greatest demand under the conditions of war and which were peculiarly adapted to the State. In this class came Arizona wool and cotton. Advantage was taken of the double cropping possibilities of southern Arizona districts and a greater utilization of the farming land was secured than ever before.

Wheat, the great war crop, has been liberally grown as well as the grain sorghum crops so well adapted to the Southwest for silage and emergency human food. Potatoes, beans, fruits, and vegetables have entered largely into the year's agricultural output during the war period.

Livestock, including beef, mutton, dairy products, pork, and poultry products, have been produced in quantity in spite of a continuation of the drouth period which has made feed for livestock scarce and expensive. The loss of livestock upon the range due to shortage of forage has been serious with many and has greatly emphasized the need of better range livestock management and the growth of supplemental feeds and silage.

This period of continued drouth has also affected the dry farmer who is dependent partially or wholly upon rainfall. It has also reduced the amount of storage water and stream flow for irrigation and made greater economy of water necessary.

During the period of this report, the most notable change by farmers and housewives in methods has been in the direction of economy and conservation. Remarkable agricultural achievements mark the period in spite of the handicap of serious labor shortage. Arizona agriculture, thus put to the test under the pressure of war, has achieved results which would have been impossible otherwise. The doing of things in new and better ways by farmers will bring permanent good to our agriculture.

THE AGRICULTURAL EXPERIMENT STATION FARMS

A very complete description of the Experiment Station farms, accompanied by maps of the properties, was published in the Twenty-eighth Annual Report. Since that time various minor improvements have been effected but no large developments have taken place, due to the exigencies of war work and numerous changes in the personnel of the Agronomy Department. Cultural operations, as usual, have been pursued on the farms and are reviewed in the report of the Agronomist.

Several of the farms were inspected and reported upon by committees of the Board of Regents. A resume of the reports of these committees follows:

TEMPE COOPERATIVE DATE ORCHARD

This property was visited by Member William Scarlett during the harvest season of 1918. Mr. Scarlett found that no particular improvement in the way of buildings had been made; that the crop of dates had been profitable; and that the farm was becoming able more and more to take care of itself. Certain experiments looking largely toward the production of seed from which dates can be grown were progressing.

The conditions which some time ago threatened the existence of the farm and a large section of the farming community round about, in the rise of the water level of the valley, were being corrected by a drainage ditch and, apparently, that danger had largely passed. The date crop appeared not to have been affected.

SALT RIVER VALLEY FARM

The University Experiment Farm near Mesa also was visited by Mr. Scarlett. He reported that extensive experiments in the growing of peas and beans for fodder and as renewers of the soil had been carried on in the course of the year. Valuable experiments regarding the spacing of cotton plants had led to conclusions that will be of great benefit to the future cotton industry of the Valley. The people of the Valley more and more had been making use of the farm. Every day numerous telephone calls had been received and visitors averaged three or four daily. The farm was found to be answering more and more the purpose for which it had been created—a demonstration-experiment farm for the Valley. In the course of the year there had been several improvements on the farm. A 120-ton capacity silo had been erected; a new metal grain bin had been installed; new wagon scales purchased, and a small cottage erected. Much new machinery had been bought in the course of the year and the mechanical side of the farm was first class.

The needs of the farm were a central cottage for the foreman, a barn for machinery, and a shed for storing hay. Otherwise, the farm was in excellent condition and numerous experiments of various kinds were going on. It was suggested that all experiments bordering the highway be clearly marked so that people going by might understand exactly what was taking place.

YUMA DATE ORCHARD AND HORTICULTURAL STATION

This property was visited December 14, 1918, by Member Bettie White. Mrs. White reported a marked degree of efficiency in the management of this station. Not only the date orchard, but various other phases of work, such as the winter garden, rotation of crops, etc., showed ability, energy, and foresight. The station was admirably located, having fine Warrenite roads on two sides. The work was proving of great value to the surrounding country as numbers of persons seeking information call at the station almost daily. The improvements were in good condition with the exception of a shed used as a barn. This was reported to be of little value as a means of protection to stock and detracted materially from the otherwise pleasing appearance of the grounds.

The limited acreage seemed unfortunate to the committee, there being but 13 acres in the tract. The purchase of additional land was recommended.

THE SULPHUR SPRING VALLEY DRY-FARM

This farm was also visited by Member White December 21, 1918. Seventy of the 160 acres were found in cultivation. All land provements were found to include a comfortable, seven-roomed was enclosed with barbed wire and rabbit-proof fences. The imresidence and other necessary farm buildings; a well, equipped with a splendid pump and pump house; two silos of 47 tons capacity each, one built in 1916, the other in 1918. The farm was well equipped with stock and implements. Tests were being made in growing wheat, barley, oats, and sweet clover. About three acres were in orchard, 3 years old, containing apples, pears, peaches, apricots, nectarines, and six varieties of grapes. The culture of tepary beans was found to be, perhaps, the most successful test that has been made on the farm. This crop was planted July, 1916, harvested October, 1916, and yielded a net profit of $37.89 per acre. Mr. Spaulding, who had been on the farm about three years, informed the committee that thus far no experiments in dry-farming, unaided by some irrigation, had proved sufficiently profitable to warrant advising prospective farmers to rely on dry-farming as a means of support; however, he called attention to the fact that the well on the farm was only 100 feet deep and had been drilled to the third stratum of water. The supply of water was sufficient for domestic purposes and with the rainfall would irrigate ten acres.

The number of visitors at this farm was limited. This was believed to be due to two facts; the thinly populated section in which the farm is located and the narrow limits within which experiments have been carried on.

On both the Yuma Date Orchard and the Sulphur Spring Valley Dry-farm failures as well as successes had been met in experimental work. This was forcibly illustrated by an immense date palm in the Yuma Orchard. The tree was large and laden with fruit, but the quality rendered is of no value. In closing, the committee reported:

We believe that failures demonstrate facts of as much value as the successful work. The "danger signal" is as necessary as the "sign board" that points to the path of safety; hence, we consider the work on the experimental farms, under efficient management, of inestimable value and believe the money thus spent by the State is a wise investment.

PERSONNEL

The Administration and Staff of the Experiment Station has suffered numerous changes during the fiscal year. Director R. H. Forbes, after more than twenty years efficient and devoted service as Chemist, Director of the Agricultural Experiment Station, and Dean of the College of Agriculture, has been appointed Research Specialist on leave so that his wide experience and exact knowledge of semi-arid, subtropical agriculture might be made available to one of our Allies. Director Forbes has taken charge of experimental work for the Société Sultanienne D'Agriculture at Cairo, Egypt. Without doubt this cooperation between two countries with almost identical cultural conditions will result in great mutual benefit.

Following the resignation of Director Forbes, the President of the University assumed the duties of Dean and Director of the College of Agriculture.

The Department of Agronomy has lost Mr. H. C. Heard, Assistant Agronomist, who has conducted the work of the department since the resignation of Dr. Macfarlane. Mr. Heard has been appointed County Agricultural Agent for Maricopa County. In May Professor G. E. Thompson was appointed Agronomist in charge of the department. The Department of Horticulture has lost Mr. S. B. Johnson, Assistant Horticulturist, who has entered commercial work. June 1 Professor F. J. Crider, Horticulturist, took charge of the department..

Minor changes have taken place in other departments and at several of the Experiment Station farms. Mr. H. E. Webber, assistant in Plant Breeding, resigned to enter military service, and Mr. C. O. Bond has been appointed to the position. Mr. C. R. Adamson, assistant in Animal Husbandry, has resigned to become County Agricultural Agent for Cochise County. After the resignation of Mr. F. H. Simmons, foreman of the Tempe Date Orchard, Mr. W. O. Hodgson was placed in charge to market the crop. Mr. G. F. Williams succeeded Mr. Hodgson in this position when Mr. Hodgson was appointed foreman of the University Farm at Tucson, left vacant by the resignation of Mr. J. B. McGuffin. This position he later resigned to enter Y. M. C. A. war work. Mr. G. J. Darling succeeded as foreman of the University Farm. At the Prescott Dry-Farm, Mr. T. F. Wilcox was appointed foreman. Changes in the personnel of the Extension Service are noted in the report of the Director.

PUBLICATIONS

Publications by the Experiment Station Staff for the year, including Annual Reports, Bulletins, Timely Hints for Farmers, and Scientific and Technical Papers are as follows:

Bulletin 81, November 15, 1917. How to Combat Rabbits, Gophers, Prairie Dogs, Coyotes, Ants, and Grasshoppers. —By Arthur L. Paschall

Bulletin 82, December 1, 1917. Johnson Grass Control. —By H. C. Heard

Bulletin 83, December 20, 1917. Poisonous Animals of the Desert. —By Charles T. Vorhies

Twenty-eighth Annual Report, December 31, 1917. —By the Station Staff

Bulletin 84, February 1, 1918. Dry-Farming in Arizona. —By A. M. McOmie and Others

Bulletin 85, March 1, 1918. A Study of Marketing Conditions in the Salt River Valley. —By J. H. Collins

Timely Hints for Farmers:

No. 127. July 15, 1917. Raising Dairy Calves. —By W. S. Cunningham

No. 128. August 15, 1917. Head Lettuce Growing in Southern Arizona. —By S. B. Johnson

No. 129. September 15, 1917. Curing Meat on the Farm. —By R. H. Williams

No. 130. October 15, 1917. How Much Seed to Sow. —By S. B. Johnson

No. 131. November 15, 1917. Sanitary Water Supply for the Home. —By J. J. Thornber

No. 132. December 15, 1917. Hairy Peruvian Alfalfa. —By W. E. Bryan

No. 133. January 1, 1918. A Little Farm Well-Tilled. —By R. H. Forbes

No. 134. January 15, 1918. Unproductive Soils, Their Cause and Management. —By A. E. Vinson

No. 135. February 1, 1918. Soapweed or Palmilla (*Yucca elata*) as Emergency Forage. —By J. J. Thornber

Scientific and Technical Papers:

Notes on the Fauna of Great Salt Lake. American Naturalist, August, 1917. —By Charles T. Vorhies

Grading Land for Furrow Irrigation. Western Engineering, IX, 1 Jan. 1918. —By G. E. P. Smith

PROJECTS

The projects listed in the Twenty-eighth Annual Report for the year 1917-1918 have been continued, or completed and several new projects have been approved. The list of projects approved for the year 1918-1919 follows.

1. Groundwater supplies and pump irrigation in the Casa Grande Valley.
State fund. G. E. P. SMITH.

2. A study of pumping machinery to determine fundamental facts relating to the action and efficiency of various types of pumping machinery.
Adams fund. G. E. P. SMITH.

3. The relation of evaporation rate to the duty of water; and the study of the factors controlling evaporation.
Adams fund. G. E. P. SMITH.

4. A study of the culture and management of date orchards with special reference to the improvement of the yield and quality of the fruit and the rooting of offshoots.
State fund. F. J. CRIDER.

5. A study of the cultural methods with citrus fruits.
Hatch fund. F. J. CRIDER.

6. A study of the effect of different methods of orchard management on the growth, yield, and size of the fruit of the olive.
Hatch fund. F. J. CRIDER.

7. A study of conditions affecting the production of fall Irish potatoes in southern Arizona.
State Horticultural and Hatch funds. F. J. CRIDER.

8. A study of spinach as a market garden crop for southern Arizona.
State Horticultural fund. F. J. CRIDER.

9. A study of cultural and storage methods of the sweet potato.
State and Hatch funds. F. J. CRIDER.

10. Miscellaneous horticultural studies including stone fruits, citrus fruits, vine fruits, small fruits, pomes, nuts, nursery stock, ornamentals, vegetables, etc.
State and University of Arizona Maintenance funds. F. J. Crider.

11. Student practice garden and greenhouse laboratory, University Campus.
State Maintenance fund. F. J. Crider.

12. An intensive quarter acre garden plat at Yuma Experiment Farm.
State Horticultural fund. F. J. Crider.

13. The same as Project 9. At Cochise Dry-Farm.
Cochise Dry-Farm and General Farm fund. F. J. Crider.

14. The same as Project 9. At Prescott Dry-Farm.
Prescott Dry-Farm and General Dry Farm fund. F. J. Crider.

15. The production by plant breeding methods of a superior variety of alfalfa, free, if possible, from the hairiness and stemmy character of Peruvian alfalfa. Methods of determining the water requirements of different varieties of alfalfa; and the biological analysis of alfalfa into its hereditary units with manipulation of these units in constructive breeding, is within the scope of this study.
Adams, State Plant Introduction and Breeding funds. W. E. Bryan.

16. The hybridization and selection for Arizona conditions of a superior grain sorghum combining, if possible, the following characters: large, upright head; uniform ripening; upright stalk; dwarf habit; earliness; drought resistance; and large individual grains.
State Plant Introduction and Breeding fund. W. E. Bryan.

17. A physiological and biological study of southwestern varieties of Indian corn to determine heat and drought resistant characters; and biological analysis of these corns with a view to the use of hereditary characters in constructive plant breeding operations.
Adams fund. W. E. Bryan.

18. The biological analysis of the genus Phaseolus and the improvement of varieties of beans by selective breeding. This project includes the improvement of Tepary beans.
Adams, and State Plant Introduction and Breeding funds. W. E. Bryan.

19. A study and comparison of durum, poulard, and bread wheats with biological analysis and constructive breeding operations for the purpose of developing a bread wheat which will retain its hardness under southwestern conditions.
Adams, and State Plant Introduction and Breeding funds. W. E. Bryan.

20. The production by crossing, selection, and inbreeding of Deglet Noor dates which will be of high quality and ripen naturally under Arizonan conditions.
State Date Orchard funds. W. E. Bryan.

21. Study of rodent control on grazing ranges.
Adams fund. C. T. Vorhies.

22. Development of a collection of economic insects.
Hatch fund. C. T. Vorhies.

23. Economic study of grasses and grass-like plants.
Hatch fund. J. J. Thornber.

24. Botanical and economical study of poison range plants.
Hatch fund. J. J. Thornber.

25. A study of range grass improvement through fencing.
Hatch fund. J. J. Thornber.

26. Tamarisks for growing in alkaline soils.
Hatch, and State Plant Introduction funds. J. J. Thornber.

27. A study of certain mulberries with reference to fruit production, the quality of fruit and its possible use in the home or in the yard.
Hatch, and Plant Introduction and Breeding funds. J. J. Thornber.

28. To determine the practicability of growing pistach trees and nut trees in the Southwest.
Hatch, and Plant Introduction and Breeding funds. J. J. Thornber.

29. Native wild fruits and nuts as stock for grafting purposes.
Hatch, and Plant Introduction and Breeding funds. J. J. Thornber.

30. Experiments in the growing of jujube nuts under our conditions.
Hatch, and Plant Introduction and Breeding funds. J. J. Thornber.

31. A study of trees and shrubs suitable for ornamentation, wind-break, and shade at the following locations:

(a) Prescott Dry-Farm, Prescott.
(b) Cochise Dry-Farm, Cochise.
(c) Tempe Date Palm Orchard, Tempe.
(d) University Farm, Tucson.

Hatch fund. J. J. Thornber.

32. Identification and studies of the life histories of certain fungi causing rot in date fruits.

Adams fund. J. G. Brown.

33. Feeding dry farm silage to range cattle to study the effectiveness of this ration for carrying cattle over short range.

Hatch fund. R. H. Williams
W. S. Cunningham

34. Economic combinations of high and low-priced feeds for meat production.

Hatch fund. R. H. Williams
W. S. Cunningham

35. A study of livestock management on the range; the present status of livestock production on the range.

Hatch fund. R. H. Williams,
W. S. Cunningham.

36. Systems of livestock farming; the coordination of livestock farming into units best suited for results, including: (1) Sheep raising on irrigated farms in Arizona; (2) Hog raising on Arizona farms; (3) A combination of hogs, beef cattle, and poultry on irrigated land; (4) Special cattle and sheep feeding operations.

Salt River Valley Farm Maintenance fund. R. H. Williams,
W. S. Cunningham.

37. Lambing ewes on irrigated farms; to ascertain the ration best suited for feeding range ewes during the lambing period in irrigated valleys.

Salt River Valley Farm Maintenance fund. R. H. Williams,
W. S. Cunningham.

38. Supplements to silage for wintering range cattle at the Cochise Dry-Farm. Cochise Dry-Farm fund. R. H. Williams,
W. S. Cunningham.

39. Cooperative crop experiments on farmers' lands, dry-farming fund.
G. E. Thompson.

40. A continuation of study at the Sulphur Spring Valley Dry-Farm.
Sulphur Spring Valley Dry-Farm fund. G. E. Thompson.

41. A continuation of study at the Prescott Dry-Farm.
General Dry-Farm and Prescott Dry-Farm funds G. E. Thompson,

42. A study of culture and varieties of legumes adapted to southwestern conditions.

Salt River Valley Farm and Hatch funds. G. E. Thompson,

43. A study of the varieties and methods of culture of Indian corn and the various sorghums.

Salt River Valley Farm and Hatch funds. G. E. Thompson,

44. The culture and field management of Egyptian cotton.
Salt River Valley Farm, Yuma Date Orchard, and Hatch funds.
G. E. Thompson.

45. The culture and management of winter and spring grains, including wheat, oats, and barley.

Salt River Valley Farm and Hatch funds. G. E. Thompson.

46 Effect of dynamiting field soil on field crops.
General Dry-Farm fund. G. E. Thompson.

47. A varietal and cultural test of grain and forage crops and of grasses and miscellaneous crops.

Salt River Valley Farm fund. G. E. Thompson.

48. Grasshopper control.

Hatch fund. A. W. Morrill.

49. Cotton square stainer or tarnished plant bug control.
Hatch fund. A. W. MORRILL.

50. Ozonium root disease of cotton and other crops. Occurrence, life history, and methods of control of the disease.
Adams fund. D. C. GEORGE.

51. Gummosis of stone fruit trees. Occurrence, causes and methods of control of this disease.
Hatch fund. D. C. GEORGE.

52. Effect of weather conditions on processing and pasteurizing dates.
State, Hatch, and Date Orchard Sales funds. A. E. VINSON, C. N. CATLIN.

53. Alkali soil studies. Concomitant soil conditions that affect the toxicity of black alkali and means for the amelioration of the effects of alkali on soil and plant.
Adams fund. A. E. VINSON, C. N. CATLIN.

54. Miscellaneous routine chemical analyses.
Adams fund. A. E. VINSON, C. N. CATLIN.

55. Reclamation of alkali land at the University Farm.
University Farm Maintenance Fund A. E. VINSON, C. N. CATLIN.

56. Meteorological observations.
Hatch funds. C. N. CATLIN.

FINANCIAL

Increased costs incident to our entering the war have necessitated extreme economy and the curtailment of much work that had been planned. The resources of the Station for the fiscal year, 1918-1919, remain the same as reported in the Twenty-eighth Annual Report for the biennium beginning July 1, 1917, as follows:

College of Agriculture and Experiment Station	1917-18	1918-19
Instruction	$ 3,650.00 i.	$ 3,650.00 i.
Administration	7,500.00 i.r.	7,500.00 i.r.
Improvements	5,450.00 i.r.	5,450.00 i.r.
Greenhouse for agriculture		2,500.00 i.r.
Extension Service (not Smith-Lever)	1,000.00 e	1,000.00 e
" " (with " ")	4,574.59 e	6,004.15 e
University of Arizona Farm—Maintenance	11,850.00 i.	11,850.00 i.
" " " " —Improvements	2,300.00 i.	2,300.00 i.
Dry-Farming Investigations—Maintenance	10,140.00 r.	10,140.00 r.
" " —Improvements	500.00 r.	
Plant Introduction and Breeding Investigations	3,000.00 r.	3,000.00 r.
Tempe Date Orchard—Maintenance	2,330.00 r.	1,770.00 r.
" " " —Improvements	600.00 r.	600.00 r.
Underflow Investigations	2,400.00 r.	2,400.00 r.
Yuma Date Orchard and Horticultural Station		
—Maintenance	2,600.00 r.	2,600.00 r.
—Improvements	675.00 r.	400.00 r.
Salt River Valley Farm Fund—Maintenance	10,000.00 r.	10,000.00 r.
Agricultural Printing	4,000.00 i.r.	4,000.00 i.r.
Total	$72,569.59	$75,164.15

Those items marked *i* are intended primarily for instructional purposes; those marked *r* are intended for the research work of the station; while those marked *e* are for extension purposes.

Available resources for the year ending June 30, 1918, are as follows:

Hatch Fund from U. S. Treasury		$15,000.00
Adams Fund from U. S. Treasury		$15,000.00
Sales funds 1917-1918 as follows:		
Salt River Valley Farm		$ 9,768.66
Yuma Date Orchard		1,153.79
Tempe Date Orchard		4,860.45
Prescott Dry-Farm		294.50
Sulphur Spring Valley Dry-Farm		73.57
Northern Arizona Dry-Farm		25.50
Hatch Sales Balance 1916-17	$2,609.01	
" " Collections	2,518.99	5,128.00
Dry-Farming Fund (Supervision)	$ 3,000.00	
" " (Prescott)	3,600.00	
Date Palm Orchards	2,630.00	
Yuma Horticultural Station	3,275.00	
Salt River Valley Farm	10,000.00	
Underflow Water Investigation	2,400.00	
Sulphur Spring Valley Dry-Farm	3,700.00	
Maintenance	11,150.00	
Plant Introduction and Breeding	3,000.00	
Printing	4,000.00	46,845.00
		$98,149.47

EXPENDITURES BY FUNDS AND SCHEDULES FOR THE YEAR ENDING JUNE 30, 1918

Abstract	State appro-priations	Sales fund	Hatch fund	Adams fund	Total
Salaries	$14,243.36	$ 1,838.91	$11,192.81	$11,940.59	$39,215.67
Labor	10,009.00	9,749.54	133.17	749.39	20,641.10
Publications	3,986.55	173.89	1,051.51		5,211.95
Postage and stationery	340.96	956.83	765.51	79.80	2,143.10
Freight and express	238.14	337.45	71.47	333.85	980.91
Heat, light, water, and power	301.40	183.80	1,073.17		1,558.37
Chemicals and laboratory supplies	.76	25.10		125.62	151.48
Seeds, plants, and sundry supplies	1,035.11	1,242.56	96.41	146.89	2,520.97
Fertilizers	584.61	75.38			659.99
Feeding stuffs	103.70	220.39		40.92	365.01
Library		10.95	138.70	10.23	159.88
Tools, machinery, and appliances	3,333.20	1,089.74	12.25	73.46	4,508.65
Furniture and fixtures	11.80	65.75	23.99		101.54
Scientific apparatus and specimens	36.50	17.50		882.53	936.53
Livestock		675.00			675.00
Traveling expenses	2,598.99	1,211.00	441.01	607.72	4,858.72
Contingent expenses	242.33	63.09			305.42
Buildings and land	2,872.62	2,297.98		9.00	5,179.60
	$39,939.03	$20,234.86	$15,000.00	$15,000.00	$90,173.89

A. E. Vinson,

AGRONOMY

During the fiscal year ending June 30, 1918, experimental work in Agronomy has been carried on the Salt River Valley Farm near Mesa, on the Prescott Dry-Farm near Prescott, on the Cochise Dry-Farm near Cochise, and on the grounds of the Yuma Date Orchard and Horticultural Station. Demonstration work along agronomic lines on plats used for teaching purposes has been carried on the University Farm near Tucson.

SALT RIVER VALLEY FARM

The experimental work with Johnson grass reported upon in the Twenty-eighth Annual Report has been completed and results summarized and published in Bulletin No. 84 by Professor H. C. Heard. During the year covered by this report the work of the Salt River Valley Farm has been more varied than in previous years. Corn, long staple cotton, wheat, oats, barley, kafir, milo, hegari, darso, sumac sorghum, feterita, Sudan grass, alfalfa, cowpeas, soy beans, velvet beans, field peas, and several varieties of table beans have been among the crops tested. In order to handle this large variety of crops it has been necessary to double crop a considerable portion of the land of the experiment farm. Practically all of the acreage given to wheat during the winter and spring was planted during the early summer to some one or more of the various legumes mentioned above. A small portion of the wheat and barley land was planted to kafir, milo, and other sorghum crops. We realize that such a system of double cropping means a severe drain upon the soil fertility, and provision has been made to maintain the soil in good tilth and in a fertile condition by plowing under green manure and by rotating the crops in a careful manner. Some long time experiments covering this feature are now being arranged, which in course of time will become valuable demonstrations for the Salt River Valley and the State at large.

During the season covered by this report one difficulty of unusual severity has been encountered. This difficulty was the extremely destructive work of the lesser corn stalk borer. Practically every variety of beans planted on the experiment farm during the season was destroyed by this insect. Most of the varieties of cowpeas were attacked to a lesser degree. All of the sorghums were injured and in some cases the stand materially lessened. Apparently due to the weakening of the stalks, a considerable portion of the milo fell down and lodged badly just previous to harvest time. Examination of the stalks that had fallen down showed that in nearly every case these stalks had been injured by the lesser corn stalk borer when the plants were small.

Unless a practical method of controlling this insect can be worked out soon it promises to become a serious menace.

LEGUMES

With the exception of tests made with cowpeas previous trials with annual legumes have resulted largely in negative results. As a basis for further work 17 varieties of cow peas and the same number of soy beans were tested on plots of ground ranging in size from 1/20 acre to 1 acre. These varieties were as follows:

COW PEAS	SOY BEANS
Brabham	Mammoth Yellow
Groit	Virginia
White Crowder	Arlington
Brown Crowder	Chiquita
Wonderful	Manchu
Early Ramshorn	Biloxi
Potomac	Peking
Arlington	Early Brown
Monetta	Tarheel Black
Early Buff	Lot 3 Manchuria
Early Catjang	Hollybrook Early
Two Crop Clay	Fancy Yellow
Clay	Ito San
Blackeye	Wilson Early
Cream	Wilson No. 5
Red Ripper	Tokio
Taylor	Blackeyebrow

Careful observation throut the growing season and at harvest time indicates that the soy beans are decidedly inferior in value to the cow peas for the conditions of the Salt River Valley. Altho some varieties of the soy beans made a creditable growth practically every variety produced an inferior quality of beans. The beans shrivelled badly and for the most part are unmarketable. It is possible that this shrivelling is due to the very dry atmosphere, since the ground was kept in first class condition thruout the time that the soy beans were growing and maturing. The three varieties of soy beans giving most promise this year are the Biloxi which is a rather large late growing and upright variety, the Wilson No. 5 which is a medium sized and medium early maturing variety but which has the disadvantage of shattering rather badly, and the Ito San. The latter is a small, early maturing variety but one of the few that produced a good quality of beans.

Of the cow pea varieties a number gave indications of being valuable and profitable under average farm conditions of the Salt River Valley. Groit and Brabham cow peas planted after wheat both produced an excellent green manure crop. Groit produced the most seed but Brabham has a little advantage from the green manure standpoint. The Red Ripper variety, tried under a number of conditions, was uniformly good. Two Crop Clay was very promising and a considerable number of other varieties are worthy of further trial. The results secured this year with cow peas would indicate that this crop can be used successfully as a green manuring

Fig. 2. Cow peas—Salt River Valley Farm.

crop following wheat. It is quick enough in growth to allow fall planting and working of the ground to a good seed bed in time for reseeding to wheat or other small grains.

Inoculation tests were made with both cow peas and soy beans. Further tests are necessary, however, before we are justified in publishing the results.

FIELD PEAS

A limited number of field peas were planted in the fall of 1917 and harvested in the spring of 1918. The variety called Warsaur proved best. It made a good vine growth and also produced seed of marketable quality.

VELVET BEANS

The following varieties of velvet beans were planted on June 14: Early Bird, Yokohama, One Hundred Day, Chinese White, and Osceola. A study of these varieties during the growing season indicated that the Early Bird and One Hundred Day were two names for the same variety. The Chinese White variety failed to make a satisfactory stand and was plowed up. The Yokohama made a poor stand but the few plants that did germinate grew well. The Osceola is a promising variety, and deserves further trial. The results indicate that velvet beans should be planted earlier in the season.

TABLE BEANS

The following varieties of table beans were planted on a field scale: Pinto, Bates, Tepary, and Pink. As mentioned earlier in this report every one of them was severely injured by the lesser corn stalk borer. The only varieties that were not plowed up due to this injury were the Teparies and the Pintos. As was proven later, the Pintos were so badly damaged that they should have been plowed up and the yield of Teparies was probably reduced 60 per-cent. Of all the varieties of table beans tested this year, Teparies were the most promising and they were far from satisfactory.

ALFALFA

There are 26 acres in the Salt River Valley Farm now given over to the growing of alfalfa. Ten of these will be plowed up this winter. This alfalfa has been handled principally as a commercial crop. Its effect in smothering out Johnson grass is being noted, and it is our purpose a little later to grow pure Hairy Peruvian seed for distribution.

CORN

During the season of 1918 all varieties of corn tested were planted after wheat or other small grain, plantings being made the latter part of July. The varieties tested were as follows: Mexican June, Sacaton June, Hammond's Select, Reid's Yellow Dent, Giant Red Cob, Giant White Two Ear, Hasting's Prolific, Frazee's Prolific, Mosby's Prolific, Improved Leaming, and a special unnamed variety the seed of which was secured from Mexico.

Due to some unusual and, so far as we are concerned, unexplainable condition not one of these varieties was satisfactory this year. The complaint was general thruout the Salt River Valley that it was a poor corn season. The best of the varieties were those planted from carefully selected strains of Mexican June corn. None of the large late growing varieties, such as Giant Red Cob, Giant White Two Ear, etc., were worth while. The Frazee's Prolific, which was sent to us with very high recommendations, proved no better than the others and inferior to Mexican June. The year's results as well as previous results secured would indicate that various varieties of sorghums properly handled are more profitable than corn under the conditions of the Salt River Valley.

SORGHUMS

The variety tests of sorghums were incomplete yet very promising. Of the grain sorghums the varieties tested were dwarf milo, hegari, feterita, kafir, and a variety developed by the Oklahoma Station called "darso." This latter variety has been recommended for a combined grain and forage crop, but this season's results indicate that it is inferior to milo, hegari, or kafir from the grain standpoint, and inferior to kafir, hegari, or sumac sorghum from the fodder standpoint. The only variety of forage sorghum tested was the sumac variety and as the seed was purchased locally the variety was badly mixed and, while promising, the results are not conclusive. Hegari yielded 65 bushels per acre, and kafir 40. The milo averaged 72 bushels per acre. The milo and hegari are quick to mature, and were fully ripened some little time before frost. The kafir was somewhat immature when frosted the last of October. The hegari stands up well. The grain is produced on a straight neck while the milo grain is produced on a crooked neck, and this gives a decided advantage to the hegari.

WHEAT

Wheats grown on the Salt River Valley Farm yielded well and were very profitable crops. The Early Baart variety averaged 45 bushels per acre. The principal acreage was devoted to this variety. Various tests as to rate of seeding, date of seeding and quantity of water applied were conducted with this variety, but it seems inadvisable to publish the results until the figures for several years have accumulated. Club wheat made a good yield, but was badly mixed and considerably affected by smut, and of inferior baking quality to the Early Baart. Red Turkey yielded well, being a close second to

Early Baart. Two varieties of macaroni gave very excellent yields but under present conditions there is no established market for this variety in the Salt River Valley and it is not advisable to plant this variety generally at the present time. Sonora wheat proved reasonably good, but the quality of grain was inferior to Early Baart and the yield was also less.

Fig. 3. Club wheat and Early Baart wheat—Salt River Valley Farm

OATS

Two varieties of oats were grown on a commercial basis. The varieties were San Saba, and Red Texas. Red Texas proved the best, the yield ranging between 90 and 95 bushels per acre.

BARLEY

Two varieties of barley were grown, namely, Common Six Row, and Wisconsin Pedigree No. 6. The latter variety produced a heavy yield of grain but the straw just below the head was very weak and many of the heads broke off and fell to the ground before harvest time. Consequently the yield secured was less than on the Common Six Row barley. This is a common fault of the Wisconsin No. 6 barley in this section of the country, and apparently will eliminate it as a commercial crop. The yield of Common Six Row barley averaged 66 bushels per acre, thus making a very profitable and satisfactory small grain crop.

COTTON

No short staple cotton was grown. Nineteen acres were given over to the growing of Egyptian long staple of the Pima variety. One acre of this was volunteer, that is, it was allowed to grow from the stubs of the previous year's planting. This acre looked very promising during the growing season, producing the first blossoms and open bolls of any cotton on the farm. However, examination of the plants at picking time showed that a considerable number of bolls were moldy or rotten. The fiber is weak and short, and the percentage of lint to seed is small. This year's results would indicate that it is decidedly unprofitable to grow volunteer cotton. Rate of thinning experiments were conducted, also date of planting experiments.

MISCELLANEOUS CROPS

A number of miscellaneous crops were tried on a small scale during the year. These crops include flax, buckwheat, castor beans, rye, rape, and kale. Two or three varieties of flax gave considerable promise. The buckwheat would be considered a complete failure. The castor beans, altho planted late, made an extremely vigorous growth and produced considerable seed. Rye was less valuable than either oats or barley.

PRESCOTT DRY-FARM

The fall of 1917 was extremely dry and it was impracticable to plow the various fields of the Prescott Dry-Farm. Thus the spring planted crops of 1918 were started under a serious handicap. The growing season of 1918 proved less favorable than for a number of years preceding. However, creditable si'age yields were secured from Club Top sorghum, darso, kafir, and milo, also from a number of varieties of corn. The grain yields of all were very light and most of the varieties were harvested for silage purposes. A total of 125 tons of silage was secured. Tests with potatoes this year proved a failure. Likewise Canada field peas were a failure and the results secured with beans were of mediocre value.

A considerable number of sweet clover plantings made at intervals of two weeks failed to germinate uniformly, and no results worth while were secured from them. Sudan grass again proved one of the most promising crops of the farm. Two cuttings of hay were secured and a reasonable seed crop, estimated at 450 pounds per acre was harvested. The season's results substantiate the results of previous years, in that a careful farmer, who is prepared to handle livestock, can grow profitably sufficient forage and silage crops to take care of a reasonable sized herd of livestock, and by this means he will be able to make a good living from a farm of ordinary size.

Fig. 4. Papago sweet corn—Prescott Dry Farm

SULPHUR SPRING VALLEY DRY-FARM

The season of 1918 in Sulphur Spring Valley was extremely dry and followed the dry season of 1917, consequently there was no reserve moisture in the soil. Practically every crop planted under strictly dry land conditions on the experiment farm proved a total failure. The same conditions prevail on the privately owned farms thruout the valleys. Various crops planted with supplemental irrigation gave reasonable yields. Among them may be mentioned kafir, Freed's sorghum, Sudan grass, and cow peas. Soy beans were not satisfactory. Velvet beans made considerable growth, but it is doubtful if they will prove worth while. One plot of sweet clover planted in 1917 made a reasonable growth and a small amount of seed. Yields of wheat, oats, and barley were extremely light. Mexican June corn planted in the early season without irrigation had sufficient moisture to germinate and while it lived thruout the season, at harvest time in the fall much of it was not above 3 feet in height, and the silage yield from the best of it was only

3300 pounds per acre. It did not pay for the time and labor expended on it.

It is planned to change the cropping system on this farm somewhat, omitting the growing of much corn or small grains and depending mainly upon certain of the quickest maturing and most drought resistant sorghums for silage purposes, maintaining the fertility of the soil by the use of legumes plowed under as green manure. Some experiments will be carried to determine the legumes most satisfactory for this purpose, but unless others are found which prove good, tepary beans and cow peas will be used.

During the season the Giant Powder Company of Los Angeles furnished dynamite and a supervisor for the work, and one acre of ground was dynamited for the purpose of breaking up the hard strata of subsoil called caliche. This dynamiting was done on 15 feet centers in holes from 2½ to 3½ feet deep, varying with the depth of the caliche, and using one-half stick of dynamite in each hole. It is planned to grow the same crop on this dynamited acre and on an undynamited adjoining acre for a period of three years, comparing the yields of the dynamited and undynamited area. Freed's sorghum was planted for this purpose this year, but due to the dry season neither area made a growth sufficient to be harvested.

YUMA DATE ORCHARD AND HORTICULTURAL STATION

A limited amount of experimental work was carried on the Yuma Date Orchard and Horticultural Station. The following varieties of sorghums were tested following wheat: Dwarf milo, hegari, kafir, feterita, Sumac sorghum, Collier sorghum, Honey Drip, and White African. Every one of these varieties made a first class growth. The milo made an excellent grain yield and, as was the case in the Salt River Valley, the hegari was the most promising of any grain sorghum. Of the sweet sorghums Honey Drip made a very heavy growth of forage of good quality and was perhaps the best. Sumac sorghum ranked second altho it fell down rather badly.

Some plantings of flax gave considerable promise and will be carried further next year. Two varieties of buckwheat made a small growth but from the practical standpoint were without value. A most excellent green manure crop of tepary beans was grown. A considerable number of vetch varieties were planted in the fall of

1918. Likewise a small area of five different varieties of root crops was tested during the winter of 1918 and 1919, but the results from these crops were not satisfactory.

UNIVERSITY FARM

No regular experimental work was carried on the University Farm, but some demonstration work was conducted and all crops grown upon the farm were utilized for teaching purposes. Several varieties of cotton, several varieties of sorghum, and a few of corn were grown. Cow peas, soy beans, peanuts, hemp, and various other crops were grown on small areas of ground.

ACKNOWLEDGMENT

The experiments with winter grains reported above were outlined and planted under the direction of Dr. R. H. Forbes and Professor H. C. Heard. The summer crop plantings were outlined and planted under the direction of the present agronomist, Dr. Forbes having gone to Egypt, in the service of the British government, in February of the present year, and Professor Heard having left the University to take up County Agricultural work June 1, The present agronomist began work with the Arizona Experiment Station on May 1, 1918.

G. E. THOMPSON,
Agronomist.

BOTANY

WEATHER CONDITIONS AND THE GRAZING RANGE

Due both to the shortage and untimely distribution of rainfall, the year ending with June 30, 1918, was a very serious one for the grazing industry. The rainfall for the period, July to September, 1917, was generally above the average over the State. At Tucson it was 7.09 inches, or 66.6 percent of the total precipitation for the year. Following this, there was practically no rainfall thruout the State during the three months, October to December, inclusive. The excellent growth of grasses and other forage plants that began with the summer rains ended by the first of October. This reduced somewhat the forage growth. However, the long dry fall favored the natural curing of the grasses on the ranges. It was remarked during the winter season that, even with short feed, stock were looking well. With average winter and spring rains, grazing conditions would have been satisfactory.

The winter rainy season began with the second week in January and ended in the latter part of March. It was of rather short duration and the precipitation was about one-half the average amount for this period. A few light showers of almost no consequence fell during the three months, April to June, 1918. In addition to the above shortage of moisture, the summer rains over much of the State for July to September, 1918, inclusive, were only one-half the average precipitation for this season. Much of the rainfall during the past year came as light showers and hence did not wet the soil to any depth.

On account of the above conditions, losses of stock on the ranges have been necessarily heavy, and, but for the fact that many animals have been shipped out to be sold or fed, the losses would have been heavier. A trip over much of the grazing part of the State in July and August, 1918, showed that the grazing ranges, generally, were in very bad condition, and that large numbers of stock must continue to be shipped out before another season or else be fed. The only grazing districts observed to be in fair condition were those about Flagstaff, Williams, Linden, Lakeside, Showlow, Prescott, Pine, and Payson. The rains in September were light; at best they came rather too late in the season, except at altitudes below 4,000 feet, to result in much additional growth.

Some feeding with native forage and concentrates has been done. In a number of instances singed chollas and prickly pears have been fed in considerable quantity on southern Arizona ranges.

With an increasing number of stockmen, the feeding of soapweed or palmilla *(Yucca elata)* as an emergency forage has become established. This is prepared by chopping in small pieces the succulent stems of the yucca, or soapweed plant, as described in a recent Timely Hint published by this department of the Experiment Station. By means best suited to his local conditions, the successful stockman must plan to carry a reserve feed supply sufficient to tide his herd over an unfavorable period of six months or longer. Until he does this his business is destined to continue uncertain. This may be done by putting up hay or silage, growing forage under irrigation, feeding concentrates, maintaining winter irrigated or range pastures, or thru diversified grazing ranges.

Unfavorable seasonal conditions like the present period, which have now extended over one full year, must make clear to stockmen the value of grazing ranges that have a diversified forage growth over those that have but one type of forage growth, as for example, the bunch grasses. Not only have losses of stock generally been less on ranges with a diversified growth of shrubs, grasses, and miscellaneous plants than on ranges with one dominant type of plant growth, but stock have likewise come thru the year in better condition. Such ranges are practically year-round pastures, tho their maximum forage production during favorable seasons may not be as great as that of some of the better perennial grass ranges. During the present droughty period the desert ranges have been of least value, since, outside of the growth of cacti, which alone is not sufficient to sustain animals, they have produced little forage. High mountain ranges, naturally, supply feed for but six or seven months at best, and during the winter period the stock must be moved to the lower altitudes and grazed or fed.

POISON PLANT INVESTIGATIONS

The writer was a member of the squad of livestock specialists that visited the stock raising areas of north central and eastern Arizona during the past summer. Beginning with August 13, three weeks were devoted to this work which was planned by Director Taylor of the Agricultural Extension Service. The subject discussed by the writer was poison plants of our grazing ranges. Prepared specimens of our more important poisonous plants were shown and the commoner poisonous plants of the locality were collected and studied in the field. Eighteen meetings were held and generally a fine interest was shown by stockmen. Particular attention was given towards helping the stockman to know poison plants on the range, and also the most practical means of preventing losses. The greatest interest was shown in the loco weeds which are widespread, growing both at low and high altitudes, and affecting all classes of stock; larkspurs, of which there are several species, all poisonous to cattle but not poisonous to sheep; pingue, or Colorado rubber plant, which grows at rather high altitudes and causes heavy losses among sheep in the spring and fall; western sneezeweed, which also is a high mountain plant and causes the spewing sickness in sheep; and death camas and water hemlock or wild parsnip, which plants are very poisonous to all classes of stock. Water hemlock is spreading in moist canyons in eastern Arizona about Springerville, Eager, Lakeside, Showlow, and Snowflake.

Information was secured concerning a number of plants that are believed by stockmen to be poisonous, but that heretofore have not been regarded as such. It is planned to continue this work on poison plants during the coming summer and publish the results as a bulletin. On this trip important collections of economic plants were made at various places and opportunity was afforded the writer to study additional types of grazing ranges over the State.

PUBLICATIONS

Timely Hint No. 31, "Sanitary Water Supply for the Home," was published in November. This includes a discussion of wells and surface contamination, contamination of water in wells thru seepage, and small storage tanks, and the pollution of water in them. A study of the commoner algae growing in open water tanks in southern Arizona was made. In some instances a layer of these plants six inches deep was found floating in the water. With partial decomposition of this material, such water becomes unsanitary, having a bad odor and a brackish taste. Open tanks require cleaning every month or two in the warmer part of the year. It was found that by covering tanks with wooden tops this plant growth ceased immediately and did not reappear until the tops were removed. Copper sulphate treatment with one part copper sulphate to 1,000,000 parts of water was successful, but since this treatment should be repeated every sixty days, it is not recommended for small lots of water that are are changed frequently thru pumping.

Timely Hint No. 135, "Soapweed or Palmilla *(Yucca elata)* as Emergency Forage," was published in February. This discusses the distribution and abundance of yucca plants over the State with brief botanical notes, the preparation of yucca forage for stock, and chemical and microscopical analyses of chopped yucca forage. A study was made of feeding yucca to cattle as practiced at Willcox, Arizona. An improvised yucca feed chopper was described as made at small expense from a discarded pump-jack. With care a silage cutter may be used. There are at this time several yucca choppers, or yucca shredding machines, on the market, which are desirable for use where a considerable number of stock are to be fed.

The chemical analysis of yucca forage as made by the Chemistry Department of the Experiment Station shows that the protein content is little higher than that of native cactus forage; the fiber was somewhat more than double that in cactus forage, and the carbohydrates or nitrogen-free extract averaged 21.94 percent as against 15 percent in cactus feed. Aside from the fact that yucca forage acts as a succulent when fed along with dry range feed, its value as a feed lies chiefly in the carbohydrates. A microscopic study showed that the carbohydrates present were largely in the form of glucose, which explains the sweet taste of the freshly chopped feed.

Circular No. 22, "The Home War Garden," was published in August by the Extension Service. This is a revision of Timely Hint No. 106, "The Home Vegetable Garden," which publication it replaces. This circular attempts a popular presentation of present day gardening under southwestern conditions. The different vegetables are considered in part from their botanical and physiological characters. The first half of the circular discusses the following topics: soil and location; fertilization, irrigation and cultivation; flat culture versus ridged culture, rotation of crops; botanical grouping of vegetables; crop pests; seeds and seed-testing; aids to earliness in the garden; and, altitudes and seasons of planting. The second half discusses vegetables for the winter and spring garden and likewise those for the summer garden.

NOTES ON PLANT INTRODUCTION

Japanese Kudzu vine *(Pueraria hirsuta)*. This herbaceous climber, noted in a recent Annual Report of this station, deserves further mention as an economic plant. It grows from starchy, tuberous roots, increasing in vigor as these become larger. The stems are hairy, and the leaves resemble those of the common bean, but are larger. The flowers are purple, produced in clusters, and pea-like. They are not showy. The pods are flat, hairy, two to four inches long, and contain several small, mottled beans. The plant propagates readily from root cuttings and by layering. It can also be grown from seeds. Being semitropic, the Kudzu vine grows most rapidly during the summer season. In the introduction garden vines have grown 50 feet in a season. This is the most rapid growing of our herbaceous climbers and with its dense foliage is excellent for shade for poultry yards and fences, sheds, and even for houses. It is much planted in parts of Japan as a covering for homes, and for the forage, which is relished by animals. It is best suited for growing in Arizona below altitudes of 2,500 feet, preferably in rich, well irrigated soils. It blossoms about September 15, and with an early frost will hardly mature seed. The leaves and stems of the season's growth are killed with minimum temperatures of 29 degrees F., and the older woody stems, which ordinarily live over, are killed with temperatures of 6 degrees F. This plant should have value as forage for growing along irrigation ditches or in areas not readily accessible to cultivation.

PLANT DISEASE STUDIES

For the most part, the plant diseases that have been destructive during the recent growing season are the ones that were predominant during the previous year. These include tomato wilt, which has been serious in many sections, cotton sore shin disease, cotton root-rot, alfalfa root-rot, fruit tree root-rot, melon wilt, and crown gall. Besides these, a serious disease of the common pepper has appeared at Tubac and in the Rillito Valley near Tucson. When nearly mature the plants cease growth, gradually turn yellow and begin to die from the roots with a full crop of peppers. In a number of respects the disease resembles tomato wilt. Practically all the plants within an affected area are killed. A study is being made of this disease. A careful rotation of crops will help both in this disease and in tomato wilt.

A serious canker disease of cottonwood and poplar trees caused by *Cytospora chrysosperma** has been found in a number of localities in Arizona. These include Flagstaff, Williams, Prescott, Douglas, Nogales, Continental, and Tucson. This disease attacks both native and introduced poplars, but is most destructive to introduced species, including the Carolina poplar and the Lombardy poplar. A considerable number of these trees have died in Flagstaff from this cause. The disease may be recognized by the presence of sunken, dead areas on the bark of the larger limbs of trees. The inner bark of these areas is blackish and has a pronounced odor. Later, small reddish, pustule-like fruiting bodies appear on the surface of dead areas of bark. On old bark these reddish bodies can

*Long, W. H. Journal of Agric. Research, XIII, 6, 1918.

often be seen in the fissures. Affected trees rarely live longer than two or three years and serve to spread the disease. It is recommended that persons who desire cottonwood or poplar trees plant the native cottonwoods, since these are more resistant to the canker disease than introduced species like the Carolina poplar. There are several species of native cottonwood in Arizona which thrive at our various altitudes.

SCIENTIFIC

The work on the herbarium, which claimed so large an amount of time last year, was completed early during the present year. The University plant collections now number 74,000 sheets. Our plant collections are complete enough now to enable one to work to advantage, both on the native and cultivated plants. During the year a collection of biological literature, numbering 2,500 pamphlets and separates, has been classified and arranged systematically for convenience in work in botany. Many of these books and pamphlets were presented to the Botanical Department by the Department of Botanical Research of the Carnegie Institution, Tucson, Arizona. Others have been secured thru exchange of botanical material, including plant specimens.

J. J. Thornber,
Botanist.

HORTICULTURE

The Horticulturist having entered upon his duties near the close of the present fiscal year, the major portion of his time during the remainder of the period was given to the study of the general horticultural conditions of the State, and in formulating plans for the future development of the work of the department as pertains both to instruction and investigation. Nine distinct station projects have been outlined and accepted, and work on some of them is now under way. The work of the Department of Horticulture falls naturally into three main divisions: Pomology, Olericulture, and Ornamental Gardening. Progress has been made during the past year in these respective branches as follows:

POMOLOGY

Plans have been developed for fruit plantings at the Salt River Valley Farm consisting of a variety orchard of eleven acres, together with additional blocks of three acres each of the standard varieties of such fruits as the fig, olive, and apricot, that have proved themselves particularly adapted to commercial growing in southern Arizona. The plantings of standard varieties will be used as a basis of experimentation in pruning, spraying, and other phases of orchard culture and management. As other varieties demonstrate their worth, block plantings will also be made of them. The first planting in the variety orchard was made with dates in July, 1918, including seventy varieties. The remainder of the orchard will be set during the coming spring.

A three-acre orchard is being developed on the University Farm at Tucson, comprising representative varieties of the leading species of cultivated fruits. This orchard is designed primarily for student instruction in Pomology, but is adaptable as well for purposes of experimentation.

The unplanted portion of the horticultural block at the Yuma Date Orchard and Horticultural Station will be set this fall with citrus and other sub-tropical fruits. The planting of citrus fruits is made with a view to determining an effective method of preventing frost injury, and to testing the adaptability of the Mandarian group of orange to the Yuma Valley.

The deciduous orchard at the Yuma Date Orchard and Horticultural Station is now in its second year. The trees have made a very satisfactory growth, and a few varieties have borne their first crop. The Smyrna and Rea Mammoth varieties of quince, and the

Royal and Newcastle varieties of apricot each produced a small number of fruit this year. The Wonderful and Papershell varieties of pomegranate produced heavy yields for the age and size of the plants.

DATES

The date orchards at the Tempe Date Orchard and the Yuma Date Orchard and Horticultural Station have continued in thrifty condition, and during the past season have produced very satisfactory crops, furnishing additional evidence of the value of the date as a commercial fruit crop for southern Arizona. The blossoming record of the palms was not high at either orchard, but the most excellent weather that prevailed thruout the harvest made it possible to gather a maximum crop from every tree that bore. Even varieties that during ordinary seasons are almost worthless yielded relatively good returns. Another feature of this year's crop was the almost total absence of fungus spots, which have been a source of serious loss of some varieties in the past, particularly during moist weather. These facts considered in the light of losses sustained in the past due to rainy weather point to climate as a most important factor in the harvesting of the date crop.

Considered from the standpoint of yield, size, quality, and appearance, the varieties that did best at the Tempe Orchard are: Hayany, Tadala, Rhars, and Deglet Noor; and at the Yuma Orchard: Deglet Noor, Hellawee, and Kaiby. The following is a summary of the yields and returns at the Tempe and Yuma Date Orchards for the past season:

TABLE I.—YIELD OF DATE VARIETIES AT THE TEMPE ORCHARD

Variety	No. of trees	Harvest season	Average yield per tree	Total yield	Average receipts per tree	Total receipts
			Pounds	*Pounds*	*Dollars*	*Dollars*
Amari	3	Aug. 12-Oct. 17	91.16	273½	21.41	64.24
Azerza	2	Sept. 22-Oct. 5	36	72	8.13	16.26
A'oochet	1	Oct. 4-Nov. 17	222	222	55.06	55.06
Arechti	1	Oct. 3-Oct. 31	20	20	4.98	4.98
Apdandon	1	Sept. 5-Oct. 31	75	75	16.79	16.79
Ascherasi	2	Oct. 2-Oct. 12	13	26	3.05	6.10
Amhat	1	Sept. 28-Oct. 28	12	12	2.01	2.01
Amri	2	Oct. 24-Dec. 1	57	115	10.85	21.70
Bent Kebala	1	Sept. 30-Nov. 22	294	294	81.84	81.84
Boo Affar	2	Sept. 28-Dec. 5	15	31¾	3.47	6.94
Burni	2	Oct. 9-Nov. 16	79	159	19.13	38.27
Berhi	4	Sept. 30-Nov. 3	148	595	37.52	150.08
Bagam Jurghi	1	Sept. 8-Oct. 15	51	51	11.34	11.34
Besser Haloo	1	Nov. 27-Dec. 1	55	55	6.40	6.40
Bedraihe	2	Oct. 1-Dec. 2	214	428	22.03	44.06
Bajoo	1	Oct. 26-Dec. 5	62	62	6.10	6.10
Dishtari	1	Aug. 31-Oct. 31	96	96	22.29	22.29
Deglet Noor	28	Oct. 11-Dec. 1	108	3043	36.25	1015.10
Deglet Barka	1	Dec. 5-	70	70	7.00	7.00
Gasby	1	Aug. 23-Oct. 5	120	120	27.59	27.59
Gush	1	Sept. 5-Oct. 12	27	27	6.57	6.57
Goondee	1	Dec. 1-	40	40	4.00	4.00
Gaggar	1	Nov. 21-Dec. 5	163	163	16.30	16.30
Hayany	9	Aug. 23-Nov. 4	213	1921	51.77	465.98
Hamraia	4	Oct. 5-Nov. 17	63	254	16.49	65.96
Hellawee	1	Sept. 28-Oct. 24	31	31	7.45	7.45
Halloua	2	Nov. 15-Dec. 1	64	129½	6.47	12.95
Horra	3	Nov. 4-Dec. 1	39	119	3.96	11.90
Hurshut	1	Sept. 25-Oct. 19	45	45	9.84	9.84
Halawi	3	Sept. 28-Oct. 28	85	257	21.09	63.26
Itima	1	Oct. 16-Nov. 8	37	37	9.09	9.09
Iteem Joher	1	Oct. 12-Dec. 1	173	173	51.21	51.21
Karooy	1	Sept. 9-Oct. 5	44	44	9.35	9.35
Kustawi	7	Sept. 10-Oct. 31	62	439	14.93	104.51
Khadrawi	2	Sept. 22-Oct. 15	32	64	6.97	13.94
Khedrwee	3	Sept. 5-Oct. 24	73	220	15.15	45.45
Khir	1	Sept. 1-Oct. 16	87	87	20.31	20.31
Kenta	2	Oct. 19-Nov. 21	18	37½	1.87	3.75
Kalara	1	Sept. 9-Oct. 13	80	80	17.12	17.12
Koroch	1	Sept. 9-Oct. 17	125	125	27.66	27.66
Khedrwee	1	Aug. 31-Oct. 26	25	25	5.82	5.82
Kesba	1	Dec. 1-	5	5	.50	.50
Karba	1	Sept. 10-Nov. 15	34	34	7.08	7.08
Kaiby	1	Oct. 15-Oct. 28	34	34	8.24	8.24
M'Kentichi, Degla	2	Dec. 1-	104	208	10.40	20.80

Table I.—Yield of date varieties at the Tempe orchard—*Continued*

Variety	No. of trees	Harvest season	Average yield per tree	Total yield	Average receipts per tree	Total receipts
			Pounds	*Pounds*	*Dollars*	*Dollars*
Maktum........	2	Oct. 17-Dec. 1	113	227	30.10	60.20
Menakher......	1	Oct. 17-Oct. 27	40	40	10.71	10.71
Mozati........	1	Sept. 9-Oct. 31	51	51	11.29	11.29
Nakkelet Feraoun.....	1	Oct. 10-Oct. 31	43	43	10.54	10.54
Nazel.........	1	Dec. 1	100	100	10.00	10.00
Naklet el Leef.	1	Oct. 1-Oct. 30	130	130	28.74	28.74
Lagoo.........	1	Sept. 22-Oct. 30	30	30	3.00	3.00
Nesheem......	1	Oct. 1-Nov. 1	182	182	45.10	45.10
Lockzee.......	1	Oct. 1-Oct. 20	30	30	6.55	6.55
Purdy Seedling	3	Sept. 23-Nov. 2	56	169	12.92	38.76
Rhazi.........	2	Sept. 5-Oct. 15	64	128	17.29	34.58
Retbet Regaia..	1	Oct. 6-Nov. 11	21	21½	4.55	4.55
Ret Bet Abdella	1	Oct. 4-Nov. 2	62	62	16.27	16.27
Rhars.........	111	Aug. 17-Oct. 21	87	9685	21.03	2334.17
Roghm Gazal...	1	Nov. 17-Dec. 1	98	98½	9.85	9.85
Rogina........	1	Sept. 27-Nov. 25	23	23	4.72	4.72
Seedling (West)......	2	Oct. 6-Oct. 6	25	5	.50	1.00
Seba Leosif....	1	Sept. 23-Oct. 24	94	94	21.27	21.27
Sayer.........	3	Sept. 11-Oct. 25	101	303	19.01	57.03
Seba Boo Dra..	1	Nov. 10-Nov. 28	91	91½	7.05	7.05
Safraia........	2	Sept. 11-Dec. 1	50	100	5.10	10.20
Sukeri.........	2	Sept. 22-Nov. 18	143	287	14.45	28.90
Saydeh........	9	Sept. 28-Nov. 23	47	427	24.50	220.48
Timdjouert (Yellow)....	4	Oct. 4-Nov. 20	54	219	13.92	55.66
Tadala.........	2	Sept. 10-Oct. 31	146	293	34.56	69.11
Tennessim.....	4	Sept. 19-Nov. 20	127	511	25.81	103.25
Tafizaomt......	1	Oct. 15-Dec. 3	266	266	72.23	72.23
Tentebusht.....	3	Oct. 13-Nov. 2	9	27¾	2.31	6.94
Taurarhet.....	1	Nov. 4-Dec. 5	67	67	7.45	7.45
Takadet.......	2	Oct. 4-Nov. 18	82	165	18.93	37.85
Totee.........	1	Nov. 2-Dec. 3	130	130	34.13	34.13
Tamzoohart...	1	Sept. 27-Nov. 17	66	66	15.45	15.45
Toorekhet.....	1	Nov. 4-Dec. 5	67	67	7.45	7.45
Tozerzaid Khala.......	1	Oct. 15-Dec. 1	120	120	31.16	31.16
Tazizaoat......	1	Oct. 4-Dec. 1	250	250	55.48	55.48
Thoree........	5	Oct. 6-Dec.	54	270	5.39	26.95
Toojat.........	1	Oct. 26-Nov. 3	40	40	3.90	3.90
Taremoont.....	1	Oct. 16-Nov. 6	124	124	31.09	31.09
Tefezoont......	1	Nov. 28-Dec. 1	85	85	8.50	8.50
Zerza..........	1	Oct. 5-Dec. 1	128	128	12.60	12.60
Zehedi.........	1	Dec. 1	14	14	1.40	1.40
Zrai...........	1	Dec. 1	5	5	.50	.50
Zeozia.........	1	Dec. 1	85	85	8.50	8.50
Nagal.........	1	Dec. 1	100	100	10.00	10.00
No Name......	7	Sept. 9-Dec. 1	34	239	10.59	74.17
Culls....		Aug. 12-Dec. 5		4988½		631.40

TABLE II.—YIELD OF DATE VARIETIES AT THE YUMA ORCHARD

Variety	No. of trees	Harvest season	Average yield per tree	Total yield	Average receipts per tree	Total receipts
			Pounds	*Pounds*	*Dollars*	*Dollars*
Angoo	1	Nov. 19-Nov. 22	91	91	11.37	11.37
Bent el Marad	1	Aug. 31-Sept. 3	12	12	3.00	3.00
Black Seedlings	1	Sept. 9-Sept. 30	12	12	2.80	2.80
Beed Hammon	2	Sept. 20 Nov. 8	66.5	133	15.90	31.80
Boo Fa Goo	2	Sept. 24-Oct. 7	139	278	35.34	70.68
Bread Dates	5	Nov. 13-Nov. 30	63	319	7.43	37.16
Deglet Noor	32	Sept. 21-Nov. 3	50.5	1616	15.14	484.56
Gasley	1	Aug. 26-	31	31	4.65	4.65
Hayany	1	Sept. 4-Sept. 30	10	10	2.57	2.57
Hellawee	8	Aug. 26-Sept. 23	87.12	697	22.92	183.35
Itima	2	Sept. 7-Oct. 22	28.5	57	6.94	13.88
Kaiby	2	Sept. 7-Nov. 22	114.8	229.5	26.77	53.54
Khedrwee	2	Aug. 24-Sept. 13	43.5	87	11.93	23.85
Lagoo	1	Nov. 23-Nov. 26	43	43	5.12	5.12
Rhars	2	Sept. 3-Sept. 13	3.5	7	.90	1.80
Rogina	2	Sept. 9	2	4	.50	1.00
Saba Boo Dra	2	Oct. 5-Nov. 28	54	108	12.48	24.95
Saydeh	4	Sept. 16-Nov. 12	23.25	93	5.68	22.71
Timdjouert (Yellow)	4	Sept. 3-Sept. 9	2.75	11	.81	3.25
Timdjouert (Red)	1	Sept. 15	5	5	1.25	1.25
No Name	1	Sept. 30 Nov. 12	98	98	21.52	21.52
Culls		Sept. 2-Nov. 30		319.83		37.16

A large number of vacant places in both the Yuma and Tempe Orchards were set with palms during the summer. The off-shoots used in the Yuma Orchard were taken directly from the trees, being too large to place in the propagating house, whereas those used in the Tempe Orchard were rooted. Upon examination in November, 52 of the 81 plants set in the Yuma Orchard were showing signs of growth. The Tempe planting is interesting from the fact that the soil in the orchard is at present extremely alkaline. While the older trees do not appear to be disturbed by the presence of alkali, it was feared that the young plants probably would not fare so well. As a precaution, therefore, about a cubic yard of sweet soil was placed in the holes prepared for the off-shoots and a heavy straw mulch applied to prevent the rise of the alkali. No ill effects from the alkali have yet been observed, as the majority of the plants give evidence of growing.

A rather unusual feature of blossoming was observed at the Yuma Orchard, in that certain varieties failing to bloom during their normal blossoming period in the spring, flowered most profusely towards the latter part of the summer. A number of the blossoms were pollinated in order to study the future behavior of the fruit, particularly as to its ability to stand thru winter.

Progress has been made on definite projects in Pomology as follows

A STUDY IN THE CULTURE AND MANAGEMENT OF DATE ORCHARDS

This project conducted at the Yuma Date Orchard and Horticultural Station was begun in the summer of 1918. The work involves a comprehensive study of a number of features of orchard culture and management, with particular reference to the comparative effect of clean tillage, cover crops, sod, and mulches, together with different methods of fertilizing, on the yield, quality, time of ripening, size of fruit and growth of tree. The orchard contains about four acres, and the trees have been set 10 years. It is divided into six plots with each plot containing two rows of trees. The plots are being handled as follows:

No. (1) Planted to alfalfa, cuttings allowed to remain where they fall.

No. (2) Planted to sour clover in the fall, followed by cowpeas in summer.

No. (3) Planted to vegetables during both summer and winter.

No. (4) Wide, shallow basin maintained about each tree with a heavy manure mulch.

No. (5) Wide, shallow basin maintained about each tree with a thick straw mulch.

No. (6) Clean culture thruout the year.

The rows are divided crosswise to allow four different treatments with commercial fertilizer.

A STUDY OF CULTURAL METHODS WITH CITRUS FRUITS

These investigations, begun in the summer of 1918, are being conducted on the Yuma Mesa in cooperation with Mr. George W. Hill. The orchard in which the tests are being made contains about ten acres, and the trees composed of the Washington Navel variety of orange and the Marsh Seedless variety of pomelo, were set in the spring of 1916. The area is divided into ten plots, each of which is being given a distinct method of culture, particularly in the matter of cover crops. The plots are divided crosswise so as to allow four trees in each plot being given a different fertilizer treatment. Records of growth and general phenological notes are being made, and it is hoped that during the next few years data may be gathered on the cumulative effect of each cultural method and fertilizer treatment on the growth of tree and the size and quality of the fruit.

DATE PROPAGATION

The results secured in the propagation of the date, have not been as satisfactory as was anticipated, and the matter has become the subject of further investigation. The off-shoots placed in the propagating house at the Yuma Date Orchard and Horticultural Station in the summer of 1917 were a complete failure but this can, however, be attributed to soil conditions. The soil being heavy and not well drained it remained cool, whereas the temperature during summer was very high, making extremely adverse conditions for root development. In the summer of 1918 this house was removed to a location where the soil is sandy and well drained, and as a result the off-shoots are rooting satisfactorily. A careful examination in the latter part of November showed that out of 237 off-shoots placed in the house only 37 failed to show evidence of growth. Several individuals were observed as having developed a good root system, whereas suckers on the outside of the house, although alive, showed no signs of root formation. In the case of suckers placed in an ordinary cutting bench in the green house, where there was a daily range of temperature from 90 to 114 degrees, roots two to four inches long were formed in six weeks.

Following is a summary of the temperature of the atmosphere and soil inside the date propagating house at the Yuma Date Orchard and Horticultural Station as compared with the outside temperature during the months of August, September, October, and November—readings made daily at 12:30 P. M.

TABLE III.—AIR AND SOIL TEMPERATURE IN DATE PROPAGATING HOUSE, YUMA

Month	Temp. inside propagating house		Temp. outside propagating house	
	Atmosphere	Soil	Atmosphere	Soil
	Degrees Fahr.	*Degrees Fahr.*	*Degrees Fahr.*	*Degrees Fahr.*
August ...	115	90	103	84
September	110	86	100	83
October ...	97	73	90	74
November	79	59	72	61

It will be remembered that while a large number of off-shoots on the inside of the propagating house had rooted by November there was no sign of root development in the case of those planted in an open bed on the outside.

OLERICULTURE

Attention was given during the past year to the maintenance of an all-the-year family garden at the Yuma Date Orchard and

Horticultural Station and on the University grounds at Tucson, with a view to stimulating a greater interest in home gardening as a means of increasing the food supply. With good cultivation and ample irrigation, tomato, eggplant, pepper, okra, carrot, and the edible cowpeas were made to produce during the hottest portion of the summer. Tomatoes did not yield a heavy crop during this period, but shaded parts of the plants continued to bear some fruit. Further tests will be made with summer vegetables with the hope of adding other varieties to the list that can be successfully grown during the hot weather of this season.

Of special interest this year was the fall garden. Notes taken October 25 in the garden at Tucson showed the following vegetables in edible condition: snap bean, chard, cucumber, cowpea, carrot, endive, kale, lettuce, mustard, onion, radish, salsify, spinach, tomato, and turnip. Other vegetables that were growing nicely at this time, and that will be available for use during winter and early spring are broccoli, cabbage, cauliflower, brussels sprouts, collard, corn salad, kohlrabi, leek, parsley, parsnip, and rutabaga. All of these vegetables were planted during the month of August and in early September, except tomato, carrot, and salsify, which were started in the spring.

IRISH POTATO STUDIES

These investigations, directed towards the accumulation of facts regarding the production and storage of Irish potatoes in southern Arizona, are being conducted at the Yuma Date Orchard and Horticultural Station. The varieties Irish Cobbler, Triumph, and White Rose were planted February 25 and harvested on July 5. The yields per acre were as follows:

Irish Cobbler, 10,192 pounds; Triumph, 9,800 pounds; White Rose, 10,976 pounds.

Immediately after harvesting a definite amount of each variety was placed under different methods of storage as follows:

No. 1. Placed in ventilated bins under shade.

No. 2. Coated with paraffin.

No. 3. Spread out thinly on ground under shade.

No. 4. Placed in twelve inches of soil under shade.

No. 5. Placed in a ventilated dugout made three feet deep in a well drained soil.

Following is a summary of the storage tests as revealed September 15 when the potatoes were examined:

TABLE IV.—STORAGE TESTS WITH POTATOES

Storage method	Variety	Sound potato
		Percent
No. 1. Ventilated bins........	Irish Cobbler	90
	Triumph	90
	White Rose	95
No. 2. Paraffined	Irish Cobbler	None
	Triumph	"
	White Rose	"
No. 3. On ground............	Irish Cobbler	75
	Triumph	75
	White Rose	50
No. 4 Dry soil..............	Irish Cobbler	None
	Triumph	"
	White Rose	95
No. 5 Dugout	Irish Cobbler	95
	Triumph	80
	White Rose	95

In the case of the potatoes that were coated with paraffin the entire lot rotted by the end of four weeks, which indicates that the exclusion of air is absolutely detrimental to the keeping qualities of the potato, and emphasizes the importance of thoro ventilation during storage. As shown in the table, the method of storage in which the potatoes were spread out thinly in ventilated bins, as well as the dugout method of storage, gave a rather high percentage of sound potatoes. While these results are not conclusive, they do indicate that it is easily possible for the home gardener to preserve the spring crop of potatoes thru the summer for culinary use and as seed for a late summer crop.

In tests made to determine the best depth and time of planting for the late summer crop, practically all the potatoes rotted in the ground. This was apparently due to the hot temperature of the soil at planting time, coupled with excessive moisture conditions.

It is believed that modified methods of planting contemplated for trial next season will give more satisfactory results. Plantings are being continued thruout fall, winter, and spring at intervals of ten days in order to determine the best planting date for the spring crop.

SPINACH AS A MARKET GARDEN CROP FOR SOUTHERN ARIZONA

Ranking first in importance among the vegetables grown for "greens" in the United States, and being particularly well adapted to climatic conditions such as are found in southern Arizona, spinach promises to become a valuable market crop for this section. In view of these facts, a series of investigations was begun in the fall of 1918 for the purpose of securing specific information as to the best cultural practices to be followed in the production of this crop—including methods and time of planting, variety tests, and fertilizer comparisons. The following methods of planting were used:

No. 1. Level planting with flooding—rows ten inches apart.

No. 2. Bedding four rows ten inches apart, made on low, flat beds with irrigation water run between the beds.

No. 3. Row and furrow method—rows two feet apart, and irrigation water run between the rows.

The varieties Savoy, Victoria, Prickly Winter, and Long Standing, typifying as many different groups of spinach, were used in each plot. The first planting was to have been made September 1, with additional planting at intervals of two weeks until November 15, but a delay in the arrival of seed necessitated its postponement until October 1. The plots are subdivided crosswise to permit of fertilizer tests with stable manure, cotton seed meal, nitrate of soda, and acid phosphate. The work has not reached the point where final conclusions can yet be drawn.

ORNAMENTAL GARDENING

The work in Ornamental Gardening has consisted largely in the developing of plans for the beautifying of the grounds at the different branch stations, particular attention having been given the Tempe Date Orchard and the Yuma Date Orchard and Horticultural Station. The central grounds at the Yuma Station have been set to lawn grass, and, during the coming spring, shrubbery and other ornamentals will be added. In addition to plantings of tested varieties of trees and shrubbery, other sorts will be set with a view to determining their adaptability to specific localities. A special feature in this connection is the attempt to establish alkali resistant types at the Tempe Date Orchard, the soil of which is very alkaline.

No work has been done in floriculture, but with the added green house and garden facilities, which are soon to be provided, something in this field will be undertaken.

SPECIAL INVESTIGATIONS

The Horticulturist served as a member of a commission appointed by the President of the University of Arizona to investigate the agricultural possibilities of the Yuma Mesa with special reference to citrus culture. In connection with these investigations considerable time has been spent in studying the climatology, topography, and general features of the soil and in making detailed descriptions of the fruit now being grown in the district and comparing it with that produced in other citrus regions. The entire matter will be treated in greater detail and published as a joint report by the committee.

MISCELLANEOUS

A number of trips were made during the past year to different parts of the State in the interest of extension work in Horticulture. The activities in this field, however, were confined largely to demonstrations in fruit and vegetable conservation by drying, in which the sulphuring process was used.

Considerable time was given to the general supervision of the work at the Tempe Date Orchard and at the Yuma Date Orchard and Horticultural Station.

Very valuable service was rendered the department during the past year by the foremen of the different branch stations in their careful execution of the work as outlined for them. The horticultural work has been given further impetus in the recent appointment of Mr. A. F. Kinnison as Assistant Horticulturist.

F. J. Crider,
Horticulturist

PLANT BREEDING

Work in the department during the past year has been confined to wheat, beans, alfalfa, and grain sorghums. The wheat work during the year has received especial consideration owing to the increased interest shown in bread wheat varieties.

WHEAT

The breeding work with wheat during the past year has been along four distinct lines: (I) The testing of the promising hybrid macaroni-bread wheat races which have been increased from last year's selections. (II) The growing and comparing of the second seed generation (first plant generation) of new hybrids secured by crossing Turkey and macaroni wheats on the native Sonora. (III) A study of the inheritance of the various characters in the bread wheats, the Poulard wheats, and the macaroni wheats. (IV) The field testing of various pure lines of wheat. The milling and baking qualities, and also yield received especial consideration

I. The work with the macaroni-bread wheat crosses at Yuma included three series of plots; the plant rows, the small pedigree increase plots, and the tenth-acre field plots. There were 540 plant rows grown from plants of good habit and producing grain of apparently good gluten content. Each row of this series was harvested and threshed separately, and the grain worked over in the laboratory for type, texture, and total yield. The seed from about one-third of these rows will be used in planting increase plots next year, so that the excellent strains may be increased as rapidly as possible.

There were 100 pedigree increase plots planted from promising plant rows of 1917. These have been carried thru a severe elimination test from which about 30 will be selected for testing under field conditions in 1919 with the present best milling wheats of the State, such as Early Baart.

There were twenty-five tenth-acre field plots of hybrid wheats which occupied the entire area of the Dyer block of the Yuma Station. Some promising yields were obtained from this series; one produced at the rate of 60 bushels per acre and two others between 50 and 55 bushels per acre. This is about 20 bushels per acre more than was produced by the Early Baart. The quality of these high yielders was fairly good, but neither the grain nor the plants were of sufficient uniformity to be recommended for bread wheat planting, and will require one or two more season's selections before they will be ready for general planting. However, these wheats are regarded as very promising on account of their high yield and strong straw which stands up well when the wheat is grown on irrigated lands rich in organic matter. One of the worst troubles in growing the present standard milling wheats of the State is that, when they are planted immediately after alfalfa, or other lands rich in nitrogen, they lodge badly.

II. The main object sought in the wheat breeding at this Station is to find, or produce by hybridization, a wheat of high gluten content of superior quality. In an effort to combine the high gluten contents of the hard wheats of Kansas, such as the Turkey Red, with the early, high yielding Sonora wheat, crosses of these wheats were made in the screen garden on the campus in the spring of 1917. Thirty-three hybrids from this cross were grown in the screen garden during the winter and spring of 1917 and 1918. Notes were taken on the earliness of the plants, type of head and other plant characters, and quality of the grain. The first heads of these hybrids appeared between April 16 and April 23, while the first heads of the Turkey parent appeared between April 29 and May 12. It thus appears that there is a possibility of getting an early Turkey wheat selection out of these hybrids when it breaks up into various types in succeeding generations. Earliness in wheat, especially in the irrigated valleys of Arizona, is regarded of prime importance in establishing a wheat with a high gluten content of superior quality. When wheats continue growing in the warm days of late spring abundant irrigation is necessary which always reduces both the quantity and the quality of the gluten in the grain.

III. Another series of wheat hybrids was made the past year for the sole purpose of studying the manner of inheritance of the various characters in wheat. Wheats were selected for these crosses in such a way that every visible character was paired with its opposite or its absence. In the succeeding generations a study will be made of the factors controlling gluten content, strength of straw, and the various factors which control yield.

IV. Several selections from each of Early Baart, Turkey Red, Arizona 39, Sonora, Algerian Macaroni, and Alaskan wheats have been under test for several years. As result of these tests one or two high yielding strains have been developed from each of these varieties. In addition to yield, the milling and baking qualities, rust resistance, and strong, non-lodging straw under irrigation have received attention. Table V gives the yields obtained from these wheats on the Salt River Valley Farm for 1918.

TABLE V.—YIELDS FROM PURE RACES OF WHEAT IN FIELD PLOTS ON SALT RIVER VALLEY FARM, 1918

Plot No.	Name	Area planted	Yield per acre	
		Acres	*Pounds*	*Bushels*
34	Early Baart..	0.2362	2180	36.33
35-12	Sonora	0.4724	2032	33.86
36-43	Turkey	0.2362	2193	36.55
36-51	"	0.4862	2557	42.62
37- 1	Poulard	0.2224	2549	42.49
38- 1	"	0.2362	2032	33.87
39A- 5	Arizona 39.....	0.4864	2742	45.70
39A- 9	" "	0.2224	2414	40.24
40A- 8	Selected	0.2362	2616	43.60
40A-57	"	0.2362	2650	44.17
41A- 1	"	0.2224	2338	38.96
1E-13	Macaroni	0.2224	2315	38.59
1E-88	"	0.2362	2349	39.16

The varieties represented in this table are those which have been selected for several years for either yield, or quality of grain, or both. It is seen from Table V that the highest yielder in the lot is Arizona 39, selection 5 (39A-5) producing at the rate of 45.7 bushels per acre. This is approximately 10 bushels more per acre than was produced by a plot of Early Baart grown in the same field under similar conditions. Section No. 9 of Arizona 39 (39A-9) also produced nearly 5 bushels more per acre than the plot of Early Baart. Baking tests have also been made of Arizona 39, but it is inferior to Early Baart in flour strength, as will be seen from an inspection of Table VI. Table VI. gives the results of the latest baking test with the varieties of wheat listed in Table V.

TABLE VI.—BAKING TEST OF ARIZONA WHEATS

No.	Name	Absorption	Maximum volume of dough	Volume of loaf	Weight of loaf
			c. c.	*c. c.*	*Grams*
34-16	Early Baart..	63.7	2050	1940	526
35-12	Sonora	63.7	2000	1780	528
36-43	Turkey	70.3	2050	1675	544
36-51	"	69.3	2200	1630	529
37- 1	Poulard	72.7	1750	1400	560
38- 1	"	70.0	1750	1405	554
39A- 5	Arizona 39...	63.7	1900	1710	522
39A- 9	" " ...	65	2000	1725	527
40A- 8	Selected	62	1600	1310	520
40A-57	"	68.3	2050	1715	535
41A- 1	"	68.8	2150	1630	543
1E-13	Macaroni	73.3	1750	1390	560
1E-88	... "	78.3	1900	1640	576

From Table VI it is seen that Early Baart (34-16) surpasses every other variety represented in the table in volume of loaf. In all these tests the same quantity of flour was taken for baking the loaf. The column of figures representing loaf volume, therefore, is of primary importance in judging the strength of the flours. Arizona 39 (39A-9) and Sonora (35-12) came nearest to the Early Baart in baking strength, but the difference is great enough to place Early Baart considerably ahead in this quality.

Of all the varieties tested so far by this department, Early Baart outranks all others as a milling wheat. Its yield is about the average of bread wheats in the State, and there is, therefore, room for considerable improvement in this direction. Early Baart has the disadvantage of being awned (bearded). Some farmers object to the presence of awns, for, if it becomes necessary to cut the grain for hay, the hay produced is of an inferior quality. The beards also render the handling of the wheat previous to threshing somewhat unpleasant. For this reason the department is bringing forward as rapidly as possible certain other bread wheat strains which, it is believed, will yield, with a few year's further breeding, as well as the Early Baart and which will at the same time be a good millling wheat free from awns.

BEANS

The work of the department with beans this year has been largely along investigational lines related to the various Mendelian genetic factors of the plant. It was anticipated that along with this scientific investigation an economic result might in the end be accomplished. The better the plant is known, genetically, the easier will it be to combine characters in the attempt to produce nearer the ideal.

Particular study was given to the variation of the internodes as affecting the variances in height of the plant and also as affecting the variation in the percentage of supernumerary leaves. In the anticipation of the latter it was assumed that internode length could vary to zero thereby causing a crowding together into within a practically immeasurable zone of the first two or three, or four nodes, each node carrying its leaf, and thus giving a set of supernumerary leaves. The plant having all internodes measurably shows two leaves at the first node and one at each node thereafter. Thus in the case of a zero length of the first internode we would find three primary leaves; zero length of the first and second internodes, four primary leaves, etc. Data covering about three years' work showed 92 percent of all plants having zero length of the first internode, 66 percent having zero length of the first and second, and 1 percent having zero length of the first, second and third internodes. This leaves 8 percent having two primary leaves. Then 92 percent of 66 percent, or 61 percent, of all plants should have had four or more, thus leaving 92 less 61, or 31 percent, of all plants with three primaries. Also 1 percent of 61 percent, or 0.6 percent, of all plants should have had five primary leaves, leaving about 60 percent with four primaries. Table VII shows how nearly the actual count in one race approaches the theoretically expected.

TABLE VII.—NUMBER PRIMARY LEAVES

		2	3	4	5
No. 202	Theoretically expected..	8	25	68	2
No. 202	Actual count...........	9	27	64	0

A number of pure races of teparies were planted in the screen garden on the campus during the last spring and summer with the plan in view to obtain a number of reciprocal crosses in order that a new set of hybrids might be produced. Considerable efforts were expended in developing a practical and effective method of open field cross pollination of beans.

An interesting segregation appeared this year coming from the F_1 seed of a cross between a tame and a wild tepary. A further investigation will be made with the various segregates.

ALFALFA

The work with alfalfa has been with three series of plots. One of these plots is located in the screen garden on the campus, and the other two are on the Salt River Valley Farm.

The plot in the screen garden consists of 342 transplanted plants from various sources. Most of these plants were taken from the best plots of the Evergreen Nursery when the work at that place was discontinued in 1916. About twenty-five of these plants were taken from the Hairy Peruvian alfalfa which was growing on the north side of the Salt River Valley Farm in the fall of 1917. An individual plant study has been made of (1) heat resistance, as indicated by rapidity of growth and yield of consecutive cuttings as the heat of the summer comes on, and (2) quality, as indicated by size of stems and percentage of leaves. The work was confined mostly to the study of heat resistance. The entire plot was irrigated about once a week so that the lack of water was probably not a limiting factor of growth. Each plant was cut as soon as the first blooms appeared. Table VIII shows the dates of cuttings and yields per plant from fifteen selected plants selected from Plot 156, which came originally from the Evergreen Nursery. A similar study was made of each of the 342 plants.

TABLE VIII.—WEIGHTS OF ALFALFA PRODUCED PER PLANT WITH DATES FOR EACH CUTTING, 1918

No.	1st cutting Date	1st cutting Wt.	2nd cutting Date	2nd cutting Wt.	3rd cutting Date	3rd cutting Wt.	4th cutting Date	4th cutting Wt.
		Grams		*Grams*		*Grams*		*Grams*
1	April 11	840	May 18	636	June 14	400	July 10	242
1	April 23	120	May 30	130	June 22	80	July 26	25
3	April 11	841	May 18	655	June 22	501	July 26	170
4	April 23	368	May 23	247	June 22	216	July 26	130
5	April 11	842	May 18	584	June 22	429	July 26	128
6	May 3	800	June 5	422	July 2	200	July 26	48
7	April 11	962	May 18	671	June 22	540	July 26	140
9	April 20	923	May 22	514	June 22	307	July 26	205
10	April 15	984	May 18	578	June 22	322	July 26	140
11	April 23	323	May 30	420	July 2	211	.... ..	...
12	April 13	308	May 22	214	July 2	165	.... ..	...
13	April 15	1840	May 22	980	June 22	689	July 26	274
14	April 11	1784	May 18	1025	June 22	845	July 26	272
18	April 24	547	May 22	416	June 22	200	July 10	63
20	April 3	810	May 7	544	June 5	310	July 2	187

It is seen from an inspection of Table VIII that all plants are considerably reduced in yield as the summer advances. In no case, except in that of plant No. 1, was the yield of the fourth cutting more than one-fourth of that of the first cutting. The yields of plant No. 6 dropped from 800 grams at the first cutting on May 3, to 48 grams at the fourth cutting on July 26. In these studies it is not the absolute yield per plant which is considered important, since it has not been shown that yield per plant is indicative of mass yield. Selections for increase will be made from those plants whose summer cuttings are high percentages of their respective first cuttings.

The 61 pedigree races sown in rows, and the 18 large field plots on the Salt River Valley Farm were continued in 1918 for further study of yield and quality of hay for the different strains. Owing to the shortage of water due to a break in the irrigation main in mid-summer only three cuttings which furnished comparable data were made from the field plots. The last cutting was made July 1. In searching for high summer yielders a comparison was made between the yields of the first cuttings, April 16, and those made July 1. Table IX shows these comparisons.

TABLE IX.—YIELDS OF ALFALFAS SALT RIVER VALLEY FARM, 1918

No.	Variety	No. plots	Yield per acre cutting April 16	Yield per acre cutting July 1	Percent July 1 cutting of April 16 cutting
			Pounds	Pounds	
11	Variegated	3	3779	3378	89
22	Arabian	3	3098	2663	86
24	Algerian	2	4110	3018	73
27	Turkestan	1	3682	2994	77
35	Siberian	1	4477	3500	78
39	Peruvian	6	4024	2625	65
41	French	2	5180	3918	76

No. 41, a French variety, was the highest yielder of all the alfalfas tested in field plots. As will be seen from the table its yield, both in April and in July, surpassed the Hairy Peruvian (39) by more than a thousand pounds per acre for each of these cuttings. Another significant fact in connection with No. 41 is that the cutting of July 1 is 76 percent of the cutting of April 16, while the percentage of the cutting of July 1 of the Hairy Peruvian (39) was only 65 percent of the cutting of April 16. The French variety will probably not grow as well through the cool winters of southern Arizona as Hairy Peruvian, but it seems to be a much more vigorous summer grower. It has been planned to take seed crops from these alfalfas next year and if these high yielders prove to be good seed producers, seed crops will be taken as rapidly as possible for general distribution.

GRAIN SORGHUMS

The work during the past year with sorghums was confined to breeding for type of plant in milo. In the fall of 1916 about 60 dwarf milo plants were selected from the Yuma plots. Nothing was done on the grain sorghum project in 1917 owing to insufficient help in the department. Each of these plants had a single upright head producing neither suckers nor branches. The purpose in making these selections was to make a study of the effect of selection on tillering and branching. It is believed that a plant producing a single upright head, provided size of head and size of grain can be maintained, would have many points of advantage over the ordinary branching plants with pendant heads. Thirty-four of the best heads from the 60 selections of 1916 mentioned above were planted in head rows on the Mesa Farm in July, 1918. When the plants were in full head a study was made of the branching habits of the plants, type of head, size of grain, and height of plant. Of the 5,270 plants grown on the 34 rows, about 80 plants were found which came true to the single head type, and about half of the heads of these plants were upright.

It appears from these studies that some of the plants were pure for the type selected, while others, due to some unusual position in the field, such as crowding or lack of moisture, failed to develop normally. Selections were made for carrying the work further next season.

W. E. BRYAN,
Acting Plant Breeder.
C. O. BOND,
Assistant Plant Breeder.

ANIMAL HUSBANDRY

A combination of scarcity of forage in most range districts, high prices of roughages and concentrates, expensive and inefficient labor, scarcity of money, and relatively low prices of animals have made stock-raising difficult in Arizona during the past year. A second year of drought has prevailed in all parts of the State, except for scattered districts and ranges in Coconino, Yavapai, and Mohave counties. Rains have been unusually local in distribution, there being small areas in the dry belt that have supplied good forage. Losses have been great among sheep and cattle, and the lamb and calf crop were below normal. Fortunately, a mild winter in the northern part of the State was most favorable for range cattle and sheep, but lack of feed and water made it necessary to purchase cottonseed cake, hay, and silage for the animals.

For the most part, stock production has been profitable on irrigated farms, but the high price of feeds made cattle and sheep feeding operations less remunerative than formerly. Where actual cost of production was considered, dairying has been profitable, although not as large returns were secured as would have been possible by selling the feed at market value. A distinct tendency to reduce the number of horses, cattle, and hogs on irrigated farms has prevailed. Many stockmen not owning their farms, or operating on a long term lease, have been forced out of the business by high price of feed, expensive leases, and scarcity of labor. The light rainfall made it difficult to raise crops on dry-farm areas during the past year. In too many cases, a reserve of feed was not retained, and when the drought came dry-farmers found it difficult to maintain their animals.

The winter of 1917 and 1918 was one of the most trying for sheepmen since 1904. Owing to the drought, scarcity of water, and the cool weather, feed did not grow on the desert. Many ewes died, and the lamb crop was much below normal. In some flocks, the lamb crop will not be sufficient to replace the loss among the ewes. Many of the ewes were moved to irrigated districts, where feed for them cost as much as \$3.00 to \$4.00 a head. Pastures in the Salt River Valley cost from \$25.00 to \$40.00 per acre for a period of six weeks with hay at \$35.00 per ton. Fortunately, the prices of lambs and wool were unusually good, and sheepmen will make a normal profit in spite of mortality and increased cost of production.

The cattle industry has had a serious set-back in Arizona during the past year. Drought prevailed in southern and northeastern counties, and many animals were forced to market. The prices of heavy cattle, two and three-year-old steers and up, increased appreciably, but there was a tendency for yearlings and cows to decrease during the year. The demand for stockers in the fall of 1917 was below normal, and many that would normally be marketed had to be wintered. The shortage of range feed and the overstocked condition of the ranges caused many thousands of cattle to starve in the drought stricken areas. Some cattle were fed, and those strong enough to stand shipping to market were sent to packers, without regard to age or sex. The number of cattle in the State has been materially reduced during the past year, and there will not be the normal number to go to market next year unless forced liquidation continues on account of the drought and scarcity of money.

A distinct tendency to place the production of range animals on a more secure and substantial basis has been observed during the past year. Over 5,000,000 acres of range land have been purchased and an equal area leased during the past two years. The control of the land in this way makes it possible for the stockmen to protect their range by fencing, developing water, and avoiding overgrazing. By the application of improved methods stockmen claim that they can double the carrying capacity of the range, and reserve feed to carry the animals over drought. Tanks and deep wells have been installed, allowing a more even distribution of the animals on the range, besides making available large areas of little value for stock production without water. More registered sires have been used than at any previous time, and they are certain to effect a distinct improvement in the quality of the offspring. The large number of cowboys and sheep herders who enlisted in the war made it necessary to perfect measures for conducting operations with a smaller labor force. Not a few of the large cattle and sheep outfits have purchased irrigated farms which are operated in conjunction with the range business. Forage crops are being produced wherever possible, and conserved in stacks and silos to be used in drought emergencies. As a result of these improvements stockmen are able to give the animals closer attention and with less labor, so that losses will be reduced in the future, and with normal rainfall there will be greater production and larger returns from Arizona ranges in spite of the apparent increase in all the items figured in cost of production.

FEEDING YUCCA TO STARVING RANGE COWS

During the past year thousands of cattle were kept from starvation by feeding them chopped yucca. Where this plant grows abundantly it makes a good emergency feed for starving cattle and sheep. The plant is found over most of Arizona at altitudes of 3,000 to 5,000 feet. It is prepared for stock by chopping with a special machine which was placed on the market early in the year. The machine works on the same principle as a root chopper and is driven by a 6 to 10-horsepower gasoline engine. One of these small machines will chop one to two tons of yucca per hour, or sufficient to keep 500 cattle alive. Only the thinnest and weakest stock are fed, but calves can be satisfactorily weaned on 10 to 20 pounds of soapweed and one pound of cottonseed cake a day. Cows are given twice as much of the pulp and will gain in strength on it, but the addition of one-half to one pound of cake daily will give better results. Cows can be fed on the pulped stems and leaves at $1.00 to $1.50 per month where it is not necessary to haul the yucca over four miles. Animals that have become so weak that they cannot get up alone will gain strength and do well on this feed, but it is best to begin feeding before they become so weak. The animals should be placed in separate lots so they can be classified according to strength and food requirements. They soon learn to eat the yucca and grow fond of it. Feeding is done by scattering the pulp on the ground or placing it in feed bunks. It is best to allow the stronger animals the freedom of a large pasture where they can gather dry grass and browse.

Pulped yucca has been demonstrated to have sufficient food quality to keep both cows and sheep alive. Undoubtedly 75 percent or more of the cows that have been fed on yucca would have died if some kind of feed had not been supplied them. While yucca will certainly keep starving cows alive, it is considered best to supplement the range by growing crops wherever possible by dry-farming, floodwater, or irrigation methods. The labor of preparing the yucca is considerable and the work is not pleasant. As this plant grows slowly, the supply will become exhausted so that yucca does not offer a permanent means of relief during dry periods which retard the growth of range forage.

Early in the spring of 1918 the problem of using yucca for tiding cattle over short range was studied. The results of these observations are given in Extension Circular No. 21.

HOGS

During the year a careful record was maintained of the hogs at the University Farm and valuable information secured regarding the effect of feeding certain foods to growing and fattening hogs.

FATTENING HOGS ON GARBAGE ALONE

Eight pigs in ordinary field condition, weighing a total of 605 pounds, were fed over a period of 25 days on garbage alone. At the outset the pigs seemed to relish the feed, and ate it greedily. All animals did well, making rapid and uniform gains. At the end of 25 days the pigs weighed 981 pounds, making a total gain of 376 pounds. This gain at 16 cents a pound, which was the local price at that time, would amount to $60.16 for the gain in live weight. The following statement gives the results of this test:

Average weight at beginning, 75.6 pounds.
Average weight at end of 25 days, 122.6 pounds.
Average gain per pig, 47.0 pounds.
Average gain per pig per day, 1.88 pounds.

TWO METHODS OF RAISING REGISTERED DUROC-JERSEY GILTS

Five gilts, born January 10, 1918, have been under observation for a period of 284 days. They were weaned when about eight weeks old, and weighed approximately 35 pounds each. All five animals were from the same litter and uniform in size, vigor, and quality. Two of them were sold April 6, 1918, and raised in the ordinary manner used in the district. The other three received good care and attention, being fed on rolled barley and corn bran until July 15 when they were given rolled barley; after this date they were fed on garbage. The weights of these animals on October 21, 1918, when the pigs were 284 days old, are given in Table X.

TABLE X.—WEIGHTS OF PIGS RAISED ACCORDING TO TWO METHODS

Pig No.	Farmer	Method of feeding	Weight Oct. 21
			Pounds
1	A	Ordinary	105
2	A	"	145
3	B	Good	295
4	B	"	315
5	B	"	303

It is interesting to note that the two gilts on Farm A weighed a total of 250 pounds, which is 40 pounds less than the lightest gilt raised on Farm B. The average weight of a gilt raised on Farm A was 125 pounds, while the average weight of gilts raised on

Farm B was 304.33 pounds. The pigs were not alike in any respect except color and it would require an expert judge to distinguish much merit in pigs No. 1 and 2. Undoubtedly these pigs would have been just as good if fed the same way. It will be most interesting to continue this study to see if they will become as large, attractive, and useful animals as those raised on Farm B. Table XI gives data regarding the weight and gains of the five pigs.

TABLE XI.—RATE OF GAINS IN PIGS RAISED ACCORDING TO TWO DIFFERENT METHODS

Pig No.	Weight at weaning, 56 days	Weight at 284 days	Gains since weaning	Average daily gains since Birth	Average daily gains since Weaning
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*
1	35	105	70	.37	.31
2	35	145	110	.51	.48
3	35	295	260	1.04	1.14
4	35	315	280	1.07	1.23
5	35	303	268	1.07	1.18

A thrifty breeding gilt should gain fully a pound a day from the time of birth, and slightly more from the time of weaning. Gains are made more rapidly as the animal becomes larger. The pigs maintained on Farm A gained only one-third to one-half as much as those on the other farm.

Undoubtedly it is unprofitable to withhold feed from young pigs, and registered breeding stock must have a liberal allowance of food. These animals have been developed to yield maximum returns from liberal feeding. Scrubs would probably do better under neglect. Razor-back hogs of the South, or wild Havalina or Pecary pigs in the Southwest, will probably thrive better than the pure breds where they must rustle for feed on the range.

GARBAGE VERSUS GRAINS FOR GROWING AND FATTENING HOGS

An experiment was conducted the past year to ascertain the value of garbage as a food for growing and fattening hogs. The garbage used in this test was of average quality, collected daily from the University dining hall, and fed as nearly as possible on the day collected.

Three registered Duroc-Jersey gilts, farrowed January 10, 1918, and weaned March 7, 1918, were fed grains and garbage over different periods. From March 7 to July 15 they were fed on dry grain, and also from September 16 to 30. Their feed consisted wholly of garbage from July 15 to September 15 and from September 30 to November 11. While they were being fed garbage, this food and water constituted their only ration.

The pigs were weighed at weekly intervals beginning May 20 and continuing to November 11. Table XII gives the date, kind of feed and average daily gain of each pig while on test.

TABLE XII.—COMPARISON OF GAINS OF PIGS FED ON GARBAGE AND GRAINS

Date	Feed	Average daily gain		
		Pig 1	Pig 2	Pig 3
		Pounds	*Pounds*	*Pounds*
Jan. 10 to May 20	Mother's milk and grains	0.68	0.62	0.71
May 20 to July 15	Grains	1.32	1.30	1.20
July 15 to Sept. 16	Garbage	1.17	1.51	1.37
Sept. 16 to Sept. 30	Grains	1.07	1.43	1.21
Sept. 30 to Nov. 11	Garbage	1.82	1.83	1.19

Table XII indicates that with two exceptions each time the pigs were changed from a grain ration to garbage, the average daily gain increased appreciably. On the other hand when changed from garbage to grain, which took place September 16 to September 30, each animal slumped decidedly in daily gain. Two of the animals showed a decided increase in daily gain when changed from a rolled barley ration to one of garbage during the last period of the experiment.

Table XIII gives the average daily gain in pounds for each of the three pigs while fed on garbage as compared to grain.

TABLE XIII.—AVERAGE DAILY GAIN OF PIGS FED ON GARBAGE AND GRAIN

Date	Feed	Average daily gain			Average of all
		Pig 1	Pig 2	Pig 3	
		Pounds	*Pounds*	*Pounds*	*Pounds*
May 20 to July 15 and Sept. 16 to 30........	Grains	1.19	1.36	1.20	1.265
July 15 to Sep. 16 and Sept. 30 to Nov. 11...	Garbage	1.49	1.67	1.28	1.455

The three gilts which weighed 81, 89, and 92 pounds, respectively, on May 20, weighed 328, 346, and 320 pounds, respectively, at the end of 175 days. The gain during this period was 724 pounds. They were fed garbage 105 days, during which time they gained 464.2 pounds and they were fed grain 65 days, gaining 259.8 pounds. At this rate the average daily gain for the entire group amounted to 1.455 pounds for the garbage fed hogs and 1.265 pounds for the period they were fed on grains. This indicates that greater gains were produced on garbage than grains as each of the pigs made greater gain while being fed garbage.

The garbage fed to the three gilts cost approximately $5.00 a month or a total of $17.50 for the 105 days. Considering the fact that hogs were worth $16.00 per 100 pounds this is a very good profit from feeding garbage. If the pigs had been fed on grains during this time it would require fully 5 pounds of grain to produce a pound of gain in live weight.. This grain costs locally 3 cents per pound and, at this rate, it would have cost 15 cents to produce a pound of gain or $69.60 for the 464.2 pounds gain. Thus garbage effected a saving of $52.10 compared with a grain ration. This saving amounted to $12.50 per hundred pounds of gain in live weight.

The feeding tests with garbage prove emphatically that it is a splendid food for growing and fattening hogs. Thruout the feeding period the animals were in slaughter condition. Garbage is a cheaper source of food for hogs than grain, at present market prices, and wherever it can be secured it should be used. Anyone situated within a reasonable distance of a supply such as that secured from hotels, restaurants, or mining camps would do well to use garbage for the production of high-priced pork at low cost. Where reasonable intelligence is used in keeping the garbage fresh and placing nothing except clean, wholesome food in the garbage can, there is no danger of disease or losses from feeding it.

FEEDING WORK HORSES ON CORN SILAGE

Silage is sometimes fed to work horses, but frequently with injurious results. During the winter of 1918 a man at Tucson lost five horses from feeding moldy silage. Other reports in the State also indicate that silage may be highly toxic for horses, but no instances have been found of it injuring cattle or sheep when properly fed.

On the Prescott Dry-Farm four horses have been fed a considerable portion of silage the past three years. During this time they were usually given all the alfalfa hay they would eat, but from time to time silage constituted the only roughage. When worked they were given an addition of about 8 pounds of rolled barley per head daily. This amount of grain was greatly reduced when the horses were idle and at times they received nothing but silage. From April 1, 1918, until late in the summer, the horses were given all the silage they would eat at all times. Daily feed records were maintained from June 15 to August 12, and the amount of silage consumed ranged from 130 to 490 pounds per day and averaged during this period 299 pounds per day for four work horses. The average amount per head was 74.75 pounds daily during the period, and varied from 32.5 to 122.5 pounds per head daily. If the silage contained 30 percent dry matter each horse averaged approximately 22 pounds of dry matter in the silage daily.

No injurious results were observed from feeding the silage. The animals were in good vigorous condition at all times, and worked well. Some observations, however, have been made to the effect that the muscles seem to be a little soft and the animals lack somewhat in ambition. One would seem justified in concluding that silage may be safely fed to horses at all times if given in reasonable amounts, and after it has been ascertained that it contains no poisonous substances. It is important, however, that the animals should be gradually accustomed to the feed and that not more than half of the dry matter is made up of silage. Where grain is abundant in the material used for silage, one should reduce the quantity of grain given to the animals. The greatest danger from feeding silage is allowing horses to consume molded material, which often proves fatal.

SHEEP

THE WOOL CLIP

Twelve sheep, including five mature and six yearling cross-bred ewes, and one Hampshire ram, yielded a total of 80.75 pounds of wool. The yearlings averaged 5.83 pounds per head, and the mature sheep 7.63 pounds. The registered flock consisted of 37 animals and these gave a total weight of 236 pounds of wool or an average of 6.38 pounds per head. Table XIV gives the wool clip for 1918.

TABLE XIV.—YIELD OF WOOL, 1918

Flock	Fleeces No.	Weight of wool	Average weight per animal	Average net value of wool per animal
		Pounds	*Pounds*	*Dollars*
Mesa...	12	80.75	6.73	3.56
U. of A.	37	236.00	6.38	3.18

It is most interesting to note that these sheep gave an average net return of $3.37 per head, for the annual clip of wool. The returns suggest that every farmer would do well to maintain a small flock of sheep. They are especially valuable in gleaning fields and keeping weeds in check in pasture fields and out-of-way places.

MARKETING WOOL IN 1918

The wool produced by the sheep during the past year was sent to two commission firms in Chicago with the request that it be graded and sold according to quality. The report from these firms is given in Table XV.

TABLE XV.—COMMISSION FIRM'S REPORT OF ARIZONA WOOL

Commission firm	Weight of wool	Grade	Price per pound	Expense of marketing	
				Total	Per lb.
	Pounds		*Dollars*	*Dollars*	*Dollars*
A	78	Western and low medium	.60	4.99	.064
B	54	¼ Semi	.58	10.16	.043
B	182	⅜ Semi	.53		

The cross-bred sheep yielded wool that was graded "western and low medium," while wool from registered Hampshire and Shropshire sheep was classified "¼ Semi and ⅜ Semi." The price secured for the cross-bred wool was distinctly higher than that from the other sheep, but this is thought due primarily to the marketing ability of the two commission firms. Another probable reason for the difference may be the fact that over half the registered sheep gave fleeces that were only 10 months old, and on this account the wool was short in staple. Naturally the cross-bred wool has more length of staple than that secured from the registered Hampshire and Shropshire sheep, and there was a special demand for that kind of wool during the past year.

COTTONSEED CAKE FOR DAIRY COWS

With the development of the cotton industry in Arizona, quantities of cottonseed by-products have become available as stock foods. It is well known that these feeds are high in food value and they are used extensively for live stock feeding in the older cotton districts. Their use in Arizona has become quite extensive since under government supervision they have been placed on the market at very reasonable prices.

This experiment was planned to test the value of cold pressed cottonseed cake as a supplement to alfalfa hay and corn silage. To test the relative value of various combinations three rations were taken, each containing as nearly as possible the same energy value. The rations used were as follows:

Ration 1—15 lbs. alfalfa hay
40 " silage

Ration 2—22 lbs. alfalfa hay
4 " cottonseed cake

Ration 3—11 lbs. alfalfa hay
40 " silage
3 " cottonseed cake

Eleven cows were available for the test. These were divided into three groups: four in each of two groups and three in the other. Since it was impossible to balance the groups evenly the test was divided into three periods of twenty-eight days each, and the rations were alternated so that each ration was fed to each group of cows for the same length of time. In this way it was possible to overcome the effects of difference of breed, period of lactation, and individuality of the cows. One week interval was allowed between each period to allow the cows to become used to the change in rations.

No attempt was made to draw any conclusions from the data secured during any one period because of so many factors entering in to influence the results, but the combined results of each ration for the three periods were studied. Table No. XVI shows the total number days each ration was fed, total feed consumed, total milk produced, and total fat yield.

TABLE XVI.—SUMMARY OF FEEDS FED AND MILK AND FAT PRODUCED

Rations		Total feed consumed	Total milk yield	Total fat yield	Number days in test
		Pounds	*Pounds*	*Pounds*	
Ration 1					
*Alfalfa hay	15 lbs...	4,956	7810.5	262.3	84
Silage	40 " ..	12,320			
Ration 2					
*Alfalfa hay	22 lbs...	7,028	8270.2	289.1	84
Cottonseed cake	4 " ..	1,232			
Ration 3					
*Alfalfa hay	11 lbs...	3,724	7679.4	268.9	84
Silage	40 " ..	12,320			
Cottonseed cake	3 " ..	924			

*3 lbs. alfalfa hay per cow per day was added during last period.

The cows gave 459.7 pounds of milk and 26.79 pounds of fat more when receiving alfalfa hay and cottonseed cake than from alfalfa and silage, and 590.8 pounds of milk and 20.2 pounds of butter fat more than from the alfalfa, silage, and cottonseed meal ration. This would indicate that the cottonseed cake was a better supplement for alfalfa hay than silage, yet Ration 3, which contains three pounds of the cake in combination with silage and alfalfa, failed to produce as much milk as the alfalfa and silage ration. The amount of milk varies almost directly with the amount of alfalfa fed.

Table XVII shows the cost of the feed fed, the cost of the feed per gallon of milk and per pound of butter fat, the value of the milk produced from each ration during the test if figured at 30 cents per gallon, and the profit over cost of feed.

TABLE XVII.—COST OF PRODUCTION AND PROFIT OVER COST OF FEED

Rations	Cost of feed	Cost per gallon of milk	Cost per pound fat	Value of milk at 30 cts. per gallon	Profit over cost of feed
	Dollars	*Cents*	*Cents*	*Dollars*	*Dollars*
Ration 1 Alfalfa hay 15 lbs.. Silage 40 lbs..	117.39	12.9	45.1	272.43	155.04
Ration 2 Alfalfa hay 22 lbs.. Cottonseed cake 4 lbs..	115.57	12.2	38.9	288.48	173.91
Ration 3 Alfalfa hay 11 lbs.. Silage 40 lbs.. Cottonseed cake 3 lbs..	122.76	13.6	45.6	267.87	146.11

To compute the costs of production the prices of the feeds were fixed as follows: alfalfa hay, $25.00 per ton; silage, $9.00 per ton, and cold pressed cottonseed cake, $60.00 per ton. These are believed to be about an average of the prevailing market prices during the past year. The cows were fed most cheaply on Ration 2 while Ration 3 was most expensive. The cost of milk per gallon was 12.9 cents on Ration 1, 12.2 cents on Ration 2, and 13.6 cents on Ration 3. The cost per pound of butter fat was less on Ration 2 than on either of the other rations. When milk was figured at 30 cents per gallon, the profit over cost of feed was $18.87 more for Ration 2 than for Ration 1, and $27.80 more than for Ration 3. The profit over cost of feed per day per cow was as follows. Ration 1—50.3 cents, Ration 2—56 cents, Ration 3—47 cents.

The results of this experiment are unusual, since the best balanced ration gave the poorest returns while the most unbalanced ration made the largest and most profitable production. Considering the fact that Ration 2, containing 22 pounds of alfalfa hay and 4 pounds of cottonseed cake gave a much better result than Ration 3, consisting of 11 pounds of alfalfa hay, 40 pounds of silage, and 3 pounds of cottonseed cake, it would seem that the larger proportion of hay was more responsible for the increased and more economical production than was the cottonseed cake. This experiment is being repeated with some minor modifications, and no definite conclusions will be drawn until it is seen whether the similar results are secured from it.

INSTRUCTION AND EXECUTIVE WORK

With the declaration of war by the United States, new responsibilities were forced upon the nation. The members of the department attempted to do something of immediate importance to increase the surplus live stock from the State. Many short and timely articles have been prepared for publication during the past year. The stockmen were encouraged to initiate certain improvements and apply methods which were best suited to local conditions. It must be said that the stockmen in the State rallied almost to a man, and patriotically did everything they could to produce more meat for the nation. In many cases they spent more money attempting to keep animals alive by giving them high priced feeds than they could secure from them.

During the year the registered Jersey cow, Gipsy Draconis, owned by the University, has completed a semi-official test for a year. This cow gave 10,162.7 pounds milk, 498.77 pounds butter fat, equivalent to 586.78 pounds of 85 percent butter, in 365 days. She has the distinction of leading every cow in the State in the amount of butter yield for the year. Other cows were tested for breeders of Holstein and Jersey cattle during the year. Table XVIII gives the yield of cows in the University herd during the past year.

TABLE XVIII.—YIELDS OF DAIRY COWS AT THE UNIVERSITY FARM, 1917-1918

Name of cow	Breed	Days in milk	Yield: Milk	Yield: Butter fat	Average butter fat
			Pounds	*Pounds*	%
Princess of Chewanbeek....	Jersey	307	5,777.4	299.30	4.74
Childberte	"	328	6,281.3	360.83	5.74
Gipsy Draconis.............	"	406	10,693.1	575.54	5.40
Belle Liscomb De Kol 2d..	Holstein	260	8,125.1	269.80	3.32
Josephine Ariz. Maid......	"	324	13,216.2	382.90	2.89
Theresa Belle Monona.....	"	326	9,765.9	325.52	3.42
Josephine Ariz. Maid 2d...	"	276	8,960.0	251.21	2.80
*Margaret De Kol Johanna..	"	233	3,396.1	106.30	3.19
Madison Martha 2d.........	"	291	8,077.1	243.89	3.09
*Miss Pell Pietertje.........	"	332	5,639.1	219.63	3.95
Thersa Belle Moncna .	"	467	7,934.0	251.92	3.17
Average for herd.........		318	7,987.7	298.79	3.74

*Part of the lactation period.

The number of registered Hereford cattle, Duroc-Jersey hogs, Hampshire and Shropshire sheep have been increased by maintaining some of the females produced by these animals. During the year a small flock of Rambouillet sheep has been added to the equipment, and these will be highly desirable for demonstration and class room purposes.

The department plans to continue the following lines of study during the coming year:

1. Systems of live stock management
2. Lambing ewes on irrigated farms
3. Tiding range cows over drought
4. Finishing cattle for market
5. Pig feeding experiments
6. Poultry managements

The Animal Husbandry Department has been short handed in the past, and a reorganization which will allow more specialization is recommended. With this end in view, a Dairy Department has been established with Professor W. S. Cunningham in charge. This department plans to carry out the following projects during the coming year

1 Study of systems of dairy management
2. Economical rations for dairy cattle
3. Raising calves on milk substitutes
4. Cheese making
5. Milk sanitation

The poultry interest in the State demands a specialist who will be able to devote his entire time to this branch. A specialist in veterinary science is also urgently needed to study local diseases that are peculiar to the district. In order to permit any specialization within the department it will be necessary to have a general assistant who will devote most of his time to teaching. The general live stock interests in range districts warrant the selection of a specialist in Animal Husbandry for agricultural extension work.

R. H. Williams,
Animal Husbandman.
W. S. Cunningham,
Dairy Husbandman.

ENTOMOLOGY

In continuation of the experiments with grasshopper baits begun in 1917, forty combinations were tested in 1918, beginning in the month of May. Definite records were made concerning applications of these combinations to 269 acres of alfalfa and cotton lands. In this work assistance was rendered in various ways by Messrs. O. C. Bartlett, D. C. George, J. L. E. Lauderdale, George Acuff, M. E. Kimsey, and R. H. Armstrong. The work was directed against the same species as in 1917, the differential grasshopper, *Melanoplus differentialis*. The tests were all made in the Salt River Valley with the exception of one application made by the writer in a ten-acre alfalfa field in the Verde Valley near Camp Verde.

The movement or drifting of the grasshoppers in the fields both toward and away from poisoned areas tends to confuse the results of experiments with poisoned baits and makes it necessary to repeat the tests many times under various conditions before drawing final conclusions. Tentative conclusions from the work done in 1917 are as follows:

1. A combination of half and half wheat bran and pine sawdust is fully equal to wheat bran alone for the bulk of the substance of the bait and is easier to distribute than when all wheat bran is used.

2. All sawdust is decidedly inferior to all bran or to a half and half bran-sawdust mixture.

3. For the fruit, oranges are in no degree inferior to lemons and are perhaps slightly better.

4. Canteloupes are in no degree inferior to lemons but on the contrary are apparently slightly superior as well as cheaper.

5. Molasses is not only an unnecessary ingredient of poisoned baits but when used with citrus fruits the effectiveness of the bait is reduced rather than increased.

From the experiments conducted in the summer of 1918 the following tentative conclusions are drawn concerning poisoned baits for the differential grasshopper:

1. Half and half and 60-40 percent wheat bran and sawdust mixtures are fully as good as all bran.

2. Barley middlings is not entirely satisfactory as a substitute for wheat bran although it usually gives fairly good results when used in half and half mixtures with sawdust.

3. Dry horse manure is not a satisfactory substitute for wheat bran altho it is not without merit for use in emergencies.

4. A mixture composed of wheat and corn bran (not over 50 percent of the latter) is as good as straight wheat bran.

5. Canteloupes are fully equal to lemons as ingredients of poisoned baits.

6. Molasses does not add to the value of the bait.

7. London purple as the poisonous ingredient in baits is inferior to Paris green.

Owing to the shortage of wheat bran, barley middlings was extensively used in Arizona in 1918 as a substitute in grasshopper baits. It was necessary to use sawdust with the barley middlings to prevent lumping, the proportion used and advised being from two-fifths to one-half sawdust. In the experiments here considered in which combinations of barley middlings were used approximately 120 acres of infested lands were treated. The results were not as satisfactory as observed in many other cases where barley middlings and sawdust mixtures were used on large areas in demonstrations and in subsequent work by alfalfa and cotton growers. Fortunately it is probable that hereafter there will rarely if ever be any occasion for the use of barley middlings as a substitute for wheat bran.

Horse manure has been recommended by the writer and successfully used in Arizona in grasshopper baits, mixed according to the formula known as "Criddle mixture," but this has not been tested particularly against the differential grasshopper as far as known. Outbreaks of the differential grasshopper occurred in 1918 in localities where neither wheat, bran, barley middlings or sawdust were available. In one instance it was reported that a farmer used dry horse manure in the place of bran with good results. Tests made in the Salt River Valley in 1918 with dry horse manure in various combinations did not give very satisfactory results but more work with this material is very desirable and is planned for next season.

Corn bran alone appeared inferior to barley middlings and sawdust but the conditions were such in the tests of this that even tentative conclusions could not be drawn. A wheat and corn bran mixture was used with almost perfect results. This mixture was purchased as wheat bran but was apparently nearly one-half corn bran.

Of the nine series of experiments in 1918, six gave results relating to the use of molasses. In four series in which molasses was omitted in one or more tests this did not appear to reduce the effectiveness of the baits. In one experiment in which the molasses was increased two-thirds over the usually recommended amount no effect could be detected. In one series in which a medium light grade of molasses was used instead of the usually recommended darker grade the results were almost perfect, tending to show, independent of all other experiments, that a darker grade, particularly "Black Strap," is not necessary.

Baits for use against the differential grasshopper which can be tentatively recommended as a result of two seasons' work reduce the cost of the materials from approximately 50 cents to less than 35 cents. When cull canteloupes are available the cost runs as low as 30 cents per acre. This is on the basis of one pound of Paris green to 5 acres of land.

Poisoned baits are the principal means of combatting cutworms. The regular grasshopper baits are generally recommended thruout the United States at present, altho a few years ago the simple combination of bran and Paris green with or without water was considered satisfactory. As far as known to the writer there are no published results of cutworm experiments showing the value of either lemons or molasses in combination with the bran and Paris green. An excellent opportunity for testing the bran, Paris green, and water combination against a common alfalfa pest *(Feltia annexa* Tr.) was afforded in the fall of 1918 with apparently perfect results. No live worms could be found in the treated field three weeks after the application altho they remained in destructive numbers in a nearby field which had not been poisoned. Cutworm poison consisting of half a sack of bran (32½ pounds) and one pound of Paris green costs at the present time at the rate of 36 cents per acre as compared with 50 cents or more per acre for the usual grasshopper bait containing molasses and lemons. It seems reasonable to assume until actual tests prove the contrary that molasses and lemons are unnecessary and of no value in baits for cutworms.

In connection with investigations of grasshoppers and cotton square daubers *(Lygus elisus* var. *hesperus* Knight and *L. pratensis oblineatus* Say) it was discovered that many cotton fields suffer from these pests as a result of the insects being driven out of adjoining alfalfa fields when the alfalfa crop is cut. As a result of observations made on this point an article was prepared and published in leading publications in cotton growing districts of the State recommending a system which helps to protect cotton from injury from this source. Alfalfa cutting and raking in fields adjoining cotton fields should be started on the sides and continued toward the central land or a land near to it on which alfalfa should be left standing temporarily. The grasshoppers and cotton square daubers are thus concentrated near the center of the field. The grasshoppers can then be destroyed by means of a comparatively heavy application of poisoned bait or by means of a hopperdozer. The hopperdozer proved successful in capturing large numbers of other destructive insects, particularly cotton square daubers and the three-cornered alfalfa hopper. In one test the daubers were captured at a rate of more than 7000 of the insects per acre. It is estimated that this number of the square daubers liberated in or driven into an Egyptian cotton field would be capable of doing damage amounting to between $5.00 and $15.00 per day. The cost of using the hopperdozer would not exceed 25 cents per acre. Even if the insects are not destroyed by this or other means it is very important in cutting alfalfa that they be driven into the middle of the field or away from the cotton rather than toward it.

The cotton square daubers are active fliers and if disturbed when feeding quickly emerge from the feeding place inside the bracts of the square and dart away, usually alighting on another plant a few feet distant. Two contrivances have been designed by the writer for the protection of cotton fields against these insects. The first is for the purpose of driving the bugs to the outside rows of the field where, when concentrated, they may be captured by means of the second device. Even if the insects are left concentrated on the outside rows there is a decided advantage in this system, since two or three of the insects per plant are sufficient to destroy all the squares as fast as they are developed, and concentrating the insects on outside rows so that there will be several times as many of them per plant can not, therefore, result in any additional injury. When concentrated in excessive numbers, however, there would probably be a tendency for the insects to spread out again over the field unless some other means was used against them. An important feature of the work planned for the coming season consists in the development of the devices mentioned to a point where they can be recommended to cotton growers.

Publications by the Consulting Entomologist during the fiscal year included the Annual Report of the State Entomologist in the Ninth Annual Report of the Arizona Commission of Agriculture and Horticulture, pages 15 to 61, December 30, 1917, and a paper entitled "Experiments with Grasshopper Baits, with Incidental Observations on the Habits and Destructiveness of the Differential Grasshopper (*Melanoplus differentialis*)" in Journal of Economic Entomology, Vol. II, No. 2, pp. 175-186, April, 1918.

A. W. MORRILL,
Consulting Entomologist.

ZOOLOGY

Early in the college year 1917-18, the writer was transferred from the College of Arts and Sciences to the College of Agriculture and the Experiment Station, as Zoologist, this line of work having been previously represented in the Station only by Entomology under the Consulting Entomologist.

The first work taken up was an investigation of cutworms in Arizona, and the preparation of a bulletin to be referred to later. Shortly after taking up the cutworm work, attention was directed to the range problems of the State, particularly with reference to the injurious effects of rodents on the native grass lands. This problem soon loomed so large as to make it desirable to drop the cutworm work, and take up an intensive study of certain range rodents, which was done. Cooperation with the Forest Service, the Biological Survey, and the Carnegie Institution has led to the development of important range studies which are being conducted on the Santa Rita Range Reserve, 40 miles south of Tucson. The Forest Service, under the direct recommendation of the Biological Survey, has furnished funds (about $800) for the construction of special fences for experimental plots, the first fences of their kind ever built. The Forest Service has also cooperated in furnishing the conveniences of a headquarters camp on the edge of the Reserve, thru the courtesy of Mr. Hensel, Forest Examiner in charge. The writer has been occupied to a considerable extent with supervision of construction of these fences, as well as actual labor on same, and with rodent studies, especially on kangaroo rats, carried on month by month with the fencing work. It was expected to have these experimental areas fenced by June 30, 1918, but difficulties in securing materials and labor forced an extension of time, and they were not entirely completed until late fall. However, the drought was so severe on the Reserve, and especially on those portions of it where the experiments are located, that the inauguration of certain features of the work will have to await the next summer's rainy season

Severe injury to corn in the Rillito Valley near Tucson, by a stalk borer, was reported to the writer in October, 1917. This borer, according to Dr. Morrill, State Entomologist, was first reported in this State in 1915 from Cochise County. (See Eighth Ann. Rep. Ariz. Com. Agri. and Hort.) Some life-history observations were undertaken in cooperation with the Commission of Agriculture and Horticulture in order to secure adult moths and determine whether this pest is identical with the larger corn stalk borer of the East. Moths have been secured which appear to be identical, but this latter point is not yet fully settled. Further reports have been received the past season indicating the presence of this borer at Sahuarita, in the Santa Cruz Valley. As a preventive measure where this borer occurs, the corn stubble should be plowed under during the fall or winter, and such stubble as is left on top of the ground should then be raked up and burned.

A beginning has been made on the task of building up a representative collection of the insects of the State, emphasizing especially the economic forms, for demonstration, and for general study purposes in the courses in Entomology in the College of Agriculture. This task will necessarily be continuous for a number of years.

The growing importance of honey during the sugar shortage and the extremely high market value of the product led to a decision to start, in a small way, an apiary for demonstration purposes and for study. Four standard 10-frame hives have been secured, and three of these now contain thriving colonies of bees, transferred from old boxes on a neighboring ranch. At the University Farm four hives, left there by some former foreman, have been cleaned up and house as many strong colonies. Thus seven colonies are ready for active operation in the next honey season. From the Farm hives some surplus chunk honey was secured the past season, which is being held against possible need in bringing all colonies thru the winter in good condition. There was also taken from these hives 24 pounds of comb honey, which was sold for thirty cents a pound, wholesale.

PUBLICATIONS

The preparation of Bulletin No. 83, on Poisonous Animals of the Desert, occupied a considerable amount of time in the earlier part of the year. This bulletin is perhaps a bit out of the ordinary in the usual run of Experiment Station bulletins. It deals with not only the poisonous animals of this region, but gives reliable information concerning many popularly feared, but actually harmless forms. The demand for this bulletin has justified its preparation.

CHAS. T. VORHIES,
Zoologist.

CHEMISTRY

The activities of the Chemists, as heretofore, have fallen under three divisions: research, routine analytical work, and instruction. The facilities for research in soil alkalinity have been improved much by the construction of a screened garden so that now laboratory investigations may be accompanied by pot cultures and even small plot experiments. Such facilities are indispensable for protection against birds, insects, and rabbits, which because of the scarcity of green food in a semi-arid country preclude experiments on a small quantitative scale in the open. The general laboratory equipment has been improved by completing the equipment of a dark and nearly constant temperature room. The room is located near the center of the agricultural chemistry laboratories in the new Agriculture Building. Besides desks for calorimeter and polariscope the equipment includes a special table for ether extractions. A large refrigerator occupies the space beneath the table usually given to cupboards and is provided with water coils, which supply ice water for condensing purposes. For several months in the year tap water cannot be used for condensing ether, a fact that heretofore has worked great inconvenience, requiring special cooling devices or the postponement of fat determinations until the winter months.

Routine analytical work has covered a considerable range of material. Many irrigating waters and soils for alkali have been examined for farmers in the State, and much analytical work was required in connection with expert advice furnished other branches of the State and Federal Governments. The Chemist, accompanied by the Agronomist of the Station, examined and reported on a number of parcels of land offered the State for a state prison farm. In the case of all properties offered soil and water tests were made at the laboratory.

During November and December the Chemist was again called upon to serve on a commission, together with the Agronomist and Horticulturist, whose duty it was to investigate the suitability of the mesa at Yuma for citrus and other subtropical fruit culture, when irrigated with the silty waters of the Colorado as proposed by the U. S. Reclamation Service. The analytical and soil experimental work required in investigating this problem has occupied the personnel and facilities of the laboratories for several weeks. Total, acid soluble, and citric acid soluble potassium and phosphorus are being determined on a number of typical soil samples from the

Mesa. Mechanical analyses and tests of water holding capacities are being made, and parallel pot cultures using inoculated legumes are also included in the investigation. In cooperation with the Horticulturist a series of samples of citrus fruit from the old Blaisdell orchard on the Yuma Mesa have been analyzed with a view to showing their early maturing and other qualities. The details of these several lines of investigation will be found in the report of the commission to the Project Manager of the U. S. Reclamation Service at Yuma. This report, which is a joint report from the three departments concerned will be published as a bulletin by the Experiment Station and is here referred to as forming a part of the Chemist's annual report.

RESISTANCE OF CROPS TO ALKALI

A series of soil analyses illustrating the resistance of cotton and other crops to alkali under field conditions have accumulated in the laboratory and are given in Table XIX.

An inspection of Table XIX reveals the extreme difficulty of attempting to establish limits of tolerance for alkali under field conditions. Possible reasons may be offered for some of the discrepancies. First should be mentioned the difficulty of getting soil samples that really represent the conditions under which the plants are growing. The surface crust is always very alkaline and should not enter into the sample in greater relative proportion than it occurs. The roots of the plants may be drawing on other zones than the one sampled, alkali being known to vary abruptly with depth. In cultivated fields the variation in concentration also varies greatly within a few feet. The mechanical composition of the soil undoubtedly has much to do with alkali tolerance. In the case of black alkali dissolved organic matter possibly may be poisonous. One salt also influences the effect of another. Water soluble salts due to calcium sulphate are harmless, but calcium chloride or soluble magnesium salts are harmful forms of white alkali.

The soil 6819 carries excessive amounts of soluble salts, mostly sodium chloride, but it was said good crops were produced the previous year, and the land had again been prepared for planting. The sample analyzed was moist subsurface when collected. Dry surface clods with capillary contact ran much higher in soluble salt. The high tolerance in this case may be explained by the subirrigation which kept the soil constantly wet.

Barley soils 6823 and 6824 show the best growth in the case of

TABLE XIX.—RESISTANCE OF CROPS TO ALKALI UNDER FIELD CONDITIONS

Crop	Description	Soluble salts	Sodium chloride equivalent	Sodium carbonate equivalent	Calcium sulphate equivalent
		%	%	%	%
Cotton 6819	Good crop previous year; subirrigated by seepage from canal	1.06	.636	...	.48
Milo 6821	Adjoining above; yielded some milo previous year	.66	.360	..	.07
Cotton 6822	$1\frac{1}{4}$ bales to acre; near above	.44	.016	...	.02
Barley 6823	Just failure at this point	.80	.306	.15	...
Barley 6824	Same field; just profitable	.71	.148	.20	...
Barley 6825	Growing but failure; hard soil; poor water relations	.30	.040	.09	...
Barley 6826	Same field; commencing to head at 12 to 15 inches; thin	.26	.004	.10	...
Cotton 6827	Failure previous year; old stalks 1 foot high; land probably bakes	.35	.068	.02	...
Cotton 6828	Part same field; cotton good; soil very hard	.24	.02	.07	...
Cotton 6752	No cotton	2.29	1.408	...	.609
Cotton 6753	Same field; some growth	0.47	.168	...	.109
Cotton 6754	Tall cotton	.37	.152	...	.065
Teparies 5887	Edge of bare spots	.63	.124	...	.152
Teparies 5888	Same; bare spots	1.30	.516	...	.416
Teparies 5889	Same; edge of bare spots	.55	.112	...	.174
Teparies 5890	Same; 50 percent injury	.42	.076	...	.109
Teparies 5898	Same healthy	.30	.008	...	.022
Asparagus 6161	Plants just alive	1.50	.50	.22	...
Barley 6004	3" to 5" high; same field	1.32	.50	.02	...
Barley 6005	$3\frac{1}{2}$" high; same field	.43	.008	.034	...
Barley 6006	4" to 7" high; same field	.88	.26	.017	...
Barley 6007	4" high; same field	.41	.008	.12	...
Feterita 6203	Barely existing	.50	.012	.15	...
Feterita 6204	Same; scattering light growth	.49	.012	.12	...
Feterita 6205	Same; 35 percent stand	.23	.008	.06	...
Feterita 6206	Same; 50 percent stand	.24	.008	.04	...

TABLE XIX.—*Continued*

Crop	Description	Soluble salts	Sodium chloride equivalent	Sodium carbonate equivalent	Calcium sulphate equivalent
		%	%	%	%
Feterita 6207	Same; good crop	.22	.008	.02	...
Feterita 6212	Adpacent land; 25 percent stand	.32	.008	.22	...
Feterita 6213	Same; good crop.............	.30	.008	.06	...
Feterita 6214	Same; almost killed..........	.33	.008	.12	...
Feterita 6215	Same; very good crop........	.32	.008	.03	...
Milo 6210	Adjacent land; barely existing	.59	.036	.13	...
Milo 6211	Same; very good crop........	.32	.008	.05	...
Alfalfa 5979	At head of land; no alfalfa...	.57	.152	.19	...
Alfalfa 5980	Same; good alfalfa...........	.38	.048	.10	...
Alfalfa 6197	Killed........................	.82	.024	.33	...
Alfalfa 6198	Same; just existing..........	.42	.012	.12	...
Alfalfa 6199	Same; affected	.27	.012	.05	...
Alfalfa 6200	Same; good growth...........	.29	.012	.04	...

the latter which contained one-third more black alkali; but it is to be noted that the first contains twice as much sodium chloride. The failure in 6825 and 6826 as compared with 6824 was due probably to a hard condition of the soil intensified by the deflocculating effect of the black alkali so that water did not penetrate well when the soil was irrigated—so-called slick land.

In the case of cotton soils 6752, 6753, and 6754 white alkali is the limiting salt but there is no apparent explanation for the marked difference in growth between 6753 and 6754. Teparies are apparently quite sensitive to soluble chlorides. Asparagus, which is ordinarily a salt-loving plant, was affected by black alkali in the presence of the rather excessive amount of white alkali. The series of barley soils 6004, 6005, 6006, and 6007 seem to yield no conclusive evidence. The injury thruout was probably due to a tight soil intensified by the varying amounts of black alkali present which prevented it from taking sufficient water. The feterita and milo series were taken from sandy soils at the University Farm, which are discussed in the section of this report dealing with alkali studies. This soil is particularly favorable for study of black alkali tolerance, since the sodium chloride is uniformly low, the white alkali being due to sodium sulphate. Here again, however, results are not entirely consistent, probably due to water conditions. In general .10 seems to be the limiting percent of black alkali for these crops, altho in one case a considerable stand was found where .22 percent was present and considerable injury was noted where .06 percent was present in samples believed to represent the soil under field conditions. The alfalfa soils illustrate to a certain extent the influence of texture. Sample 5980 was a rather heavy soil occurring near Wellton, Arizona, while 6197, 6198, 6199, and 6200 were from the sandy soil of the University Farm.

MISCELLANEOUS ANALYSES

One interesting set of samples came from a mining company that had failed in an attempt to raise a war garden and sought a remedy. The soil was impregnated with copper, and the mine water which was used for irrigating carried so much copper that possibly it might have been recovered with profit. Such conditions would inhibit practically all plant growth.

Various materials of agricultural interest other than soils and irrigating waters have been examined by the Chemists. These include foods and feeding stuffs such as barley flour, barley bran, cottonseed meal, and fish meal. Only moisture, ash, and ether extract were determined in the barley flour. Barley flour, being a wartime product, probably will be of transient interest, but since the product is rather uncommon and produced in Arizona the results are recorded in Table XX.

TABLE XX.—COMPOSITION OF ARIZONA BARLEY FLOUR

Date of Mill Run	Moisture	Ash	Ether Extract
	%	%	%
August 12, 1918.....	7.63	1.13	2.18
" 13, "	7.73	1.12	2.19
" 14, "	6.57	1.19	2.08
" 15, "	6.45	1.25	2.21

Fertilizing materials or materials supposed to carry fertilizer values, especially bat guanos, have been sent in from time to time. On one occasion the Chemists visited a bat cave deposit with a prospector and advised against the shipment as unprofitable.

At the time when food stuffs in general were suspected of having been tampered with, a number of samples of corn meal and cocoa were sent in to be examined for powdered glass. Several grams of the material were dissolved in boiling sulphuric acid till almost colorless, the acid diluted and decanted from any residue remaining undissolved. All the corn meals left small residues of easily identified minerals, such as quartz and garnet, but no glass. One sack of meal contained several large fragments of glass which could not have been eaten and evidently were intended to create prejudice rather than to do injury. No fine glass was found in any of the samples, but the millers in all cases were cautioned to clean their corn so that no adhering soil would be carried into the meal, causing grit that might be mistaken for glass. One sample of cocoa was found to contain a few very minute fragments of glass-like material which may have been chipped off the porcelain lining of some machinery used in its preparation. One sample of bran that was reported to have killed a calf was found to contain cyanide.

THE TEMPE DRAINAGE DITCH

In continuation of the work reported in the Twenty-seventh and Twenty-eighth Annual Reports occasional analyses of the discharge of the Tempe drainage ditch have been made. The results for the year 1918 are detailed in Table XXI which should be studied in connection with previous results given in the Twenty-eighth Annual Report on page 475.

TABLE XXI.—MONTHLY VARIATION IN COMPOSITION OF WATER FROM THE TEMPE DRAINAGE DITCH, PARTS PER 100,000—BY C. N. CATLIN

Date	Total Solids	Chlorides as NaCl.	Hardness (permanent) $CaSO_4$	Hardness (temporary) $Ca(HCO_3)_2$	Alkalinity Na_2CO_3	Qualitative		
						SO_4	CaO	MgO
1918								
Jan. 10	212.6	133.0	1.1	127.5		Str.	Mod.	Sl.
Feb. 10	322.0	219.0	11.5	130.0		Str.	Mod-S	Mod.
Mar. 10	303.0	211.0	18.5	127.2		Str.	Mod-S	Mod.
Apr. 10	226.4	154.0		112.6	1.7	M.S.	M.	M.S.
May 11	351.2	248.0	11.9	128.4		M.S.	M.	M.
June 5	296.6	207.0	6.5	118.3		M.S.	M.	M.
July 8	301	206.0	1.1	113.8		S.	M.	M.
Aug. 1	249.8	181.0		69.5	2.5	M.S.	M.	M.
Sept.				No Sample				
Oct. 10	205.8	137.0		93.5	5.9	M.S.	M.	M.
Nov. 3	245.0	170.0		87.4	5.9	M.S.	M.	M.
Dec. 12	216.6	138.0	2.2	127.5		M.S.	M.	M.

ALKALI STUDIES

The research work of the department conducted under the Adams Fund has been limited to alkali problems. During the past year the Chemists have studied the influence of various chemicals in different amounts on the rate of percolation and on the composition of the percolate. This involves much analytical work. Attempts were made to parallel the laboratory studies by pot cultures which at first proved unsatisfactory due to the difficulty of preventing leaching when the pots were irrigated and the consequent change of concentration of alkali in the soils. Successful pot culture studies in this climate require that the pots be sunk in soil to prevent too high temperature and excessive drying. Benches have now been constructed in the screened garden in which the pots are sunk in sand at the level of the surrounding soil and any percolating water due to heavy irrigating is caught in receptacles and returned to the pots. The pots are paraffined to prevent losses by transfusion.

The percolation experiments with gypsum have been especially interesting. When a percolation test is made comparing untreated University Farm soil with samples to which the theoretical amount and half that amount of gypsum have been added, it is found that the second half of the gypsum applied has two or three times the effect of the first half in promoting percolation. Large plot experiments are now being conducted which are planned to test this result in a practical way. Several lands at the University Farm have been divided into numerous small plots each of which has been analyzed to a depth of three feet and the necessary amount of gypsum calculated separately for each plot of 1500 to 2000 square feet. These lands had been treated previously by applying gypsum uniformly over the surface, but without reclaiming them successfully. After the proper amount of gypsum has been applied, the lands will be leached by confining the water on the more alkaline areas. Without gypsum, percolation is very slow, altho the soil is a very fine sand. In the laboratory water applied an inch deep to the wet soil in 10-inch flower pots and covered to prevent evaporation has stood for two or three weeks without entirely disappearing. It appears from the investigations in the laboratory that light or insufficient applications of gypsum would be unprofitable. On some areas it is necessary to apply 30 or even 40 tons of gypsum to the acre. Under some conditions this would be prohibited, and never could be considered for large areas. Gypsum beds, however, are available near the University Farm and hauling is done by the farm teams when other work is light. Small areas of black alkali in otherwise good lands, as is the condition at the University Farm, would often warrant the expenditure of several hundred dollars for reclamation. How permanent the effect will be remains to be shown. The groundwaters are slightly black alkaline and occasionally rise to within seven or eight feet of the surface. The effect of gypsum on the rate of percolation with this soil in 10-inch pots is given in Table XXII.

TABLE XXII.—PERCOLATION THRU UNIVERSITY FARM SOIL AFTER GYPSUM TREATMENT

Amount used	Percolate in 24 hours[1] after standing 5 days	Percolate in 24 hours[3] after standing 7 days
	C.C	C.C.
None	400	288
Half enough to neutralize Na_2CO_3.....	880	696
Just enough to neutralize Na_2CO_3.....	2560	2112
Twice amount to neutralize Na_2CO_3...	3680[2]	4320

1. Calculated from a 6-hour test by adding 1000C.C. of water to each pot. 2. Insufficient head to keep up percolation for 5 hours. 3. Calculated from a 5-hour test by adding 1000 C.C. of water to each pot. Note: The 10-inch pots used in these tests each contained 10 kilos of soil. The soil used gave the following analysis: Total water soluble salts dried at 110° C. .70 percent, chlorides as sodium chloride .012 percent, black alkali as sodium carbonate .254 percent.

An analysis of the percolates showed a saving in humus and all plant foods with the exception of potassium. The saving in nitrogen values at customary fertilizer prices would go far toward paying for the gypsum treatment, even if it were possible to reach the black alkali from the soil without the previous application of gypsum.

DATE PROCESSING AND MARKETING

During the summer the appliances for ripening and processing dates at the Tempe Date Orchard were inspected and put in order for handling the fall crop. Several visits were made to the orchard during the harvest to supervise the packing house operations and give instructions in handling the different varieties under varying weather conditions. A suitable packing house for the Yuma Orchard has been designed but not yet constructed. Before the arrival of the Horticulturist the Chemist temporarily supervised cultural operations at the date orchards.

In the opinion of the writer after thirteen years of close study, the date industry in Arizona, properly managed, can be recommended to the investing public. Fresh dates of the soft varieties which can be grown of such excellent quality in Arizona and marketed as safely as any other crop are becoming known thruout the country, and orders and inquiries from every part of the United States are coming in quantities—a marked contrast to the condition ten years ago when the foreman of the orchard with difficulty disposed of a few hundreds pounds at a nominal price by house to house peddling in nearby towns. During the past year over $6000 without soliciting have been received for the product of palms that could have been placed on about four acres. After paying liberal wages and other operating expenses, exclusive of the foreman's salary, a net profit of 40 or 50 per cent on the gross sales will be realized. Had the usual business policy of selling for all the market would bear been followed, the gross sales probably would have reached $10,000. The policy followed, however, has been to maintain a uniform, fair price, estimated safely to cover expenses, and limit sales to the individual. A part of the crop has been marketed in the east to introduce the product and create a market for future growers. The immediate vicinity would have consumed the crop many times over at even higher prices, had limitations not been placed on sales to the individual. The Experiment Station has proven at least some of the varieties that are successful in Arizona; climatic difficulties have been overcome to the extent that losses due to this cause are almost negligible; and a market has been made that will take the output of a large acreage at profitable prices. Fresh soft dates, such as Hayany, Rhars, Tadala, and similar varieties, promise to become a staple food as soon as they can be supplied in quantity, and may be carried for months in dry cold storage without serious deterioration in quality. Culls and stock that have been damaged for the fresh date trade by weather conditions can be processed quickly for ordinary commercial dried dates. The close of the war should mark the importation of large numbers of Hayany offshoots from Egypt, and the establishment of the date industry in Arizona on a firm basis.

EDUCATIONAL AND EXTENSION WORK

Altho the department is not identified with the Extension Service, a large amount of correspondence regarding soils and irrigating waters is necessarily carried on with the farmers of the State. These demands, as previously mentioned, often require much analytical work. In February and March a four weeks' short course for farmers was given, during which the Chemist conducted a class in soils for two periods each week. A correspondence course in soil physics is being given. In the College of Agriculture the Chemist has conducted classes in soil physics and soil fertility. A laboratory course in agricultural chemical analysis is also offered, but due to temporary disarrangements has not been given. Two new courses in household chemistry for young women in Home

Economics are being given. The first semester's course, after a brief introduction to organic chemistry, largely nomenclature, deals with the chemistry of foods. The laboratory exercises are designed to familiarize the student with the compounds occurring in foods rather than as a drill in analytical methods. The second semester deals with textiles and laundering, including the removal of stains.

The department is well equipped for work with advanced or graduate students. Some of the problems under investigation in the Experiment Station may be entered into by the students or independent investigations may be made. Work in this line should be encouraged by offering suitable fellowships which would be to the mutual benefit of the student, the department, and the Experiment Station.

A. E. VINSON,
Chemist.
C. N. CATLIN,
Assistant Chemist,

IRRIGATION INVESTIGATIONS

Owing to the absence of the assistant engineer, Capt. A. L. Enger, and the difficulty in obtaining technical assistance, the work of this department has been much restricted during the past year. Certain features of Experiment Station work inseparable from the office were performed as in previous years, while other features, and especially research, suffered disproportionately.

STATUS OF IRRIGATION WATER SUPPLIES

The year has been one of light rainfall and the necessity for irrigation has increased. The stream flows have been meagre and many areas have suffered for water. The advantage of water storage has been exemplified in the Salt River Valley where plentiful water has been available for an increased acreage, because of the supply in Lake Roosevelt, stored during the flood years of 1915 and 1916. The lack of simi'ar storage on the Gila River has been felt keenly. The hundreds of thousands of acre-feet of water that were wasted to the sea in 1915 and 1916 could have been used with great advantage in 1917 and 1918 if a storage reservoir had been available. Surely no other project in Arizona offers such inducement for governmental action as the building of the San Carlos dam and irrigation project. On the Colorado River, too, the time has arrived when storage is necessary, for the natural flow during the period of low discharge is entirely appropriated, and it will be necessary soon for Arizona to join with other states in storage projects on the Colorado, else even the right to flood waters of the river will be lost. The Parker Val'ey, especially, should be provided with a water supply at the earliest possible time. The need for action in the development of storage projects has become more urgent by the call for new lands on which returning soldiers can make homes. Arizona is one of the states in which there is abundant opportunity to prepare new lands under projects that are known to be economically feasible.

AN IRRIGATION CODE

Arizona, the most arid state, the one most in need of the modern system of establishing and administering rights to water, is the only irrigated state which has not adopted the system. The chaotic condition of water rights in the Gila River watershed is retarding the development of agriculture in southern Arizona and the lack of a state water commission is jeopardizing the interests of this State in the waters of the Colorado River. In Yuma County the water rights have never been adjudicated and in the other counties, with the exception of Maricopa, the adjudications have been only partial, are admittedly ineffective, and in many instances are counter to well-established irrigation law. Moreover, there are scores of small sources of supply, where a few farmers struggle for the water and not infrequently a murder is the inevitable result.

Water rights should be as well protected by the State as are land rights, and the irrigation supplies which belong, and always will belong to the State, should be administered by the State. This department has exerted its efforts to stimulate a demand on the part of the agriculturists for the modern code. It is hoped that the coming legislature will attack this problem and enact a code based on the principles of the Wyoming and Oregon codes but with such modifications as are needed to meet the needs of this State.

In the absence of any workable method of adjudication of the water rights of the Gila watershed, the conflicting interests of Pinal County have endeavored to settle their priorities by mutual agreement, but so far without success. This department is assisting in the negotiations.

CAISSON WELLS

The type of well, originated by this Station in 1907, has proved to be well adapted to the groundwater conditions of such valleys as the Santa Cruz, and these wells are being adopted increasingly. The station is called upon frequently to plan and start the construction of wells,—sometimes in emergencies where the groundwater must be developed quickly in order to save a crop. The high cost of steel casing during the past year has increased the preference for concrete caisson wells.

PUMP IRRIGATION

The acreage of land irrigated from wells has been increased greatly during the past two years. The location of the best groundwater supplies is being ascertained and the high prices of agricultural products have warranted even a high cost for irrigation. Problems of pumping machinery are being given more attention. No new types of machinery have demonstrated any advantages over older types, but more care is being observed in designing pumping plants to fit the conditions of lift and discharge.

Fig. 5.—Longitudinal crack in 20-inch pipe line. The open section has been broken out with hammer. Photo by W. C. Axelton.

A few years ago pump irrigators had available an engine fuel oil of suitable quality, but of low cost. This oil has been called by various names, including tops and gas oil. Gas oils with a flash point of about 100° F. and with a gravity of about 44° B. were to be bought at five to six cents a gallon. Recently, while the price has been going up the quality has been going down. The tops now being furnished by many refineries is of about 37° gravity and is very troublesome in engines of the ordinary type and size. Meanwhile engine distillate has depreciated in quality until it is no better for irrigation pumping than was the gas oil of five years ago, altho the price is three times as great. The increase in cost is due in part to the fact that the engine distillate is classified as a finished product and therefore takes the same freight rate as gasoline. The Fuel Administration offers no relief. A few of the smaller oil companies continue to furnish a satisfactory tops at a reasonable price. Pump irrigators should demand an unrefined distillate of 40° to 44° gravity and with flash point under 120° F. This oil takes a low freight rate, and moreover the cost of refining will be saved. Unless some relief is obtained in this matter, pump irrigation will be more restricted and less profitable than has been thought hitherto.

CEMENT PIPE FOR IRRIGATION PIPE LINES

CEMENT PIPE FAILURES

Several important studies of cement irrigation pipe have been made during the past year.

The study of failures of cement pipe was necessitated by failure

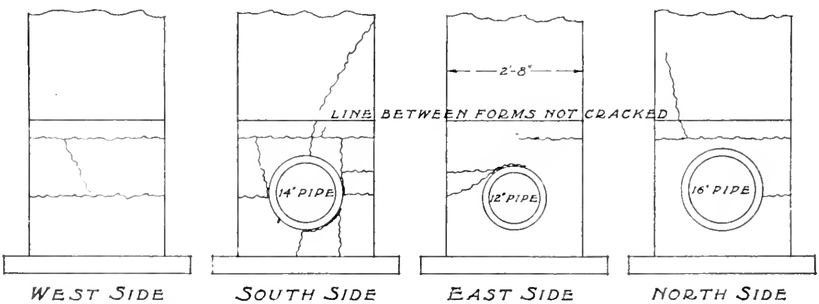

Fig. 6—A cracked gate pit at Continental, caused by expansion of pipe line.

of a long line of 20-inch pipe at Continental, Arizona. Sections of this line, from 20 to 1000 feet at a time, failed by longitudinal cracks. An example of a break is shown in Fig. 5. The photograph was taken after a cross-section of the pipe had been broken out by the pipe layer. Patching of these breaks was not possible and the long sections were removed from the trench and replaced.

The cause of the breaks was not apparent and inquiry among cement pipe men did not throw any light upon the problem.

Additional trouble was being had with the gate pits which occur at intervals of about a thousand feet along the line, and this trouble was not confined to the line of 20-inch pipe. In Fig. 6 is shown a broken gate pit. Examination showed that the gate pits were being destroyed by the thrust of the pipe lines caused by longitudinal expansion. Most of the pipe had been allowed to become very dry in the stack yard, as is recommended by pipe men. This caused a considerable shrinkage. When water was admitted to the completed pipe line, the pipe walls absorbed it slowly and expanded, crushing the gate pits. In experimenting with expansion joints, it was found that these joints must be placed closer than 200 feet in order to absorb expansion.

Some laboratory tests were made to determine the nature and rate of expansion, and its relation to the absorption of water. It was found that the absorption of water under no head was rapid on the outside of the pipe specimens but extremely slow on the inside, the difference being due to the glaze left on the inside in the process of manufacture. Under considerable head the absorption on the inside would be more rapid. The expansion lagged somewhat behind the absorption.

The first longitudinal break occurred on a curve and it was thought therefore that the cause might be longitudinal shear. Mathematical analysis of the problem demonstrated that while this might be true for pipe lines laid on sharp curves, the deviations from a straight line made by a careless pipe layer could not account for the cracks.

Two 16-inch pipe which had been broken in the internal pressure testing machine and had subsequently become dry, were further tested in the laboratory by being placed horizontally and immersed to cover the lower one-fourth and lower one-half, respectively. The pipes were placed so that the open cracks were at the top. Absorption from the outside caused the cracks first to close and then to reopen in part. In a similar test on a 14-inch unbroken pipe, the lower side was found to expand almost normally while no expansion occurred on the top, and a slight crack opened on the inside at the top at one end.

While making percolation and internal pressure tests of pipe, it was found that certain specimens failed at very low pressures. The pipe walls when broken showed that the water had penetrated from one-fourth to one-third of the thickness. Apparently the expansion of the inner portion of the wall produced tension in the unwetted portion and caused the pipe to burst. This action, which may be called differential expansion, doubtless is the main cause of the failures of pipe lines by longitudinal cracks.

The intensity of differential expansion must vary with many factors, including the thickness of the pipe walls, the richness of mixtures, the mortar consistency, and the climate. It is believed also that the magnesia content in the cement affects the amount of expansion.

Several methods of overcoming the danger have been proposed, but it is believed that the only thoroly safe method is to prevent the drying of the pipe between the curing and laying. The curing should be continued up to the time of laying.

METHODS OF TESTING CEMENT PIPE

The technique of cement pipe testing has not been well standardized and different methods are in use by those engaged in pipe testing. It is quite impossible, therefore, to make comparisons between pipes made and tested in different places. Factors of safety in design must depend on the methods employed in testing. A paper on this subject, discussing certain alternative methods and pointing out the importance of standardizing the condition of the test specimens as well as the methods of testing, has been contributed to the technical press.*

REINFORCEMENT FOR CEMENT PIPE

Several trials of reinforcing cement pipe were made during the year, but in all cases the reinforced pipe was found to be weaker than plain pipe. Electro-welded wire rings, hog wire, and Triangle Mesh were tried. Reports from other sources show similar disappointing results. This matter needs further extensive investigation. If a means of making the reinforcement effective can be found, the field of usefulness of cement pipe will be widened greatly.

The publication of the bulletin on cement pipe noted in the last annual report has been delayed, but the bulletin is now in press and will be issued shortly as No. 86 of the Station series.

TRACTOR POWER ON FARMS

This department has watched the development of traction en-

*Concrete, Vol. 13, No. 5, p. 156.

gines with a view to their usefulness on Arizona farms. Tractors have been bought quite freely in Arizona and every type on the market has been represented among those in use. During the past year, particularly, many new tractors have been brought into the State, partly on account of the widespread change from alfalfa farming to cotton, which requires much more plowing.

Many of the tractors first used in Arizona did not prove successful. Some were too heavy and too expensive for the purposes to which they were put, some suffered from operators who could neither care for nor repair them, and some were ill-suited to the soil conditions. In many cases the usual number of mules or horses were retained on the farm, and repair bills have been very heavy.

The writer has tended to favor the round-wheel type of tractor; four wheels; slow speed engines; number of cylinders proportional to the power, one or two cylinders for small tractors; long stroke; and a transverse main shaft. As a rule, the more closely a tractor engine resembles automobile engines, the less useful it will prove to be. High speed engines cannot burn low grade distillates. The rating of many tractors is not very liberal, and usually they should be loaded with one less plow than they are advertised to pull. The rating by manufacturers is very variable; of two tractors much used in Arizona, one rated at 20 horsepower and one at 25, the 20-horsepower tractor has the more power. Wide tires with cleats are required for farm work. The utmost protection is needed against the dust and fine sand which usually flies during the plowing seasons. Gears should be housed and run in oil wherever possible. Forced feed lubrication for cylinders and bearings is very desirable. The standard speed adopted by tractor engineers is two and one-third miles per hour; higher speeds are not to be recommended. The creeping tread tractor is justifiable on California unirrigated grain lands where the spring planting is done while the ground is still soft from the winter rains, and on difficult tasks such as dragging the giant V's that clean the Yuma lateral canals.

The criteria for estimating the relative success of a tractor on any farm are: The type of farming, and number of days per year when the tractor is used; the mechanical ability of the owner or operator; and the fitness of the type and size of tractor to the soil and nature of the work to be done. There are many farms where tractors can be employed profitably; there are many others where a tractor would be a proverbial white elephant.

The employment of tractors in custom work should be increased. This implies that each tractor is operated by an expert tractioneer and in most cases that he is the owner of the machine. Failures that have occurred in this line have been due usually to the fact that the owners underestimated certain items of costs, such as repairs and depreciation and fixed their prices too low. Tractor garages should be established in agricultural centers, where tractors can be engaged for farm work.

G. E. P. Smith,
Irrigation Engineer.

The University of Arizona

College of Agriculture

Agricultural Experiment Station

Bulletin No. 91

Steers in Lot VI, February 12, 1920

Fattening Native Steers for Market: 1920

By R. H. Williams

Tucson, Arizona, September 1, 1920

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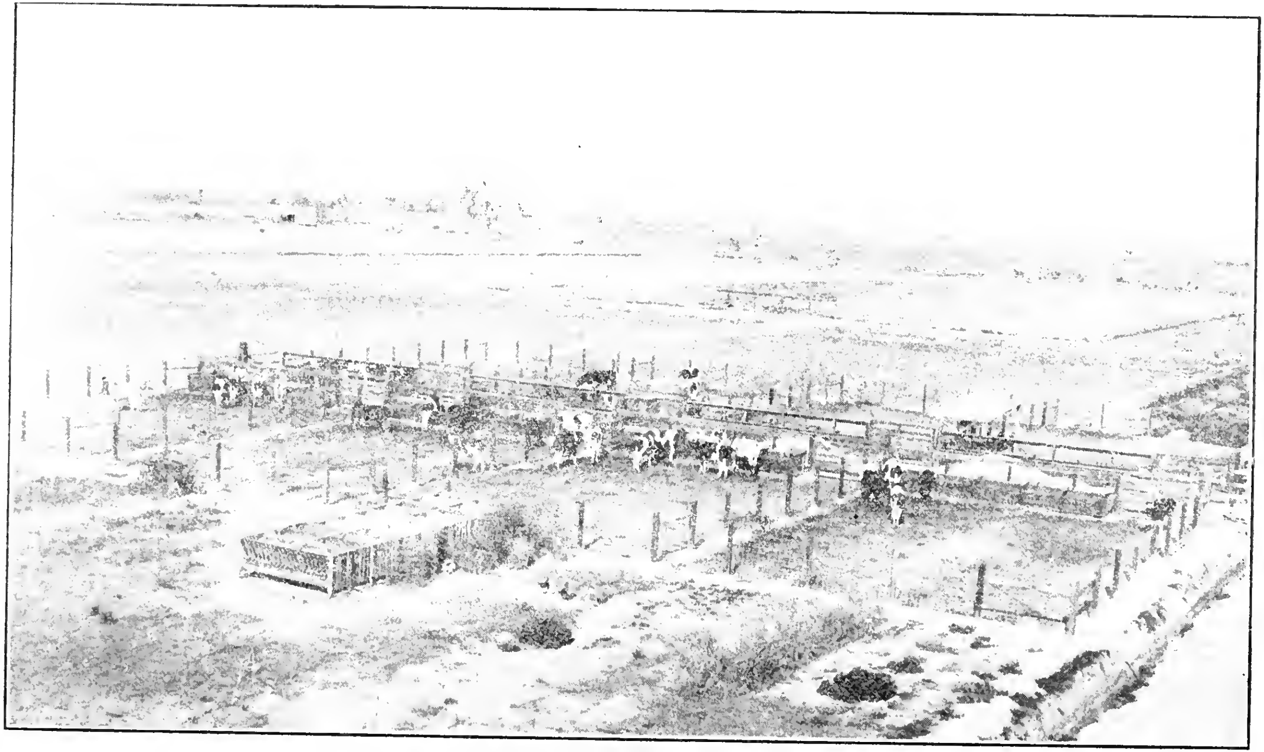

Experiment steers in feed lots, January 23, 1920

Fattening Native Steers for Market: 1920

By R. H. Williams

INTRODUCTION

Cattle feeding has been an important industry for many years in the irrigated valleys in Arizona. Annually upwards of 30,000 cattle are finished for market in the Salt River Valley alone. Conditions have been especially favorable there for cattle feeding. A diversified system of crop production and rotation is necessary in the irrigated districts. Certain high-priced crops must have other crops rotating with them to maintain fertility and occupy the ground. Cattle offer a special means for marketing home-grown feeds; in this way bulky feeds may be concentrated into gains in weight and the finished animals shipped to market On almost all farms can be found certain by-products, such as cotton stalks, Bermuda grass, Johnson grass, corn stalks, or even silage and winter pasturage, which cannot find a profitable market except through livestock. Barley and other green feeds may be secured at small expense and animals finished for market on these feeds alone.

Arizona is favorably situated for cattle feeding. The light rain fall and absence of cold stormy weather, combined with bright sunny winters with even temperatures, are favorable for cattle feeding from December to April. Range cattle are grown close to the irrigated farms and may be taken into the valleys after the fall round-ups and fed during the winter months when there is little other work to do.

Not only the Salt River Valley but the other irrigated districts in Arizona, as well as dry farms, are suited to cattle feeding. The area of irrigated lands will be greatly increased and a large acreage suitable for dry-farming by means of floodwater will be developed. Large quantities of feed will be produced. These home-grown feeds are of a bulky nature so that it is difficult to secure a market for them. There is always a good local demand for home grown beef, and Arizona farmers should be able to supply this market rather than have meat shipped in from other states.

The cattle-feeding industry is in its infancy in Arizona. There are many new problems to be solved in this phase of the business. A careful investigation is necessary in order to supply feeders with practical information regarding the cattle-feeding industry.

PLAN OF THE EXPERIMENT

The Agricultural Experiment Station conducted a cattle-feeding test during the winter of 1920 at the Salt River Valley Farm. Little has been done, heretofore, to study the various phases associated with this industry.

The object of the steer-feeding trials was to obtain information relating to the problems of feeding these animals. The effect of the various rations was one of the aims. These rations were so planned that common feeds in the district could be studied. Since a large number of steers are fed on alfalfa hay alone, one of the lots was given this feed for a ration. Two of the lots were not given any alfalfa hay, five lots were given silage, and four cottonseed meal. The detailed objects of the experiment from the standpoint of the rations alone were: (I) To compare alfalfa hay with a ration of alfalfa hay and silage; (II) To compare silage and alfalfa hay with silage and cottonseed meal, and also to compare these two rations together forming one of silage, alfalfa hay, and cottonseed meal; (III) to compare the addition of alfalfa hay to a basal ration of silage and cottonseed meal with the addition of ground milo maize; and (IV) to determine the effect of adding alfalfa hay to a basal ration of silage, cottonseed meal, and ground milo maize. Other secondary considerations included: (1) the amount of feed cattle will consume; (2) rate of gains made by steers; (3) feed required per pound gain; (4) dry matter, total digestible nutrients, and therms consumed per hundred pounds gain; (5) cost of gains in live weight; (6) the margin in cattle feeding; (7) length of time required to finish cattle for market; (8) the dressed percentage of cattle as affected by the different rations; (9) kind of cattle to feed; (10) shrinkage in shipping fat cattle, and other matters of general interest.

ANIMALS USED

Thirty-six steers were selected for the experiment. Twenty-seven of these were polled, being out of native cows, mostly Holsteins, and sired by a Polled Shorthorn bull. The remaining nine were high-grade Holsteins. All the animals were raised in the Salt River Valley and were in good pasture condition averaging 889 pounds, and about 30 months old. The steers had been maintained on alfalfa pasture, but some of them were accustomed to eating hay. These cattle were divided into six lots of six steers each. Each lot was made as nearly alike as possible in size, condition, age, previous treat-

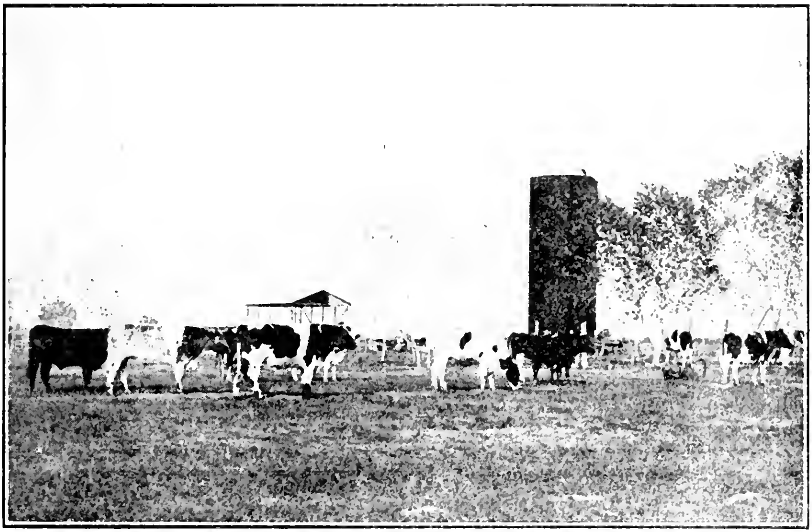

Fig. 2.—Experiment steers as they came from the field, January 8, 1920

ment, conformation, weight, and other characteristics, with the one exception that the animals in Lot I were high-grade Holsteins, and Lots IV, V, and VI each contained one of the high-grade Holstein steers. There was very little difference in the condition of the different animals, but the Holstein steers were probably a little thinner than those sired by the Polled Shorthorn bull. The animals cost 10 cents a pound, the weights being taken after they were driven about six miles without feed or water. Each of the animals was

TABLE I—ANIMALS AT THE BEGINNING OF THE EXPERIMENT, JANUARY 9 1920

Lot	Average weight of steer in lot	No. of steers in lot	Weight distribution of the steers in the lots				
			1000 lb.	900 to 1000 lb.	800 to 900 lb.	700 to 800 lb.	600 to 700 lb.
	Pounds						
I	891	6	0	2	4	0	0
II	889	6	1	3	1	0	1
III	890	6	1	1	3	1	0
IV	889	6	1	2	2	1	0
V	889	6	1	2	2	1	0
VI	888	6	1	2	2	1	0

given a number to identify him and records were taken throughout the test according to the number of the animals. Table I gives a statement of the steers in each lot at the beginning of the experiment.

Lot I averaged 891 pounds or a little heavier than any of the other lots. The average weight of the steers in Lots II, IV, and V was 889 pounds. Lot III weighed an average of 890 pounds, and Lot VI was the lightest, averaging 888 pounds.

Although there was considerable difference among the steers in each lot, yet the animals in the various lots were similar. The animals in Lot I were slightly thinner than those in the other lots, but they were the most uniform in weight. Two of them weighed between 900 and 1000 pounds, and the other four between 800 and 900 pounds. Lot III contained three animals whose weight ranged between 800 and 900 pounds, one animal over 1000 pounds, one between 900 and 1000 pounds, and the other between 700 and 800 pounds. Lot II had one animal that weighed over 1000 pounds; three weighed between this and 900 pounds; one in the 800 to 900 pounds group; and one weighed a little less than 700 pounds. The animals in Lots IV, V, and VI fell into the same general distribution.

FEED LOTS AND EQUIPMENT

Six feed lots 48 by 60 feet were used for the experiment. In each lot was a feed manger 3 feet wide and 36 feet long, which was ample for containing the feed. An automatic drinking fountain placed in each lot kept fresh water before the animals at all times. No covering or shed was needed, and the earth floor of the lots was dry and firm throughout the test except after a few light rains. The highest temperature while the experiment was in progress was 82 degrees F. and the lowest was 31 degrees F. No snow fell during the time the steers were in the feed lots. The days were bright and clear there being a total of only 3.13 inches rainfall during the feeding period. The cattle were in a public place where many visitors inspected them, so that they were more restless than they would be on an average farm.

WEIGHING THE ANIMALS

At the beginning of the test each animal was weighed. The cattle at this time had suffered a reasonable shrinkage in weight from the time they left the pasture field. Every Friday morning throughout the test the animals were weighed individually. On Thursday night they were given a regular feed but no water till after weighing.

Frequently a small amount of feed was left in the mangers from the night before, but the cattle were weighed with a small shrinkage estimated to be about 2 percent, or half the amount usually allowed in marketing such animals. The cattle were weighed as soon after 8 o'clock as possible and according to a regular system, so that the weights would be uniform each week.

FEEDS USED

The feeds selected were those most available and commonly used by cattle feeders in the Salt River Valley. Loose alfalfa hay, sorghum silage, cottonseed meal, thrashed ground milo maize, and thrashed ground hegari were used in this experiment. The prices of these feeds at the time the experiment began were as follows:

Loose alfalfa hay, $25 per ton.
Sorghum silage, $8 per ton.
Thrashed ground milo maize, $54 per ton.
Thrashed ground hegari, $54 per ton.
Cottonseed meal, $80 per ton.

The above prices have been used in calculating the cost of the rations and the cost of producing gains. The quality of the feeds was about average. The hay was fairly free from weeds but somewhat coarse in texture. The sorghum silage varied somewhat from time to time, but it had been cut when fairly green and was of about average quality. While the cottonseed meal was purchased and labelled to contain 47 percent protein, the direct analysis showed that it had only 38.46 percent of protein. The chemical composition of the various feeds used was determined by direct analysis by the Department of Agricultural Chemistry as given in Table II.

TABLE II—CHEMICAL COMPOSITION OF FEEDS USED
(Expressed in percent of fresh substance)

Feed	Dry Substance	Protein	Carbohydrates		Ash	Fat
			Fiber	Nitrogen free extract		
	%	%	%	%	%	%
Alfalfa hay	96.30	15.73	29.75	40.59	8.02	1.67
Sorghum silage	24.83	1.13	6.41	13.93	2.88	0.48
Corn silage	25.57	1.89	7.30	14.13	1.84	0.42
Cottonseed meal	94.45	38.46	12.23	31.38	6.44	5.94
Ground milo maize	91.41	12.13	1.81	74.67	1.60	1.20
Ground hegari	89.76	9.41	1.88	75.27	1.44	1.76

RATIONS

The experiment was planned after consulting many local feeders who have made a careful study of the business. It was finally decided to use rations bulky in character, similar to those most frequently used in the district. Cattle are not made prime in Arizona. The local market pays as much for half-finished cattle as for those that are fat. Since the last hundred pounds of gain usually requires a longer time and more feed, as well as a ration of more concentrated nature, local feeders prefer to give only small amounts of grains. The lots receiving cottonseed meal were limited to a maximum of three pounds per steer daily, and at no time was more than six pounds of ground milo maize fed to a steer. The animals receiving silage or hay were given all of either or both of these feeds they would consume. The various lots received a bulky ration not suitable for making large or rapid gains. The rations supplied the animals are given in Table III.

TABLE III.—RATIONS FED THE DIFFERENT LOTS

Lot	RATION
I	Loose alfalfa hay ad lib.
II	Alfalfa hay ad lib, sorghum silage ad lib.
III	Silage ad lib, cottonseed meal 2.66 lb.
IV	Silage ad lib, cottonseed meal 2.66 lb., alfalfa hay ad lib.
V	Silage ad lib, cottonseed meal 2.66 lb., ground milo maize 5.70 lb.
VI	Silage ad lib, cottonseed meal 2.66 lb., ground milo maize 5.77 lb., alfalfa hay ad lib.

The steers in Lot I received all the loose alfalfa hay they would eat; no other feed was given them. Lot II was fed a combination of alfalfa hay and sorghum silage. The aim was to supply each lot with as much of these rations as they would consume and not have any left over. Lot III received a ration of all the silage they would eat together with 2.66 pounds of cottonseed meal per head daily. The steers in Lot IV were given all the silage and alfalfa hay they would eat and in addition an average of 2.66 pounds of cottonseed meal per head daily. This lot was a combination of Lots II and III from the standpoint of feed. Lot V. was allowed all the silage they would eat and 2.66 pounds of cottonseed meal per head daily and 5.70 pounds of ground milo maize. This lot was fed the same as Lot III but given the addition of a light feed of grain. The cattle in Lot VI were given all four of the feeds, being allowed all the silage and hay they would eat, but limited to 2.66 pounds of cottonseed meal and 5.77 pounds of ground milo maize.

PLACING CATTLE ON FEED

The cattle were in dry lots throughout the test, and they could not receive anything that they were not given. The daily allowance of feed was given the steers in two feeds, one in the morning after 8 A. M. and the evening feed from 4 to 6 P. M. From the outset, the animals receiving hay and silage were given all of these feeds they would consume. The first week all the cattle receiving cottonseed meal were given one pound per head daily; the second week this amount was increased to two pounds; and after the third week they were given three pounds per head daily. The steers in Lots V and VI were given four pounds of thrashed ground milo maize per head daily the first week, five pounds the second, and six pounds throughout the rest of the experiment.

CHANGES IN FEEDS

From January 9 to February 14 the sorghum was the Goose Neck and Honey Drip varieties. This sorghum was cut somewhat green and produced silage that was sour and not so good in quality as the silage used after February 14. After this time the silage was from Orange Cane sorghum. This was riper, sweeter, and had more grain than the sorghum previously fed. The steers preferred this silage to the varieties fed up to this date.

Beginning March 15 the cattle were given corn silage made from Mexican June corn and a small amount of cowpeas. The steers did not eat this silage with as much relish as the sorghum silage previously used. They seemed restless, nosed over the silage, ate a few bites, and then moved around the corral. A few days were required for them to change to the corn silage, which they eventually ate with relish.

Thrashed ground milo maize was fed from January 9 to February 29 covering a period of 51 days. Beginning March 1 hegari that had been thrashed and then ground was supplied the animals until the end of the test. In discussing the results "milo maize" is used, but it should be remembered that hegari replaced the milo maize after March 1. No difference was observed in the palatability or feeding quality of these two grains.

REFUSED FEED

A small quantity of the feed given the cattle in each lot was wasted. Good mangers were used and an effort was made to supply the cattle with only the amount of feed they would consume without waste. Small quantities of feed dropped from the mouths of the cattle to the ground and some waste resulted in this manner. All feed the animals did not eat and left in the manger was weighed and a careful record kept of it. The alfalfa hay was easily separated from the other feed and a close record of the amount of hay actually consumed by the animals was secured. The silage lost moisture so that the record of the refused silage has little significance. The cracked grain and cottonseed meal became so mixed with the silage that it was difficult to ascertain how much of each of these feeds was refused by the different lots. It was noticed, however, that the cattle made an effort to eat the grain and cottonseed meal, and no doubt only small quantities of these concentrates were left behind as refuse. The amount of feed refused in the various lots is given in Table IV.

TABLE IV.—HAY AND SILAGE REFUSED BY THE CATTLE IN THE DIFFERENT LOTS

Lot	Feed refused by the steers			
	Alfalfa hay		Silage	
	Pounds	%	*Pounds*	%
I	316	2	......	.....
II	181	4	65	0.3
III	......	..	297	1.0
IV	164	8	70	0.2
V	......	..	618	3.0
VI	138	8	60	0.3

As was to be expected, Lot I left more alfalfa hay than any of the other lots, but the refused hay in this lot was only 2 percent, although a total of 316 pounds of hay was weighed back. Lots II, IV, and VI refused from 138 to 181 pounds of alfalfa hay, this amount being from four to eight percent of the total given these lots. Lots III and V received no alfalfa hay. It is believed that if they had been allowed the refused alfalfa hay from the other four lots they would have eaten it and probably made better gains.

Lot V refused 618 pounds of silage. This was more than twice as much as the silage refused by Lot III. Most of the silage refused by Lot V was during the time that two steers in this lot were off feed. These were the only two steers in the experiment that were not always ready to eat their feed. The proportion of loss of silage is much less than that of refused alfalfa hay. Lot V had 3 percent of the silage weighed back; Lot III 1 percent; and Lots II, IV, and VI each less than 1 percent. Here again it is believed that if the refused silage in the five lots had been given the steers in Lot I that received no silage, they would have made good use of it. Since these amounts of feed are ordinarily wasted in practical feeding, and the steers selected the best of the feed, leaving the inferior portions, the steers were charged with all the refused feeds in calculating the costs.

DURATION

The steers were placed in the feed lot on January 9, 1920, and the test was completed after the cattle had been on feed 77 days ending March 25. At this time, an offer of 11 cents per pound live weight, deducting 4 percent shrinkage from the filled weight was accepted. This was an extremely satisfactory price, considering the market at that time. During January and February the outlook for higher prices was especially favorable. February 20 a local buyer offered 12 cents a pound for the animals for delivery April 1. This was a good price and would have allowed a profit on the feeding operations. Other feeders in the district had been offered 13 cents a pound for similar steers to be delivered April 1. Shortly after this time Kansas City packers began shipping dressed beef to the Salt River Valley. This intimidated the local butchers, as the Kansas City beef was placed on the market at a lower price than the cost of beef from home fed cattle. Towards the first of April the Federal Government sold large quantities of frozen beef that had been in storage two years. Los Angeles, one of the most promising markets for cattle fed in the Southwest, purchased large quantities of this frozen beef at very low prices. Another contributing factor to the drop in prices of finished cattle resulted from the desert range being unusually good, and the cattle maintained on these ranges were sufficiently fat for butchers as early as the middle of April. With all these contributing factors, as well as a depressed market in Denver and Kansas City, we felt extremely fortunate in being able to secure 11 cents a pound for the steers. They were purchased by Cowden and Babbitt, and shipped to Flagstaff for local consumption.

A careful estimate was made of the value of the steers in the differ-

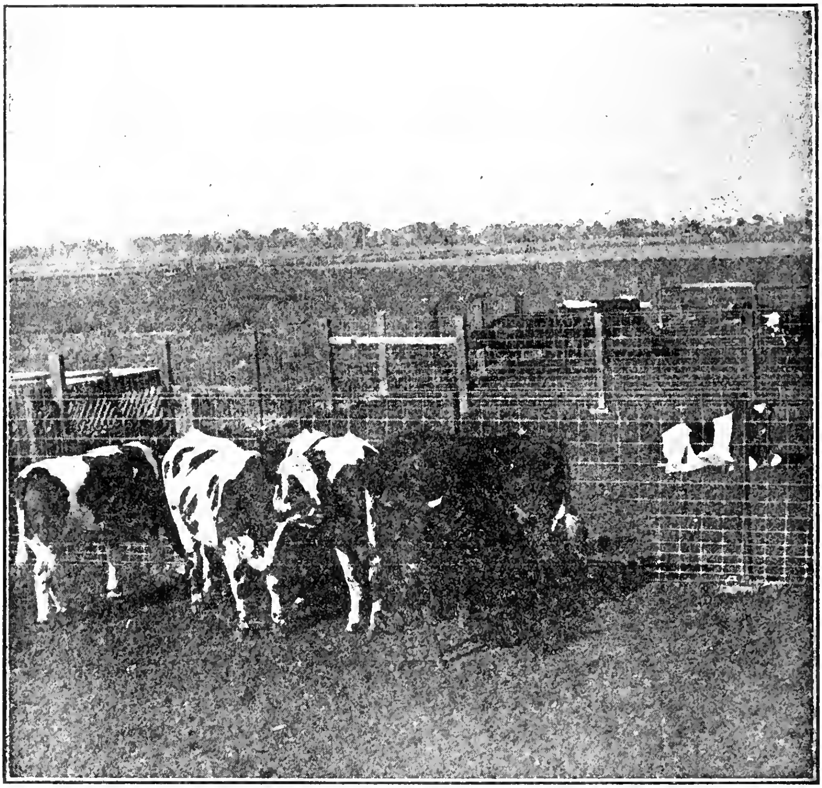

Fig. 3.—Steers in the feed lots, March 29, 1920

ent lots at the close of the test. Table V gives the value of the animals at the end of the first 77 days on feed.

TABLE V.—ESTIMATED VALUE OF ANIMALS AT THE END OF 77 DAYS

	Lot I	Lot II	Lot III	Lot IV	Lot V	Lot VI
Value per hundred live weight	$10.25	$10.75	$10.60	$11.20	$11.35	$11.50

Local butchers estimated that there was a range of $1.25 per hundred between the value of the steers in Lots I and VI. Lot II was fatter than Lots I and III and estimated to be worth 15 cents per hundred more than Lot III. Lots IV, V, and VI were distinctly fatter than any of the other lots.

RESULTS OF THE EXPERIMENT

Extreme care was exercised in planning and conducting the experiment to secure results which would be reliable and accurate for the different lots. The weighing of the feeds and the animals was as thorough and uniform as possible. The results of the experiment and the following discussion are based on these weights.

ALFALFA HAY COMPARED WITH ALFALFA HAY AND SILAGE

A few years ago, when alfalfa hay cost $5 to $10 per ton, it was often used as an exclusive ration for fattening cattle. Since 1918 the price of this feed has increased greatly, and now feeders are endeavoring to secure a more effective ration than alfalfa hay alone. Many silos have been constructed in the State, and feeders wish to know if silage when added to alfalfa hay will make larger and more economical gains.

Two lots of steers containing six animals each were used for this test. Lot I was given all the alfalfa hay they would eat, and Lot II allowed all the alfalfa hay and silage they cared for. The steers were fed twice a day. In Table VI is given a summary of the results giving a comparison of the weights, gains, average daily rations, feeds required per pound gain, nutrients required per 100 pounds gain, cost of 100 pounds gain, and the total cost of the animals, their value and profit at the end of the test in Table VI.

At the beginning of the test, the six steers in Lot I averaged 2 pounds heavier than those in Lot II. During the 77 days the steers fed on alfalfa hay alone gained 107 pounds per head, while those fed on alfalfa hay and silage gained 184 pounds per head. The average daily gain was only 1.40 pounds per head in Lot I, and 2.39 pounds in Lot II. Not one of the steers in Lot I gained as much as the lightest steer gained in Lot II. This shows that the addition of silage to alfalfa hay made the animals gain more rapidly. Steers fed on alfalfa hay alone will gain an average of about 1.40 pounds per head daily during the first 11 weeks. On the other hand, if silage is added to a ration of alfalfa hay, they will gain almost a pound more daily. This increased gain in the lot where the steers were allowed all the silage they cared for in addition to alfalfa hay means the difference between rapid and slow gains. The steers in Lot I gained slowly and would have required a long feeding period to finish, while the steers in Lot II made what would be considered medium gains.

TABLE VI.—SUMMARY OF THE RESULTS FOR LOTS I AND II FED 77 DAYS

	Lot I	Lot II
Number of steers in lot	6	6
Ration	Alfalfa hay	Alfalfa hay and silage
Average initial weight	891 lb.	889 lb.
Average final weight	998 lb.	1073 lb.
Average gain	107 lb.	184 lb.
Average daily gain	1.40 lb.	2.39 lb.
Average daily ration:		
Alfalfa hay	28.63 lb.	8.99 lb.
Silage	....	47.14 lb.
Feed required per pound gain:		
Alfalfa hay	20.51 lb.	3.76 lb.
Silage	....	19.71 lb.
Nutrients required per 100 lbs. gain:		
Dry matter	1869.29 lb.	793.72 lb.
Total digestible nutrient	1055.00 lb.	456.49 lb.
Number of therms	700.00 therms	442.68 therms
Cost of 100 pounds gain	$25.63	$12.58
Initital cost per head at $10.00 cwt	$89.10	$88.90
Feed cost per head	27.55	23.18
Interest on investment at 8%	1.50	1.50
Estimated cost of marketing	1 45	1.45
Total cost	$119.60	$115.03
Value per cwt. March 26	$ 10.25	$ 10.75
Returns per head without shrink	102.33	115.38
Loss per head	17.27	....
Profit per head	....	.35
Necessary selling price per cwt	11.98	10.72

The average daily ration consumed by the steers in Lot I was 28.63 pounds of alfalfa hay. The first four weeks they consumed an average of 25.87 pounds per day; the second four weeks, 30.30 pounds; and the last three weeks 30.08 pounds. Steers weighing 891 pounds and about 30 months old will consume slightly less than 30 pounds of alfalfa hay daily for the first 11 weeks they are in the feed lot. The first few days they will probably be nervous and not accustomed to the feed, but after the first month they should reach their maximum capacity. The steers in Lot II consumed an average of 47.14 pounds of silage and 8.99 pounds of alfalfa hay per head daily throughout the test. At the outset these cattle ate more hay and less silage, but as the period progressed they ate less alfalfa hay and more silage. In each of the lots, the animals seemed to be well contented with their feed and did as well as could be expected from the kind of feed given them.

The steers in Lot II did not require as much dry matter, total

Fig. 4.—Steers in Lot I, February 12, 1920

digestible nutrients, or therms to make 100 pounds of gain as the cattle in Lot I. This would indicate that the addition of silage to a basal ration of alfalfa hay balanced the feed constituents in some way so that the animals could utilize the nutrients more efficiently. Owing to the greater variety in the ration supplied to the steers in Lot II, they consumed more feed, or else the ration was more concentrated so the cattle could make greater gains and at less cost. Gain in Lot I cost \$25.63 per 100 pounds and in Lot II only \$12.58, or a little less than half as much. The total cost of feed in Lot I was higher than in Lot II, so that the cattle fed on alfalfa hay alone required more money to buy the feed for them than where a combination ration was fed. Gains, however, were not in proportion to the cost of the feed, and the increase in the value of the animals was also less with the steers fed on alfalfa hay. This means that alfalfa hay alone is not so good a ration as alfalfa hay and silage from the standpoint of rate of gains, cost of the daily feed ration, cost of gains, or increasing the value of the animals. The steers fed on alfalfa hay lost an average of \$17.27, while the cattle fed on alfalfa hay and silage made an average profit of 35 cents per head. To break even, the selling price would have had to be \$10.72 per hundred for Lot II and \$11.98 for Lot I. In every particular it was found that the addition of silage to a ration of alfalfa hay was beneficial.

SILAGE AND ALFALFA HAY COMPARED WITH SILAGE AND COTTONSEED MEAL; ALSO WITH SILAGE, ALFALFA HAY, AND COTTONSEED MEAL

Having proved that a ration of silage and alfalfa hay is better than alfalfa hay alone for fattening steers, it is next desired to compare this ration with silage and cottonseed meal and with a combination of all three of the feeds. Three lots of steers were used to make this study. Lot II was fed on silage and alfalfa hay; Lot III, silage and cottonseed meal; and Lot IV, silage, cottonseed meal, and alfalfa hay. Each lot receiving silage or alfalfa hay was given all of these feeds they would eat, and Lots III and IV were given an average of 2.66 pounds cottonseed meal per head daily for the entire period. It will be noted that Lot IV was given a combination of the rations given Lots II and III. A detailed summary of the results of this test is given in Table VII.

TABLE VII.—SUMMARY OF THE RESULTS WITH LOTS II, III, AND IV.

	Lot II	Lot III	Lot IV
Number of steers in lot	6	6	6
Ration	Silage, alfalfa hay	Silage, cottonseed meal	Silage, alfalfa hay, cottonseed meal
Average intial weight	889 lb.	890 lb.	889 lb.
Average final weight	1073 lb.	1041 lb.	1086 lb.
Average gain	184 lb.	151 lb.	197 lb.
Average daily gain	2.39 lb.	1.96 lb.	2.55 lb.
Average daily ration:			
Alfalfa hay	8.99 lb.	....	4.20 lb.
Silage	47.14 lb.	61.76 lb.	60.68 lb.
Cottonseed meal	....	2.66 lb.	2.66 lb.
Feed required per pound gain:			
Alfalfa hay	3.76 lb.	.....	1.65 lb.
Silage	19.71 lb.	31.49 lb.	23.78 lb.
Cottonseed meal	......	1.36 lb.	1.04 lb.
Nutrients required per 100 pounds gain:			
Dry matter	793.72 lb.	843.37 lb.	789.41 lb.
Total digestible nutrients	456.49 lb.	520.41 lb.	479.61 lb.
Number of therms	442.68 therms	628.06 therms	532.55 therms
Cost of 100 pounds gain	$12.58	$18.03	$15.73
Initial cost per head at $10.00 cwt	$ 88.90	$ 89.00	$ 88.90
Feed cost per head	23.18	27.22	30.93
Interest on investment at 8%	1.50	1.50	1.50
Estimated cost of marketing	1.45	1.45	1. 5
Total cost	$115.03	$119.17	$122 78
Value per cwt. March 6	$ 10.75	$ 10.60	$ 11.20
Returns per head without shrink	115.38	110.35	121.59
Loss per head	.	8.82	1.19
Profit per head	.35	.....	....
Necessary selling price per cwt	10.72	11.45	11.31

Although the steers were as nearly alike as possible at the beginning of the test, yet the ration given them soon began to prove that the steers in Lot IV were making the most rapid gains and Lot III the slowest. At the end of 77 days the average gain in Lot IV was 197 pounds; Lot II, 184 pounds; and Lot III only 151 pounds. The average daily gain was 2.55 pounds in Lot IV, 2.39 pounds, in Lot II and 1.96 pounds in Lot III. The average steer in Lot IV gained .16 pound per day more than the average steer in Lot II and .59 pound more than those in Lot III. The steers given all three feeds made the most rapid gains, and those fed on alfalfa hay and silage gained more rapidly than steers given a limited quantity of cottonseed meal and all the silage they would eat.

Each lot received all the silage they would eat. Lot II ate only 47.14 pounds of silage along with 8.99 pounds of alfalfa hay. Lot III consumed most silage, averaging 61.76 pounds per day, along with 2.66 pounds of cottonseed meal; and Lot IV ate about a pound less of silage per day than Lot III, the same quantity of cottonseed meal, and in addition 4.20 pounds of alfalfa hay. Owing to the small gains made by the steers in Lot III, and the large gains by the animals in Lot IV, relatively less feed and nutrients were required to produce an equal gain in weight in Lot IV than in Lot III. The steers in Lot II seemed to make better use of their feed than those in Lot IV, except in the total amount of dry matter required to produce 100 pounds gain. The cost of 100 pounds gain was lowest in Lot II, averaging \$12.58; highest in Lot III, being \$18.03; and Lot IV ranked between the other two, costing an average of \$15.73. The steers in Lot IV made the largest gain, but at the highest feed cost. These steers were much fatter than those in the other lots and were valued at a higher price at the end of the test. The difference in the condition of the cattle in Lot IV and the greater gain in weight did not overcome the more effective utilization and the lower feed cost of the steers in Lot II, so that the steers in this lot made a profit of 35 cents per head, while those in Lot IV lost an average of \$1.19 per head. The ration in Lot III was decidedly inferior to that in Lots II and IV, for the average steer in Lot III lost more money than the entire six steers in Lot IV. The necessary selling price per 100 pounds at the end of the 77 days, in order to break even without gain or loss, was \$10.72 for Lot II, \$11.31 for Lot IV, and \$11.45 for Lot III. These selling prices are based on a cost price of \$10 per hundred for the feeders, the cost of the feeds consumed, the interest on the money invested for cattle, and cost of marketing, as well as the rate of gain made by the different lots. A margin between the cost price of feeders and the selling price of the finished steers at the end of 77 days of 72 cents per hundred for Lot II, \$1.31 for Lot IV and \$1.45 for Lot III would have been necessary to cover the entire expenses in the different lots:

ALFALFA HAY COMPARED WITH GROUND MILO MAIZE AS A SUPPLEMENT TO SILAGE AND COTTONSEED MEAL

Lots IV and V were used for this test. The steers in Lot IV were given all the silage and alfalfa hay they would eat and 2.66 pounds of cottonseed meal per head daily. Each steer in Lot V received 2.66 pounds of cottonseed meal, 5.70 pounds of ground milo maize, and all the silage they would eat. The daily consumption of silage in Lot IV was 60.68 pounds per steer, while those in Lot V ate 52.70 pounds. Each steer in Lot IV ate 7.98 pounds more silage daily, the same amount of cottonseed meal, and 4.20 pounds of alfalfa hay in place of 5.70 pounds of ground grain consumed in Lot V. Table VIII gives the summary of the results with this test.

The steers in the two lots weighed an average of 889 pounds at the beginning, but those in Lot IV gained 197 pounds and the steers in Lot V 189 pounds each. At the end of the test the steers in Lot IV had gained an average of 8 pounds more than those in the other lot. Less dry matter, total digestible nutrients, and therms were required to produce 100 pounds of gain in Lot IV than in Lot V. The animals fed more evenly in Lot IV throughout the test and seemed to be more vigorous and to relish their feed better than those in Lot V. Two steers were off feed for a week in Lot V, and three in this lot gained less than 140 pounds each, while the lightest gain in Lot IV was 160 pounds.

Owing to the greater gain made by the steers in Lot IV and the apparently more effective use of the feed, which was of a bulky nature costing less than the concentrated feed given Lot V, the cost of gains was less in Lot IV than in Lot V. The cost of feed to produce 100 pounds of gain in Lot IV was \$15.73, and in Lot V it was \$19.18. During the feeding period the average steer in Lot IV cost \$30.93 for feed, and in Lot V, \$36.28. In spite of the larger gains made by

TABLE VIII.—SUMMARY OF THE RESULTS WITH LOTS IV AND V FED 77 DAYS

	Lot IV	Lot V
Number of steers in lot	6	6
Ration	Silage, cottonseed meal, alfalfa hay	Silage, cottonseed meal, ground milo maize
Average initial weight	889 lb.	889 lb.
Average final weight	1086 lb.	1078 lb.
Average gain	197 lb.	189 lb.
Average daily gain	2.55 lb.	2.46 lb.
Average daily ration:		
Alfalfa hay	4.20 lb.	......
Silage	60.68 lb.	52.70 lb.
Cottonseed meal	2.66 lb.	2.66 lb.
Ground milo maize	......	5.70 lb.
Feed required per pound gain:		
Alfalfa hay	1.65 lb.	......
Silage	23.78 lb.	21.45 lb
Cottonseed meal	1.04 lb.	1.08 lb.
Ground milo maize	......	2.32 lb.
Nutrients required per 100 pounds gain:		
Dry matter	789.41 lb.	795.12 lb.
Total digestible nutrients	479.61 lb.	550.81 lb.
Number of therms	532.55 therms	648.37 therms
Cost of 100 pounds gain	$15.73	$19.18
Initial cost per head at $10.00 cwt	$ 88.90	$ 88.90
Feed cost per head	30.93	36.28
Interest on investment at 8%	1.50	1.50
Estimated cost of marketing	1.45	1.45
Total cost	$122.78	$128.13
Value per cwt. March 26	$ 11.20	$ 11.35
Returns per head without shrink	121.59	122.39
Loss per head	1.19	5.74
Profit per head	......	......
Necessary selling price per cwt	11.31	11.88

the steers fed on silage, cottonseed meal, and alfalfa hay, the steers given silage, cottonseed meal, and ground milo maize fattened more rapidly and were valued at 15 cents more per hundred at the close of the experiment than those in the other lot. The steers in Lot IV seemed to grow rather than to finish for market. The average steer in Lot IV lost $1.19 and in Lot V the average lost $5.74. In order to break even on the two lots, it would have been necessary to sell the steers in Lot IV at $11.31 per 100 pounds and those in Lot V at $11.88 per 100 pounds. The margin required to feed the steers in Lot IV was $1.31 per 100 pounds, and in Lot V it would have been necessary to sell the animals at $1.88 more than their purchase price.

ALFALFA HAY ADDED TO A RATION OF SILAGE, COTTONSEED MEAL, AND GROUND MILO MAIZE

A variety of feeds is considered advisable in a ration for animals. Two lots of six steers each were fed in making this test. The steers in Lot V were given 2.66 pounds of cottonseed meal, 5.70 pounds of milo maize, and all the silage they would consume. In Lot VI the steers were given the same amount of cottonseed meal, almost the same quantity of ground milo maize, and allowed free choice of alfalfa hay and silage. A summary of results with Lots V and VI is given in Table IX.

TABLE IX.—SUMMARY OF RESULTS WITH LOTS V, AND VI, FED 77 DAYS

	Lot V	Lot VI
Number of steers in lot	6	6
Ration	Silage, cottonseed meal, ground milo maize	Silage, cottonseed meal, ground milo maize, alfalfa hay
Average initial weight	889 lb.	888 lb.
Average final weight	1078 lb.	1080 lb.
Average gain	189 lb.	192 lb.
Average daily gain	2.46 lb.	2.49 lb.
Average daily ration:		
Alfalfa hay	...	3.97 lb.
Silage	52.70 lb.	48.38 lb.
Cottonseed meal	2.66 lb.	2.66 lb.
Ground milo maize	5.70 lb.	5.77 lb.
Feed required per pound gain:		
Alfalfa hay	...	1.60 lb.
Silage	21.45 lb.	19.43 lb.
Cottonseed meal	1.08 lb.	1.07 lb.
Ground milo maize	2.32 lb.	2.32 lb.
Nutrients required per 100 pounds gain:		
Dry matter	795.12 lb.	893.98 lb.
Total digestible nutrients	550.81 lb.	605.62 lb.
Number of therms	648.37 therms	669.88 therms
Cost of 100 pounds gain	$19.18	$20.30
Initial cost per head at $10.00 cwt	$ 88.90	$ 88.80
Feed cost per head	36.28	38.91
Interest on investment at 8%	1.50	1.50
Estimated cost of marketing	1.45	1.45
Total cost	$128.13	$130.66
Value per cwt. March 26	$ 11.35	$ 11.50
Returns per head without shrink	122.39	124.20
Loss per head	5.74	6.46
Profit per head	...	....
Necessary selling price per cwt	11.88	12.10

The rations in the two lots were the same except that the steers in Lot VI consumed an average of 3.97 pounds alfalfa hay per head daily, while those in Lot V were given no alfalfa hay and they ate 4.32 pounds more silage per head daily than the steers in Lot VI. The steers in Lot V gained a total of 189 pounds or an average of 2.46 pounds per head daily, and those in Lot V gained 192 pounds during the feeding period, or an average of 2.49 pounds per head daily. The amount of feed required per pound gain was very similar in each lot, Lot VI using 2.02 pounds less silage, but 1.60 pounds more of alfalfa hay.

From the standpoint of the efficiency of the rations as indicated by the nutrients required to make a hundred pounds of gain, the steers in Lot V seemed to have a distinct advantage in this respect. In dry matter, total digestible nutrients, and number of therms required to produce 100 pounds of gain, the steers in Lot VI required about ten percent more than those in Lot V. The feed in Lot V seemed to be more efficient than in Lot VI in making gain, or else the tables giving the digestibility of feeds are not reliable for Arizona conditions. Throughout it was observed that there was an apparently greater food value attached to alfalfa hay than actually obtained in this test, or the constituents in silage as given in text-books on the subject were underestimated. There is an apparently illogical condition in the tables giving the nutrients consumed or required to produce 100 pounds gain.

The feed cost was \$36.28 for an average steer in Lot V and \$38.91 in Lot VI. The gains in Lot VI were not sufficiently greater to counteract this increased cost of the food, for gain costs \$19.18 per 100 pounds in Lot V and \$20.30 in Lot VI. Both of the lots lost money, Lot V losing \$5.74 per head and Lot VI \$6.46. In order to purchase the animals, to supply them with feed, pay interest on the cost price of the steers, and to market them, \$11.88 per 100 pounds was necessary in Lot V and \$12.10 in Lot VI.

The chief differences between the two lots were: (1) greater uniformity of gains made by the steers in Lot VI; (2) the animals in Lot VI finished more rapidly for market; (3) better appetites of the animals in Lot VI; and (4) the higher price received for them at the end of the test. There seemed to be some quality associated with the alfalfa hay which had a beneficial effect on the animals. The steers in Lot VI were all in good vigorous condition with ready appetites but two of the steers in Lot V went off feed during the test.

These were the only steers in the entire experiment that showed a tendency to refuse feed at any time. Three of the animals in Lot V made very light gains, and two of them gained large amounts. In Lot VI all the steers made large gains, and at the end of the test the animals in this lot were much more uniform and fatter than those in Lot V. One may conclude that, from the standpoint of keeping animals in good condition, with good vigorous appetites, and in order to make them finish for market at an early date, without many culls, the addition of alfalfa hay to a ration of silage, cottonseed meal, and milo maize is beneficial.

In each of the lots receiving alfalfa hay, with the exception of Lot I where the steers were fed exclusively on this feed, alfalfa hay seemed to have a beneficial effect. Animals do not care for more than three or four pounds of alfalfa hay per day, but they will do better if given this amount. They will gain more rapidly, feed more uniformly, and take on flesh faster than when no alfalfa hay is given them. Apparently the cost of producing gains may be slightly more when the alfalfa hay has been fed, but at least a small amount of alfalfa hay or some other good substitute for it should be used in cattle feeding.

FINANCIAL STATEMENTS

FINANCIAL STATEMENT FOR 36 STEERS, 1920

Cost of steers (32,020 lb.) at 10 cents	$3202.00
Cost of feed	1360.29
Interest on investment at 8%	54.00
Estimated cost of marketing	52.20
Total cost	**$4668.49**
Returns from 23 steers Wt. (25,398 4% shrink) at 11 cents	$2682.03
Returns from 13 steers Wt. (14,892 4% shrink) at 11 cents	1572.60
Total returns	**$4254.63**
Loss	413.86
Loss per steer	11.50

FINANCIAL STATEMENT ASSUMING ALL STEERS WERE SOLD AT THE END OF 77 DAYS AT 11 CENTS PER LB. AND 4% SHRINK

Cost of steers (32,020 lb.) at 10 cents pound	$3202.00
Cost of feed	1104.45
Interest on investment at 8%	54.00
Estimated cost of marketing	52.20
Total cost	**$4412.65**
Returns from 26 steers (38,140 lb. 4% shrink) at 11 cents	$4027.58
Loss	$ 385.07
Loss per steer	10.70

GENERAL DISCUSSION

COST OF 100 POUNDS GAIN WITH VARYING FEED PRICES

The main object in feeding cattle is to make a profit. In order to make a profit the feeder must select feeds which will produce good gains at low cost. The use of home-grown feed will often bring a larger return if marketed through live stock than when shipped to some distant market. Table X has been prepared to give the cost of 100 pounds of gain with varying prices of feed.

TABLE X.—COST OF 100 POUNDS GAIN WITH VARYING FEED PRICES

Alfalfa hay	$12.00			$18.00			$25.00			Alfalfa hay		
Silage	$ 6.00	$ 8.00	$10.00	$ 6.00	$ 8.00	$10.00	$ 6.00	$ 8.00	$10.00	$12.60	$18.00	$25.00
Lot I—Alfalfa hay..										12.30	18.45	25.63
Lot II—Alfalfa hay and Silage..........	8.17	10.14	12.12	9.29	11.26	13.24	10.61	12.58	14.56			
Lot III—Silage and cottonseed meal												
Cottonseed meal...... $60	13.52	16.67	19.82									
$70	14.20	17.35	20.50									
$80	14.88	18.03	21.18									
Lot IV—Alfalfa hay, Silage and Cottonseed meal.												
Cottonseed meal $60	11.25	13.63	16.01	11.74	14.12	16.50	12.32	14.70	17.08			
$70	11.77	14.15	16.53	12.26	14.64	17.02	12.84	15.22	17.60			
$80	12.29	14.67	17.05	12.78	15.16	17.54	13.36	15.74	18.12			
Lot V—Silage, milo and cottonseed meal												
Milo........ ...	30.00	40.00	54.00									
Cottonseed meal............. $60	13.17	16.47	20.25									
$70	13.71	17.01	20.79									
$80	14.25	17.55	21.33									
Lot VI—Alfalfa hay, silage, milo and cottonseed meal												
Milo	30.00	40.00	54.00	30.00	40.00	54.00	30.00	40.00	54.00			
Cottonseed meal $60	13.47	16.57	20.14	13.95	17.05	20.62	14.50	17.60	21.17			
$70	14.00	17.10	20.67	14.48	17.58	21.15	15.03	18.13	21.70			
$80	14.54	17.64	21.21	15.02	18.12	21.69	15.57	18.67	22.24			

The different prices have been taken for the various feeds as follows: Alfalfa hay, $12, $18, and $25 per ton; silage $6, $8, and $10 per ton; cottonseed meal $60, $70, and $80 per ton; and ground milo maize $30, $40, and $50 per ton.

The method of using this table is as follows: Suppose the feeder is considering what the cost of 100 pounds of gain will be with alfalfa hay at $25 per ton, silage at $8, cottonseed meal at $80, and milo maize at $40 per ton. First look under the heading of alfalfa at $25 per ton; follow down the column marked silage at $8 per ton until the milo column marked $40 a ton is reached; follow down from here to the figure opposite cottonseed meal at $80 per ton, and the sum of $18.67 is found. This amount is the cost of 100 pounds of gain if the above prices are used and gains are made the same as the steers in Lot VI. Other combinations of feeds and prices are found in the same manner. Thus alfalfa hay at $12 per ton, silage at $6 and cottonseed meal at $60 a ton will cost $11.25 to make 100 pounds of gain at the rate made by the steers in Lot III. Where alfalfa hay alone is fed, the cost of 100 pounds of gain is about the same as the cost per ton of the hay.

Table X has been given to supply a ready reference to cattle feeders. It is believed that it will give a close approximation of the costs of making 100 pounds gain in steers with any of the six rations used in this test. Before beginning the feeding operations, it would be wise to compare the ruling prices of feeds with this table to ascertain whether to feed or not. It almost always costs more to make cattle gain in live weight than one can secure for the finished animals. With a two cent margin over a short feeding period one can expect the cost of gains to be two to four cents per pound greater than the fat cattle will bring.

In order to give a brief summary of the test which will enable one to follow the data from the lots fed in the six different ways and make a comparison of them a complete summary is presented in Table XI. Some secondary factors of interest to stockmen are found in this table. Among these may be mentioned: (1) amount of feed cattle will consume; (2) rate of gain made by steers; (3) feed required per pound gain; (4) dry matter, total digestible nutrients, and therms consumed per 100 pounds gain; (5) cost of gains in live weight; (6) margin in cattle feeding; (7) length of time required to finish cattle for market; and (8) dressed percentage of cattle as affected by the different rations.

AMOUNT OF FEED CATTLE WILL CONSUME

According to the results obtained in this test, steers weighing 891 pounds will consume an average of 28.63 pounds of alfalfa hay per day. For the same length of time a similar animal, when given free choice of alfalfa hay and silage, will consume 8.99 pounds of the former and 47.14 pounds of the latter. When steers are given a limited amount of concentrated feed along with roughage consisting of silage or alfalfa hay or both, the amount of roughage consumed will

TABLE XI.—COMPLETE SUMMARY OF THE TEST FOR 77 DAYS

	Lot I	Lot II	Lot III	Lot IV	Lot V	Lot VI
Number of steers in lot	6	6	6	6	6	6
Ration	Alfalfa hay	Alfalfa hay, silage	Silage, cottonseed meal	Alfalfa hay, silage, cottonseed meal	Silage, cottonseed meal milo maize	Alfalfa hay silage, cottonseed meal milo maize
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Average initial weight	891	889	890	889	889	888
Average final weight	998	1073	1041	1086	1078	1080
Average gain	107	184	151	197	189	192
Average daily gain	1.40	2.39	1.96	2.55	2.46	2.49
Average daily ration	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Alfalfa hay	28.63	8.99		4.20		3.97
Silage		47.14	61.76	60.68	52.70	48.38
Cottonseed meal			2.66	2.66	2.66	2.66
Milo maize					5.70	5.77
Feed required per lb. gain:	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Alfalfa hay	20.51	3.76		1.65		1.60
Silage		19.71	31.49	23.78	21.45	19.43
Cottonseed meal			1.36	1.04	1.08	1.07
Milo maize					2.32	2.32
Nutrients required per 100 lbs. gain:	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Dry matter ①	1869.29	793.72	843.37	789.41	795.12	893.98
Total digest. nutrients ①	1055.00	456.49	520.41	479.61	550.81	605.62
Therms ①	700.00	442.68	628.06	532.55	648.37	669.88
Cost of 100 lbs. gain	$25.63	$12.58	$18.03	$15.73	$19.18	$20.30
Initial cost at $10.00 cwt.	$89.10	$ 88.90	$ 89.00	$ 88.90	$ 88.90	$ 88.80
Feed cost per head	27 55	23.18	27.22	30.93	36.28	38.91
Interest at 8%	1.50	1.50	1.50	1.50	1.50	1.50
Estimated cost of marketing	1.45	1.45	1.45	1.45	1.45	1.45
Total cost	$119.60	115.03	$119.17	$122.78	$128.13	130.66
Value per cwt. March 26	$ 10.25	$ 10.75	$ 10.60	$ 11.20	$ 11.35	$ 11.50
Returns per head	$102.33	$115.38	$110.35	$121.59	$122.39	$124.20
Loss per steer	$ 17.27		$ 8.82	$ 1.19	$ 5.74	$ 6.46
Profit per steer		$ .35				
Necessary selling price	$ 11.98	$ 10.72	$ 11.45	$ 11.31	$ 11.88	$ 12.10
Necessary margin	$ 1.98	$ .72	$ 1.45	$ 1.31	$ 1.88	$ 2.10
Time required to finish ② steers for market	139 days	81 days	99 days	76 days	79 days	78 days
Dressing percent	54% ③	57% ⑥	57.2% ④	57.7% ⑤	58.5% ④	58.9% ⑤

①"Feeds and Feeding" by Henry and Morrison.
②Based on the length of time it would require the steers to gain 194.5 pounds at the rate of 2.53 pounds gain per day.
③Estimated dressing per cent at the end of 110 days.
④Estimated dressing per cent from 77 days and 110 days.
⑤Actual dressing per cent at the end of 77 days.
⑥Estimated for only 1 steer at the end of 77 days, the others at the end of 110 days.

depend upon the quantity of concentrated feed. If 2.66 pounds of cottonseed meal are fed to steers, they will consume an average of 61.76 pounds of sorghum silage per day. Steers given 2.66 pounds of cottonseed meal will consume an average of 4.20 pounds of alfalfa hay and 60.68 pounds of silage per day. When 2.66 pounds of cottonseed meal and 5.70 pounds of milo maize are given, an average steer will take 52.70 pounds of silage. When all four of the feeds are combined, the steers being limited to 2.66 pounds of cottonseed meal and 5.77 pounds of milo maize, an average of 3.97 pounds of alfalfa hay and 48.38 pounds of silage will be about the daily consumption. It is believed that the above amount of feeds will be a close approximation to what it may be expected 2-year-old steers weighing 889 pounds will consume during the first 77 days in the feed lot. Steers that have been accustomed to silage before being placed in the feed lot will consume relatively larger quantities of silage and less alfalfa hay when these feeds are in the ration. It should be a simple matter for stockmen to estimate the amount of feed the animals will require daily when any of these rations are used. A slight modification may be made in the amount of feeds animals will consume if other rations are planned.

RATE OF GAINS MADE BY STEERS

The average daily gain made by the steers in the various lots ranged from 1.40 pounds to 2.55 pounds. The steers receiving alfalfa hay, silage, and cottonseed meal made the most rapid gains, averaging 2.55 pounds per head daily. The second largest gain was made by Lot VI on alfalfa hay, silage, cottonseed meal, and milo maize, these steers averaging 2.49 pounds per head daily. Lot V, receiving silage, cottonseed meal, and milo maize, ranked third with a daily gain of 2.46 pounds. The steers fed on alfalfa hay and silage made an average daily gain of 2.39 pounds. Lot III gained an average of 1.96 pounds per head daily from a ration of silage and cotton-seed meal. The lowest daily gain was obtained in Lot I fed on alfalfa hay alone, and they averaged only 1.40 pounds per head daily.

FEED REQUIRED PER POUND GAIN

The amount of feed required to make a pound of gain was 20.51 pounds of alfalfa hay in Lot I. Lot II consumed 3.76 pounds of alfalfa hay and 19.71 pounds of silage for every pound of gain. Lot III consumed 31.49 pounds of silage and 1.36 pounds of cottonseed meal per pound of gain. The feed required to make a pound of gain in Lot IV was 1.65 pounds of alfalfa hay, 23.78 pounds of silage, and 1.04 pounds of cottonseed meal. In Lot V 21.45 pounds of silage, 1.08 pounds of cottonseed meal, and 2.32 pounds of ground milo maize were required to make a pound of gain. Lot VI required 1.60 pounds of alfalfa hay, 19.43 pounds of silage, 1.07 pounds of cottonseed meal and 2.32 pounds of ground milo maize to make a pound of gain.

DRY MATTER, TOTAL DIGESTIBLE NUTRIENTS, AND THERMS CONSUMED PER 100 POUNDS GAIN

Lot I consumed the largest amount of dry matter and total digestible nutrients as well as the greatest number of therms for 100 pounds gain, the amount being 1869.29 pounds dry matter, 1055.00 pounds total digestible nutrients, and 700.00 therms. This lot received distinctly more of the constituents required to make gains than any of the other lots. Lot VI ranked the next highest, averaging 893.98 pounds of dry matter, 605.62 pounds of digestible nutrients and 669.88 therms. In total dry matter Lot III was the third highest, but in the other constituents Lot V ranked decidedly ahead of Lot III. Lot II consumed slightly more dry matter than Lot IV, but in total digestible nutrients and therms required to produce 100 pounds of gain Lot II was the most efficient in the experiment. It is interesting to note that less than half as much dry matter or digestible nutrients were required to make 100 pounds of gain in Lot II as in Lot I. There seems to be a close association between the rate of gains and the amount of nutrients required to produce them. The rule is that steers gaining most rapidly require relatively smaller amounts of nutrients to make gains than the animals that increase slowly in weight. A slight tendency was observed in lots receiving relatively larger proportions of concentrates to require more nutrients to make gains.

COST OF GAINS IN LIVE WEIGHT

The cost of making 100 pounds of gain in the steers varies from \$12.58 in Lot II to \$25.63 in Lot I. Thus gain was produced in Lot II at about half the cost of gain in Lot I. The other four lots varied from \$15.73 in Lot IV to \$20.30 in Lot VI. Lot III cost \$18.03 to make 100 pounds of gain, and Lot V \$19.18. Several factors seem to have a pronounced effect upon the cost of gain. The first undoubtedly was the cost of the different feeds. Alfalfa hay was very expensive when fed in large amounts. Cottonseed meal and milo maize also seemed to be more expensive than silage. The rate of gain made by the animals was one of the prominent factors affecting the cost of making 100 pounds increase in weight. Another factor was the combination of the feed. Thus alfalfa hay when fed alone was too bulky to be suitable for making rapid gains. On the other hand, when this feed was supplemented with silage the cheapest gains were secured. It is interesting to note that the lots making the cheapest gains were fed on alfalfa hay and silage, and alfalfa hay, silage, and cottonseed meal.

MARGIN IN CATTLE FEEDING

The margin, which is the difference between the cost price of feeders and the selling price of the finished animal, often determines whether or not a profit is made in feeding cattle. As a rule, the longer cattle are fed the wider must be the margin. These cattle were fed only 77 days, and it was necessary to have a margin of from 72 cents to $2.10 in order to pay for the feed and other expenses in feeding the animals. The necessary margin for the different lots varied closely according to the cost of producing gains in live weight. Lots II, IV, and III were distinctly the lowest, while Lots I, V, and VI required $1.98, $1.88, and $2.10 respectively. Lot VI required the largest margin of all the lots due to the highest cost of feed and the greatest finish made by the animals. In a measure this wide margin was justified, for the animals were worth more than those of any other lot at the close of the test. In spite of the fact that the cost of feed amounted to less in Lot I than in Lots IV, V, and VI, it was necessary to secure a margin of $1.98, or more than twice as much as in Lot II, in order to avoid loss. When prices of feeds are as high as during this test, it is necessary to receive a margin of at least $2.00 per 100 pounds to break even.

LENGTH OF TIME REQUIRED TO FINISH CATTLE

"The shorter the feeding period the lower the cost of making gains and the greater the profit," is the rule often followed by stockmen. All the steers in Lots IV and VI were considered finished for market at the end of 77 days. During this time Lot IV had made a gain of 197 pounds and Lot VI, 192 pounds per head. From these data it was calculated that steers gaining 2.53 pounds daily would be finished for market when they had gained 194.5 pounds. There will be variations from this weight due to individuality and a tendency for the cattle to grow rather than to fatten. Calculated according to this basis, Lot IV required 76 days, Lot VI 78 days, Lot V 79 days, Lot II 81 days, Lot III 99 days, and Lot I would have required 139 days to finish. From these data it will be noticed that the steers receiving a ration of hay, silage, and cottonseed meal, or these feeds and the addition of ground grain, make an early finish. Steers fed on alfalfa hay alone require approximately twice as long to come to a finish as where alfalfa hay, silage, cottonseed meal, or these with the addition of ground milo maize are fed.

DRESSED PERCENTAGE OF CATTLE

The report from Babbitt Brothers, Flagstaff, Arizona, who dressed the animals and retailed the beef, was that the carcasses from the steers were satisfactory for that trade.

All the steers in Lots IV and VI were sent to market after being in the feed lots 77 days. In each of Lots III and V one steer was thin. None of the steers in Lot I were sold at this time, and only one in Lot II. This made it necessary to estimate the dressed percentage of the steers in the various lots at the end of the 77 days. In Lots IV and VI the dressed yield was 57.7 and 58.9 percent respectively. Making allowance for the one steer in Lot V, it was estimated that this lot would average 58.5 percent, and similarly in Lot III, 57.2 percent. It is doubtful if Lot I would have dressed as high as 54 percent, while 57 percent was estimated for Lot II. The actual dressed percentage of the animals remaining 110 days was secured. From these figures it may be concluded that the steers with milo maize in their ration were fatter and dressed a higher percentage than those receiving no concentrates. The following table gives the weight of the cattle off cars at Flagstaff, dressed weight of the cooled beef, and the percentage yield in beef:

TABLE XII.—DRESSED PERCENTAGE OF STEERS

Number of steers	23 steers	13 steers	Total for 36 steers	Average per steer
Weight at Flagstaff off cars	22290 lb.	12810 lb.	35100 lb.	975 lb.
Dressed weight	13029 lb.	7272 lb.	20301 lb.	564 lb.
Dress percentage	58.45%	56.77%	57.84%	57.84%

The 23 steers weighed a total of 22,290 pounds off the cars and yielded 13,029 pounds of beef, which was an average of 58.45 percent. The 13 steers gave a dressed percentage of 56.77 percent. The average dressed percentage of beef from the 36 steers was 57.84. The average weight of the 36 steers was 975 pounds weighed off the cars at Flagstaff, and they gave 564 pounds of beef, which was 57.84 percent of the live weight.

KIND OF CATTLE TO FEED

A study was made of the steers in this experiment to determine the effect of size on the rate of gain and length of time required to finish them. The steers were classified into large, medium, and small sizes. The basis of this classification was the size of the frames and the conformation of the animals. The animals varied imperceptibly from large to medium and from medium to small; and it was extremely difficult to secure a different standard for these different groups. As a rule the large steers weighed more than those in either of the other groups. There were twenty steers in the large sized group and eight in each of the other groups.

At the end of the test the steers were classified according to their condition. The fullness of the cods, and the thickness and covering of flesh over the body and flanks were used as a basis in estimating the condition of the steers. The animals were grouped by this method into fat, medium, and thin classes. None of the steers, however, were prime, so that the term fat is of relative importance indicating that group was among the more fleshy ones in the experiment. Table XIII gives the number and percentage of the animals of different sizes, finishing fat, medium, and thin.

TABLE XIII.—CONDITION OF THE ANIMALS AS AFFECTED BY SIZE

Size	Number and percentage finishing					
	Fat		Medium		Thin	
	No.	%	No.	%	No.	%
20 Large	13	65.0	6	30.0	1	5.0
8 Medium	7	87.5	1	12.5	0	0.0
8 Small	4	50.0	3	37.5	1	12.5

There was a tendency for the large animals to become fat more rapidly than the small ones; but a greater percentage of the medium-sized steers was fat at the end of the test than of any of the other groups. None of the medium-sized steers were considered thin at the end of the experiment.

The steers were grouped into three classes according to the amount of gain made. Group I was called "Good" and contained steers which gained from 170 to 343 pounds. Steers in the "Medium" group gained from 140 to 159 pounds; and the "Low" group gained less than 139 pounds. The data showing the effect of the size of the animals on the rate of gains made by them are given in Table XIV.

TABLE XIV.—SIZE OF STEERS AS AFFECTING THE AMOUNT OF GAINS

Size	Good gains		Medium gains		Low gains	
	No.	%	No.	%	No.	%
20 Large..........	10	50.0	4	20.0	6	30.0
8 Medium	4	50.0	2	25.0	2	25.0
8 Small.....	2	25.0	3	37.5	3	37.5

Of the 16 steers that made good gains ten were large, four medium, and two small. There seemed to be a slight tendency for the medium-sized steers to make larger gains than either of the other lots. The small steers made distinctly less gains than the medium or the large-sized animals.

In order to make a comparison of the size of the animals and the average gain made by them, the Table XV has been prepared.

TABLE XV.—ACTUAL GAINS MADE BY THE STEERS CLASSIFIED AS LARGE, MEDIUM AND SMALL

Size	Initial weight	Final weight	Gains
	Pounds	*Pounds*	*Pounds*
20 Large..........................	947	1116	169
8 Medium......................	856	1025	169
8 Small......	779	952	173

There was little or no difference in the average gain made by steers from the large, medium or small groups. The three groups varied only from 169 to 173 pounds.

A further study of the animals shows that there was a greater range among the individuals of the same groups than the average of the different groups. The study, however, goes to indicate that there may be a slight advantage in selecting medium-sized, blocky steers that are smooth in conformation, in preference to the large, coarse steers or the small, fine animals. It was unfortunate that the individual dressing percentage could not be secured for each of the animals, for probably there is a closer relationship between the dressed percentage and the size than in any other respect.

From the standpoint of making gains and rapid finish, it is more important to select steers which are vigorous and gentle than to select according to size. Fleshy animals are better than thin ones; for they will be ready for market sooner, and not so wide a margin is necessary with such cattle. Other things being equal, the steers of medium size with short legs, wide, deep bodies, broad foreheads, short well-dished faces, large heart girths, strong loins, large barrels, and showing beef breeding will be best.

SHRINKAGE IN FAT CATTLE

A study of the shrinkage in the animals when ready for market was made with the steers in the feeding test. In Arizona the custom has been to stand cattle 12 hours in a dry lot without feed or water or deduct 4 percent from the feed lot weight.

There is a distinct difference in the shrinkage of cattle, whether they are weighed out of the feed lot or after having been driven from one to ten miles through the dust in the warm weather. Cattle driven even a short distance will undoubtedly lose weight more rapidly than when standing or lying down contentedly in the feed lot. The more nervous and restless animals are, the more they will lose in weight. Cattle driven to market will perspire and lose more excrement than when maintained in the feed lots where they are quiet and contented.

Twenty-three of the thirty-six steers were in the feed lot for 77 days and the remaining 13 for 117 days. The method of handling these steers previous to weighing was slightly different. The 23 steers were weighed between 4 and 5 p. m. after having received nothing since the morning's feed. The 13 steers received their regular morning feed and about 3 p. m. an additional quantity of four pounds of alfalfa hay per steer. These steers ate most of their hay, and, as water was in the lots, probably drank freely of it. About 4:30 p. m. each of the lots were weighed and returned to their respective feed lots; they were again weighed about 8:30 o'clock the next morning. Some of the animals had a small amount of feed left from the morning's rations, and this was removed at 7 p. m. and the water fountains adjusted so the cattle could receive no more water. After weighing the animals the next morning, they were turned back to the feed lots for about an hour, then allowed to mix together in an open space where they frisked around for half an hour. After this the steers were driven to the Mesa stockyards, a distance of two miles, and weighed at 11:45 a. m. The steers were shipped to Phoenix the same evening, unloaded, given hay and water, and shipped to Flagstaff the next day, where they were weighed off cars. The weather was quite warm when the 13 steers were shipped to market, but cool and comfortable the day the 23 were shipped. The summary of the weights of the cattle, pounds lost, and the percentage of shrink at different times are given in Table XVI.

The 23 steers after being off feed and water for 16 hours lost 1026 pounds in weight, or 4.04 percent of the total weight; and the 13 steers under similar conditions, except that they were given about 4 pounds of alfalfa hay, lost a total of 698 pounds or a shrinkage of 4.69 percent. No doubt the large shrinkage in the group of 13 steers was due in part to the steers having taken large quantities of water after consuming the alfalfa hay; but the weather was also warmer and this may have been a contributing factor. It is interesting to note, however, that each lot lost fully 4 percent in weight during the 16 hours which elapsed between the weighings.

Between the time they were weighed at 8:30 a. m. and again at 11:45 a. m., the 23 animals lost a total of 342 pounds and the 13 lost 519 pounds. The loss due to shrinkage was 1.40 percent with the large group and 3.66 percent with the 13 steers. It is noteworthy that in 3¼ hours these steers lost an average of 2.23 percent while standing in the feed lots, walking a distance of two miles, and remaining in the stock yards.

TABLE XVI.—STATEMENT OF SHRINKAGE FOR 36 STEERS

Number of steers	23 steers	13 steers	Total for 36 steers	Average per steer
Filled weight n feed lot, 1-5 P. M.	25398 lb.	14892 lb.	40290 lb.	1119 lb.
Shrunk weight in feed lot 8-9 A. M.	24372 lb.	14194 lb.	38566 lb.	1071 lb.
Shrinkage	1026 lb.	698 lb.	1724 lb.	47.89 lb.
Percent of shrinkage	4.04%	4.69%	4.28%	4.28%
Weight at yards after driving two miles; 11:45 A. M.	24030 lb.	13675 lb.	37705 lb.	1047 lb.
Shrinkage	342 lb.	519 lb.	861 lb.	23.92 lb.
Percent of shrinkage	1.40%	3.66%	2.23%	2.23%
Weight at Flagstaff off cars	22290 lb.	12810 lb.	35100 lb.	975 lb.
Shrinkage	1740 lb.	865 lb.	2605 lb.	72.36 lb.
Percent of shrinkage	7.24%	6.33%	6.91%	6.91%
Total shrinkage	3108 lb.	2082 lb.	5190 lb.	144.17 lb.
Total percent of shrinkage	12.68%	14.68%	13.42%	13.42%

The weights off cars at Flagstaff showed that the 23 steers had lost in transit 1740 pounds, or 7.24 percent from the time they were weighed in the Mesa stock yards. The total shrinkage of the 23 steers from the time they were weighed directly out of the feed lots until they were unloaded at Flagstaff was 3,108 pounds or 12.68 percent. The 13 steers lost a total of 2082 pounds or 14.68 percent from the time they were weighed out of the feed lots until they were weighed off cars at Flagstaff.

The average shrinkage of the two groups of steers was 13.42 percent. This is divided into an average loss of 4.28 percent for the first 16 hours shrinkage in the feed lot, 2.23 percent lost between the shrunk weight out of the feed lot and the weight of the animals after 3¼ hours in the stock yards two miles distant, and 6.91 percent lost between the Mesa and Flagstaff stockyards. The percentage losses in the two groups were very similar in every respect, except that the 13 steers had a greater total loss of 2 percent, which took place during the first 19 hours. These steers were weighed several times in the stockyards at Mesa. They lost 2.78 percent during the drive from the feed lot, .91 percent the first 45 minutes they were in the feed lot, 1.76 percent between 11:45 a. m. and 3 p. m. During the four hours these steers were in the stock yards they lost an average of 7.02 pounds an hour, or .66 percent per hour. The weather was warm and the cattle restless; for during this time they were hair branded.

SUPPLEMENTAL TEST—FEEDING 9 STEERS FOR 40 DAYS

Nine of the 13 steers remaining from the first test were continued in two lots until May 4. Lot I had four steers and Lot II five. The animals remained in the same lots as previously and all were given 2.56 pounds of cottonseed meal per head daily and all the alfalfa hay and silage they would eat. The steers in Lot I were high-grade Holsteins and those in Lot II were sired by a Polled Shorthorn bull. Those in Lot I were much thinner than the steers in Lot II and had been fed previously on alfalfa hay, while those in Lot II received alfalfa hay and silage. The first three days the steers in Lot I were fed alfalfa hay, and those in the other lot alfalfa hay and silage. After this a mixed ration was given. The weight of each steer was taken weekly and a careful record kept of the amount of feed consumed. The objects of this test were to learn if the high-grade Holsteins would make as rapid gains as the other steers, to study the effect of previous rations on the rate of gains, and to learn the amount of roughages these animals would consume when given a small amount of cotton-seed meal.

After being on feed for forty days the animals were sold. At the end of this time they were as fat as the steers sold March 25. Table XVII gives a brief summary of this second test.

TABLE XVII.—SUMMARY OF TEST WITH 9 STEERS FOR 40 DAYS

	Lot I	Lot II
Number steers in lot	4	5
Ration	Alfalfa hay, silage cottonseed meal	Alfalfa hay, silage cottonseed meal
	Pounds	*Pounds*
Average initial weight	1030	1070
Average final weight	1181	1185
Average gain	151	115
Average daily gain	3.78	2.88
Average daily ration:		
Alfalfa hay	10.67	4.93
Silage	48.58	54.23
Cottonseed meal	2.56	2.56
Feed required per pound gain:		
Alfalfa hay	2.82	1.71
Silage	12.85	18.83
Cottonseed meal	0.68	0.89
Cost of 100 pounds gain	$11.39	$13.23

The steers in Lot I averaged 40 pounds lighter than those in Lot II at the beginning of the test. At the end of 40 days the steers in Lot I had gained an average of 151 pounds or 3.78 pounds per head daily; those in Lot II made an average gain of 115 pounds or 21.88 pounds per head daily. The steers in Lot I gained almost a pound a day more per head than those in Lot II. They were allowed the same ration. It is believed that steers which have been maintained

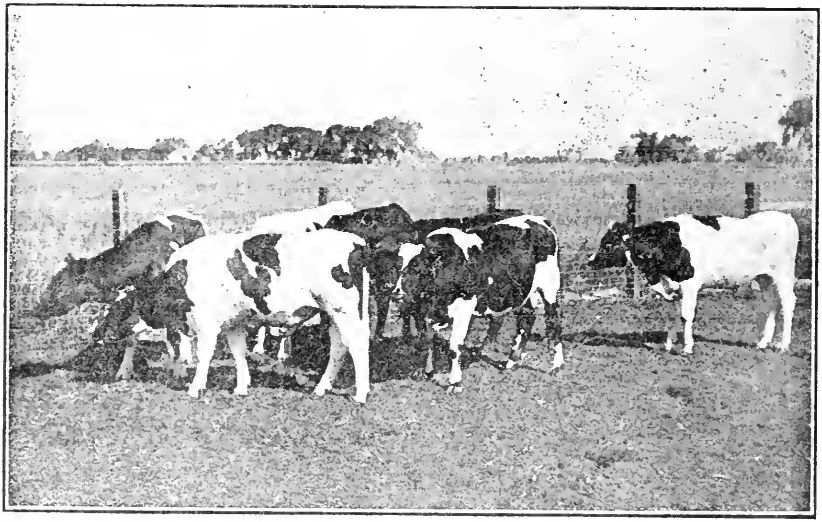

Fig. 5.—Steers in Lot II, May 5, 1920

a considerable length of time on alfalfa hay will make more rapid gains than animals that have been given a combination of feed. No doubt the higher condition of the animals in Lot II induced them to make slower gains than the thinner animals. Neither of the lots, however, were fat. This test also indicated that the grade steers with Holstein blood predominating made just as rapid gains as those with beef blood predominating. There was, however, an apparent difference due to breeding. Lot I did not finish into as full, smooth animals or have as high proportion of high-priced cuts as the steers in Lot II. It was believed that a somewhat longer period would be required to feed the steers in Lot II.

The steers in Lot I consumed 10.67 pounds of alfalfa hay and .58 pounds of silage, while those in Lot II ate only 4.93 pounds of alfa hay and 54.23 pounds of silage. The steers in Lot I consumed twice as much hay but hardly as much silage as those in Lot II. It was apparent that steers accustomed to alfalfa hay, but not to silage, required some time to adjust their rations, and there was a tendency for them to reduce the amount of alfalfa hay and increase the consumption of silage.

The cost of 100 pounds of gain was $11.39 in Lot I and $13.23 in Lot II. The steers in Lot I consumed more feed when given a variety, and made larger as well as cheaper gains. No doubt the ration of alfalfa hay alone was somewhat bulky, monotonous, and unbalanced; and when a variety and concentrates were added to the alfalfa hay, the animals were induced to consume larger quantities of feed with good results. The test also proved that the Holstein steers made just as rapid and economical gains as the steers sired by a Polled Shorthorn bull when given the same ration.

SUMMARY

MAIN TEST 36 STEERS FOR 77 DAYS

ALFALFA HAY ALONE COMPARED WITH ALFALFA HAY AND SILAGE

1. Steers fed on alfalfa hay gained an average of 1.40 pounds per day; on alfalfa hay and silage, 2.39 pounds. The addition of silage to the alfalfa hay increased the daily gain at the rate of .99 pounds per steer.

2. The addition of silage to a ration of alfalfa hay will make steers gain more rapidly in weight, shorten the feeding period, reduce the cost of making gains, increase the market value of the animals, and increase the profits.

3. Steers averaging 891 pounds and 30 months old will consume about 30 pounds of alfalfa hay daily the first 77 days in the feed lot.

4. Steers fed on alfalfa hay and silage finished more rapidly than those given alfalfa hay and were worth 50 cents per hundred more at the end of the test.

5. Each steer fed on alfalfa hay lost $17.27, and those given silage and alfalfa hay made a profit of 35 cents per steer.

6. The cost of feed was $27.55 per steer for alfalfa hay in Lot I, and these steers gained an average of 107 pounds; while in the other lot the cost of feed was $23.18 per steer, and these steers gained an average of 184 pounds.

7. All the steers given silage and alfalfa hay gained more than any of the steers fed exlusively on alfalfa hay.

8. A margin of $1.98 per hundred pounds was necessary in the lot fed hay and only 72 cents per hundred pounds was necessary where the steers were fed silage along with hay.

9. The cost of producing a hundred pounds gain was $25.63 with alfalfa hay and $12.58 with silage and alfalfa hay, or less than half as much in the lot where silage was fed with alfalfa hay.

10. The addition of 47.14 pounds of silage per head daily decreased the consumption of alfalfa hay 19.64 pounds.

11. The steers receiving alfalfa hay and silage consumed less dry matter, total digestible nutrients, and therms per hundred pounds gain.

12. Alfalfa hay alone is not a balanced ration for fattening two-year-old steers, and the addition of silage to a ration of alfalfa hay was beneficial in every respect.

SILAGE AND ALFALFA HAY COMPARED WITH SILAGE AND COTTONSEED MEAL; ALSO WITH SILAGE ALFALFA HAY AND COTTONSEED MEAL

1. The steers fed on all the silage and alfalfa hay they would eat and 2.66 pounds of cottonseed meal made the most rapid gains and were worth most at the end of the test.

2. Steers fed silage and cottonseed meal made the lowest and most costly gains and were worth less than either of the other lots at the end of 77 days.

3. When cottonseed meal costs $80 per ton, it is doubtful if it is a profitable supplement to a ration of silage and alfalfa hay when steers are fed 77 days.

4. When alfalfa hay was added to a ration of silage and cottonseed meal, 7.71 pounds less silage and .32 pounds less cottonseed meal were required to make a pound of gain.

5. The steers receiving alfalfa hay, silage, and cottonseed meal consumed less dry matter than the steers receiving silage and hay or silage and cottonseed meal.

6. Although the steers receiving alfalfa hay and silage did not make as large gains as those in Lot IV, and the animals were not worth as much per hundred pounds at the end of the test, yet the steers brought a profit of 35 cents per head due to the cheapness of bulky feed and low cost of gain.

7. The use of alfalfa hay as a supplement to silage proved more satisfactory than cottonseed meal, giving larger, more rapid, and cheaper gains, and the animals were worth 15 cents more per hundred at the end of the test.

ALFALFA HAY COMPARED WITH GROUND MILO MAIZE TO SUPPLEMENT SILAGE AND COTTONSEED MEAL FOR FATTENING STEERS.

1. The steers fed on silage, cottonseed meal, and alfalfa hay gained an average of .09 pounds more per head daily than those fed on silage, cottonseed meal, and a light feed of ground grain.

2. The cost of feed for the cattle in Lot IV was $30.93 per steer and in Lot V $36.28.

3. Ground milo maize in the ration fattened the steers more rapidly and increased their selling value 15 cents per hundred.

4. The ration in which alfalfa hay was used as a supplement gave larger gains per steer, was less expensive, and produced gain at less cost.

5. The steers receiving the alfalfa hay supplement consumed less dry matter and apparently made more effective use of the feed than those which received milo maize.

ALFALFA HAY ADDED TO A RATION OF SILAGE, COTTONSEED MEAL, AND GROUND MILO MAIZE

1. The addition of alfalfa hay to a ration of silage, cottonseed meal, and ground milo maize increased the rate of gain .03 pounds daily per steer.

2. The addition of 3.97 pounds of alfalfa hay per head daily decreased the amount of silage consumed by 4.32 pounds.

3. Steers fed silage, cottonseed meal, and ground milo maize required an expenditure for feed of $19.18 per hundred pounds of gain; those fed silage, cottonseed meal, ground milo maize, and alfalfa hay required an expenditure of $20.30 per hundred pounds gain.

4. The steers in Lot V were valued at $11.35 per hundred pounds, and returned a loss of $5.74 per steer; the steers in Lot VI were valued at $11.50 per hundred pounds, and gave a loss of $6.46 per steer.

5. The addition of alfalfa hay to the ration made the steers finish more rapidly for market.

6. More uniform gains were made by the steers in Lot VI. All the steers in this lot continued well on feed; two of the steers in the lot not receiving alfalfa hay went off feed about a week.

7. The chief advantage of adding alfalfa hay to a ration of silage, cottonseed meal, and milo maize was in the more uniform gains made by the cattle, but at slightly greater cost.

SUPPLEMENTAL TEST, 9 STEERS FOR 40 DAYS

1. Holstein steers will make as rapid and as economical gains as steers from Polled Shorthorn bulls.

2. Steers that have been maintained on a ration of alfalfa hay alone will gain more rapidly when placed on a variety of feed than similar animals that have been maintained on a mixed ration.

3. A few days are required for steers to adjust their appetites to a changed ration. There was a tendency for these steers to reduce the amount of alfalfa hay and increase the silage as the test progressed.

University of Arizona College of Agriculture

Agricultural Experiment Station

Thirtieth Annual Report

For the Year Ended June 30, 1919

(With subsequent Items)

Consisting of reports relating to

Administration

Agricultural Chemistry, Agronomy, Animal Husbandry, Botany, Dairy Husbandry, Entomology, Horticulture, Irrigation Investigations, Plant Breeding, Poultry Husbandry

Tucson, Arizona, December 31, 1919

University of Arizona College of Agriculture

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For the Year Ended June 30, 1919

(With subsequent items)

Consisting of reports relating to

Administration

Agricultural Chemistry, Agronomy, Animal Husbandry, Botany, Dairy Husbandry, Entomology, Horticulture, Irrigation Investigations, Plant Breeding, Poultry Husbandry

Tucson, Arizona, December 31, 1919

REGENTS OF THE UNIVERSITY

Ex-Officio

His Excellency, the Governor of Arizona

The State Superintendent of Public Instruction

Appointed by the Governor of the State

Epes Randolph........................President of the Board and Chancellor
William Scarlett, A.B., B.D..................................Regent
John H. Campbell, LL.M......................................Regent
Timothy A. Riordan..Regent
James G. Compton..Secretary
William Jennings Bryan, Jr., A.B............................Treasurer
Edmund W. Wells...Regent
Louis D. Ricketts, Sc.D., LL.D..............................Regent

AGRICULTURAL EXPERIMENT STATION STAFF

*Rufus B. von KleinSmid, A.M., Sc.D....President of the University, Director
**D. W. Working, B.Sc., A.M...........Dean College of Agriculture, Director
†Robert H. Forbes, M.S., Ph.D..........................Research Specialist
John J. Thornber, A.M.......................................Botanist
Albert. E. Vinson, Ph.D.....................................Chemist
Clifford N. Catlin, A.M...........................Associate Chemist
†Howard W. Estill, M.S............................Assistant Chemist
George E. P. Smith, B.S., C.E.....................Irrigation Engineer
W. E. Code, B.S............................Assistant Irrigation Engineer
H. C. Schwalen, B.S........................Assistant Irrigation Engineer
‡George F. Freeman, Sc.D.............................Plant Breeder
‡C. Omer Bond, B.S.A..........................Assistant Plant Breeder
Walker E. Bryan, M.S..........................Assistant Plant Breeder
Richard H. Williams, Ph.D.........................Animal Husbandman
Charles T. Vorhies, Ph.D..............................Entomologist
‡Austin W. Morrill, Ph.D.....................Consulting Entomologist
‡D. C. George............................Consulting Plant Pathologist
Walter S. Cunningham, B.S..........................Dairy Husbandman
Franklin J. Crider, M.S...............................Horticulturist
A. F. Kinnison, B.S.A.......................Assistant Horticulturist
George E. Thompson, B.S.A................................Agronomist
R. S. Hawkins, B.S.A..........................Assistant Agronomist
Francis R. Kenney, B.S.A...........................Poultry Husbandman
Ethel Stokes.................Secretary Agricultural Experiment Station

*Until February 28, 1919.
**After March 1, 1919.
†On leave.
‡Resigned.

LETTERS OF TRANSMITTAL

To His Excellency, Thomas E. Campbell,
Governor of Arizona,
Phoenix, Arizona.

SIR: I have the honor to transmit to you herewith the Thirtieth Annual Report of the Agricultural Experiment Station of the University of Arizona College of Agriculture for the fiscal year ended June 30, 1919, with subsequent items.

This report is made in accordance with Act of Congress, approved March 2, 1887, establishing agricultural experiment stations, Act of Congress, approved March 16, 1906, known as the Adams Act, and Article 4483, Title 42, Revised Statutes of Arizona, 1913.

Respectfully yours,

EPES RANDOLPH,
Chancellor and President of the Board of Regents.

Honorable Epes Randolph,
Chancellor and President of the Board of Regents.
University of Arizona, Tucson, Arizona.

SIR: I beg to submit herewith my report as President of the University of Arizona covering the work of the Agricultural Experiment Station of the College of Agriculture for the fiscal year ended June 30, 1919.

Faithfully yours,

R. B. VON KLEINSMID,
President.

President R. B. von KleinSmid,
University of Arizona,
Tucson, Arizona.

DEAR SIR: Herewith I submit the Thirtieth Annual Report of the Agricultural Experiment Station of the University of Arizona College of Agriculture for the fiscal year ended June 30, 1919, with subsequent items.

D. W. WORKING,
Dean and Director.

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CONTENTS

ILLUSTRATIONS

Honey Drip sorghum, November 11, 1919—University Farm, Tucson. Yield 60 tons frm 3 acres.

Thirtieth Annual Report

ADMINISTRATION

D. W. WORKING

This report covers a period of shift and of adaptation to new conditions. At the beginning of the fiscal year the Great War was at its greatest intensity and every man and woman connected with agriculture was working under a serious strain. The farmers of Arizona had undertaken to produce more than in any previous year. They were working out a plan that had been adopted at a conference called by Dean R. H. Forbes and held at the University of Arizona on April 20 and 21, 1917. This conference resulted in a production program which led to increased output of farm and garden crops and had the added advantage of bringing the College of Agriculture and its workers into closer and more sympathetic and helpful relations with the people on the farms. The latter achievement is one that needs to be frankly recognized and more fully appreciated.

COLLEGE ORGANIZATION

The College of Agriculture of the University of Arizona is a teaching organization with its special group of teachers of technical agricultural subjects. In addition to its teachings on the University campus, and an increasing amount of instruction by correspondence, the College has two special kinds of work of outstanding importance. As an investigating agency, it functions through its Agricultural Experiment Station; as an extension agency it works through its Agricultural Extension Service.

THE EXPERIMENT STATION

The Agricultural Experiment Station exists to study the more fundamental scientific problems that underlie agricultural practice, as well as to make such experiments as will enable it to answer with sure confidence the questions arising in connection with the growing of the common crops of the State and the breeding, feeding, and management of livestock.

In order to do its work as it should, the Station needs to have a strong and relatively permanent staff of trained investigators. The State cannot afford to adopt or to tolerate a policy that will result in the doing of slovenly work and the publication of bulletins and reports of less than the highest standard of scientific excellence. This implies that the State must make such provision for the adequate support of an organization that needs an increasing financial support if it is even to maintain its present standard of efficiency; it is to be remembered that Arizona is making great advances as an agricultural state. During the past ten years the rural population has increased tenfold. The Experiment Station is thus brought face to face with new crop problems, and into direct contact with an enlarging number of farmers and others, who call at the Station offices and laboratories in Tucson and at the several Station farms.

THE EXTENSION SERVICE

The Agricultural Extension Service, like the Agricultural Experiment Station, is an integral part of the College of Agriculture. It is the College working throughout the State for the purpose of teaching by means of demonstrations, lectures, extension schools, and popular publications, the facts, principles and practices which it presents on the University campus by class and laboratory methods. The Extension Service, in order to meet its obligations to the public, will continue to need increasing financial support. Its accomplishments for the year are set forth in detail in a separate report. But it covers a broader teaching field, for the reason that cooperative agricultural extension work includes the field of home economics.

PERSONNEL

After the resignation of Dr. R. H. Forbes, effective February 15, 1918, President von KleinSmid became Dean of the College of Agriculture and Director of the Agricultural Experiment Station. March 1, 1919, the appointment of D. W. Working took effect.

On August 30, 1918, Dr. G. F. Freeman left the Station to become Botanist to the Sultanic Agricultural Society, Cairo, Egypt. Mr. C. O. Bond resigned as Assistant Plant Breeder, April 30, 1919. The services of Dr. A. W. Morrill, Consulting Entomologist, and Mr. D. C. George, Consulting Plant Pathologist, terminated with the D. C. George, Consulting Plant Pathologist, terminated with the fiscal year June 30, 1919. The Department of Animal Husbandry was divided, Assistant Professor W. S. Cunningham being made head of a new Department of Dairy Husbandry under the title of associate professor. Frances R. Kenney was appointed Associate Professor of Poultry Husbandry, February 1, 1919. Two other appointments were made on January 1. Mr. R. S. Hawkins as Assistant Professor of Agronomy, and Mr. A. F. Kinnison as Assistant Professor of Horticulture. Each of these appointments carried the corresponding Station title.

PUBLICATIONS

Measured by the number of publications issued, the year has been comparatively lean. Following is a list of numbers, titles, and authors. The number of copies of each publication is given in parenthesis.

Bulletin No. 86, "Machine-Made Cement Pipe for Irrigation Systems and Other Purposes," by G. E. P. Smith. October 30, 1918, (6000).

Bulletin No. 87, "Insect Pests of Interest to Arizona Cotton Growers," by A. W. Morrill. December, 1918, (6000).

Bulletin No. 88, "Use and Waste of Irrigation Water," by G. E. P. Smith. May 15, 1919, (6000).

Agricultural Experiment Station Index, Vol. VII, (3000).

Twenty-ninth Annual Report, December 31, 1918. By the Station Staff

Circular No. 23, "The Citrus Thrips," by A. W. Morrill. August, 1918, (4000).

Circular No. 24, "Wheat Planting and the Seed Supply," by E. P. Taylor. September, 1918, (6000).

Circular No. 25, "The Hot Lunch for Rural Schools," by Mary Pritner Lockwook, Agnes A. Hunt, and Hazel Zimmerman. November, 1918, (4000)

Circular No. 26, "Water Storage and the Water Code," by G. E. P. Smith. December, 1918, (6000).

There is an increasing demand for our bulletins and circulars, making necessary large editions to avoid the necessity of expensive reprinting.

PROJECTS

AGRICULTURAL CHEMISTRY

A. E. Vinson, C. N. Catlin, H. W. Estill (From Jan. 1, 1919)

Alkali Soil Studies: Concomitant soil conditions that affect the toxicity of black alkali and means for the amelioration of the effects of alkali on soil and plant	Adams	
Chemical Analyses: Miscellaneous	Hatch	
Meteorological observations	Hatch	
Effect of weather conditions on processing and pasteurizing dates	State	Hatch
Reclamation of alkali land at the University Farm	State	

AGRONOMY

G. E. Thompson, R. S. Hawkins (From Jan. 1, 1919)

Cooperative Crop Experiments: Seeds of various crops have been furnished farmers in order to make comparative tests with each other and with the varieties already being grown	State	
Corn and Sorghums: Variety tests and cultural methods	State	Hatch
Cotton: Date of planting, irrigation tests, thinning methods, intercropping with legumes, and leaving every third row blank	State	Hatch
Crop Studies on Prescott Dry-Farm and Sulphur Spring Valley Dry-Farm: Variety tests, rate and date of seeding tests, method planting tests, inoculation of legumes; tests to determine whether dry-farming to raise feed for stock is feasible	State	

Dynamiting: Effect of dynamiting subsoil on the succeeding field crops	State	
Grains, Forage Crops, and Grasses and Miscellaneous Crops: Varietal and cultural tests	State	
Legumes: Variety and cultural tests to determine the worth of the various legumes and varieties of legumes for Southwest conditions	State	Hatch
Legumes (Inoculation): A study to ascertain the necessity for inoculation and the possibility of increasing yields by intercropping with legumes	Adams	State
Winter and Spring Grains: Culture and management of winter and spring grains, including wheat, oats, barley, and rye	State	Hatch

ANIMAL HUSBANDRY

R. H. WILLIAMS

Cattle Feeding (at Prescott): To determine minimum amount of silage required to keep thin cows alive	Hatch	State
Hog feeding experiment at University Farm	State	Hatch
Lambing range ewes in dry lot (at Mesa Farm)	Hatch	State
Systems of livestock management	Hatch	State

BOTANY

J. J. THORNBER, J. G. BROWN, D. C. GEORGE

Fungi causing rot in date fruits: Identification and study of	Adams	
Grasses and Grass-like Plants: Economic study of	Hatch	
Jujube Fruits: Adaptability to the Southwest	Hatch	State
Mulberries: A study with reference to fruit production	Hatch	State
Pistasch Trees: Practicability of growing pistasch trees in the Southwest	Hatch	State
Poison Range Plants: Economic study of	Hatch	
Range Improvement Through Fencing: A study of	Hatch	
Resistant Native Stocks for Grafting	Hatch	State
Tamarisks: Their growth in alkaline soils	Hatch	State
Trees and Shrubs for Ornamentation: An economic study of	Hatch	
Ozonium Root Disease of Cotton and other crops: Occurrence, life history, and methods of control	Adams	
Gummosis of Stone Fruits: Occurrence, causes, and methods of control	Hatch	

DAIRY HUSBANDRY

W. S. CUNNINGHAM

Rations for Dairy Cows: A comparison of (1) alfalfa and silage, (2) alfalfa hay and cottonseed meal, and (3) alfalfa hay, silage, and cottonseed meal	Hatch	State

ENTOMOLOGY

C. T. VORHIES, A. W. MORRILL

Rodent Control: A study of grazing ranges	Adams	
Insect Collection: Collecting and arrangement of economic insects	Hatch	State
Grasshopper Control	Hatch	
Cotton-square stainer or tarnished plant bug control	Hatch	

HORTICULTURE

F. J. CRIDER, A. F. KINNISON (From Jan. 1, 1919)

Citrus: The effect of different methods of culture, fertilizer treatment, and pruning upon the growth of tree and the size and quality of fruit	Hatch	
Date: Culture and management of date orchards with special reference to the improvement of the yield and quality of fruit and the rooting of offshoots	State	

Olive: The effect of different methods of orchard management and pruning upon the growth of tree and yield	Hatch	
Potato: Study of conditions affecting the production of potatoes in Arizona	Hatch	State
Spinach: Study of spinach as a market garden crop for southern Arizona	State	
Sweet Potato: Study of cultural and storage methods	Hatch	State
Variety Studies: Type and varietal adaptation of fruits, vegetables, and ornamentals	State	

IRRIGATION

G. E. P. SMITH, W. E. CODE (From Nov. 4, 1918)

A study of the relation of the evaporation rate to the duty of water and of the factors controlling evaporation	Adams	
Ground-water supplies and pump irrigation in the Casa Grande Valley and San Simon Valley	Adams	State
Pumping Machinery: A study to determine fundamental facts relating to the action and efficiency of various types	Adams	

PLANT BREEDING

G. F. FREEMAN (Until Aug. 30, 1918) W. E. BRYAN

Alfalfa: Breeding for yield and quality	Adams	State
Bean: Biological analysis of genus *Phaseolus*	Adams	State
Corn: Selective breeding for the improvement of corn varieties adapted to general farming in Arizona	State	
Date: To produce by crossing, selection, and inbreeding a variety of dates of high quality which will ripen nautrally under Arizona conditions	State	
Wheat: (a) To produce a wheat which will be productive and at the same time maintain a high average of bread-making qualities under Arizona conditions; (b) to make a biological analysis of the unit characters of wheat varieties	Adams	State

FINANCES

Table A following gives a complete statement of receipts and disbursements for the College of Agriculture, including the Experiment Station and the Agricultural Extension Service. It does not include amounts spent by the Federal Department of Agriculture in partial support of cooperative agricultural extension workers. These items are shown in detail in the separate report of the Extension Service. Table B shows receipts and expenditures for the Agricultural Experiment Station as reported to the Director of the Office of Experiment Stations of the United States Department of Agriculture. Table C gives in detail the several appropriations by the State Legislature for the two years following the year covered by this report.

TABLE A.—SHOWING RECEIPTS FROM ALL SOURCES AND DISBURSEMENTS FOR ALL PURPOSES ON ACCOUNT OF THE COLLEGE OF AGRICULTURE FOR YEAR ENDED JUNE 30, 1919

Fund	Balance	Receipts	Total	Disbursements	Balances
College of Agriculture					
Maintenance	$.......	$ 13,535.86	$ 13,535.86	$ 13,535.86	$.......
Morrill	....	3,056.10	3,056.10	3,056.10	....
Farm Maintenance	18.77	11,850.00	11,868.77	11,868.77	....
Farm Improvement	303.90	2,302.75	2,606.65	2,606.65	....
Printing	....	2,926.00	2,926.00	2,926.00	....
Improvement	....	2,256.85	2,256.85	2,256.85	....
Plant Introduction	.41	3,000.00	3,000.41	2,999.41	1.00
Tempe Date Palm Orchard Fund..	33.52	2,650.00	2,683.52	2,665.62	17.90
Yuma Date Orchard Horticultural Station...	....	3,136.19	3,136.19	3,136.19	....
Dry-farming Fund	.62	3,000.00	3,000.62	3,000.62	....
Prescott Dry-farming Fund	.20	3,690.00	3,690.20	3,690.20	....
Salt River Valley Farm	1.70	10,000.00	10,001.70	9,997.11	4.59
Sulphur Spring Valley Farm....	911.69	3,700.00	4,611.69	4,594.95	16.74
Surface Water Investigation	175.43	3,000.00	3,175.43	3,155.74	19.69
Underflow Water Investigation ...	227.50	2,400.00	2,627.50	2,627.50	....
Experiment Farm Sales	1,068.74	22,548.07	23,616.81	23,375.37	241.44
University of Arizona Farm Sales	1,517.82	7,771.97	9,289.79	8,283.56	1,006.23
Hatch Sales	.87	2,625.49	2,626.36	2,036.07	590.29
Adams	....	15,000.00	15,000.00	15,000.00	....
Hatch	....	15,000.00	15,000.00	15,000.00	....
Student Fees.....	....	134.50	134.50	81.38	53.12
Smith-Lever	....	16,004.15	16,004.15	16,004.15	....
State Extension..	....	1,029.67	1,029.67	1,029.67	....
County Extension Work	573.89	12,062.76	12,636.65	9,129.79	3,506.86
Cooperative Agri. Extension	....	6,004.15	6,004.15	6,004.15	....
Total........	$4,835.06	$168,684.51	$173,519.57	$168,061.71	$5,457.86
Grand Total..	$173,519.57			$173,519.57	

TABLE B.—EXPENDITURES BY FUNDS AND SCHEDULES FOR THE YEAR ENDED JUNE 30, 1919

Abstract	State fund	Sales fund	Hatch fund	Adams fund	Total
Salaries	$11,828.01	....	$11,758.62	$11,737.76	$35,324.39
Labor	9,064.10	10,855.15	....	1,104.81	21,024.06
Publications	2,926.00	250.85	75.40	....	3,252.25
Postage and Stationery	200.32	614.48	458.92	102.85	1,376.57
Freight and Express	345.57	563.97	71.52	53.22	1,034.28
Heat, light, water, and power	256.84	576.24	725.91	13.75	1,572.74
Chemicals and laboratory supplies	23.00	31.63	213.73	127.91	396.27
Seeds, plants, and sundry supplies	1,290.01	1,943.24	110.24	281.20	3,624.69
Fertilizers	709.06	91.98	38.28	....	839.32
Feeding stuffs	1,038.98	883.79	....	....	1,922.77
Library	....	....	12.21	....	12.21
Tools, machinery, and appliances	2,475.41	3,168.27	112.56	108.41	5,864.65
Furniture and fixtures	64.33	....	188.21	.75	253.29
Scientific apparatus and specimens	33.89	....	207.25	161.85	402.99
Livestock	600.00	510.00	....	....	1,110.00
Traveling expenses	2,449.55	1,639.67	1,027.15	1,112.20	6,228.57
Contingent expenses	377.62	78.23	....	....	455.85
Buildings and land	1,954.91	4,203.94	....	195.29	6,354.14
Returned to State Treasurer	40.23	241.44	....	....	281.67
Balance	....	590.29	....	....	590.29
	$35,677.83	$26,243.17	$15,000.00	$15,000.00	$91,921.00

TABLE C.—STATE APPROPRIATIONS FOR THE TWO-YEAR PERIOD BEGINNING JULY 1, 1919

Fund	1919-20	1920-21
Maintenance	$16,950.00	$16,950.00
Improvements	8,150.00	8,150.00
University Farm Maintenance	12,500.00	12,500.00
University Farm Improvement	6,050.00	2,250.00
Dry-farming Supervision	4,500.00	4,500.00
Printing	4,500.00	4,500.00
Citrus Investigation	10,000.00	5,000.00
Plant Introduction and Breeding Investigations	4,260.00	4,260.00
Prescott Dry-farm Maintenance	6,090.00	5,690.00
Prescott-Dry-farm Improvement	2,000.00	1,500.00
Salt River Valley Experiment Farm	16,510.00	12,510.00
Sulphur Spring Valley Dry-farm	4,490.00	4,540.00
Tempe Date Orchard	3,175.00	2,575.00
Underflow Water Investigations	2,400.00	2,400.00
Surface Water Investigation	3,000.00	3,000.00
Yuma Date Palm Orchard Maintenance	5,925.00	4,825.00
Yuma Date Palm Orchard Improvement	12,500.00	....
College of Agriculture Extension	18,000.00	18,000.00
Cooperative Agricultural Extension	7,433.71	10,000.00
	$148,433.71	$123,150.00

AGRICULTURAL CHEMISTRY

A. E. VINSON, C. N. CATLIN, S. W. GRIFFIN

The Department of Agricultural Chemistry has been strengthened materially and the work promoted by the appointment of Mr. C. N. Catlin, formerly Assistant Chemist, as Research Specialist and the addition of an assistant chemist for analytical work. Mr. Howard W. Estill was Assistant Chemist from January, 1919, until September; since that date Mr. S. W. Griffin has served in that capacity.

The number of analyses of irrigation water and soil for alkali made by the department has been increasing continually with the increasing agricultural development of the State. While this is a public service akin to the extension service and county agent work, it occasionally presents problems of more general interest and importance. With the aid of the Assistant Chemist we have been able to meet these demands and make a number of feeding stuff analyses for other departments, although considerable work of this kind remains uncompleted. A very few miscellaneous examinations, mostly for poisons, have been made.

ADAMS FUND WORK

The research work of the department has been concentrated on the study of black alkali. In this connection progress has been made in working out the technique of a method of determining the colloidal swelling of dry soils when wetted. The further study of the influence of chemical treatment on the rate of percolation through black alkaline soil is being deferred until it can be accompanied by and correlated with the colloidal swelling studies.

Pot cultures are being conducted with a view of establishing the tolerance for black alkali in a type soil, which it is proposed to use later in the study of the influence of concomitant conditions on tolerance. For this purpose soils of uniform texture from close proximity in the same field, but showing different black alkali on analysis, are selected and mixed to give any desired series. The white alkali constituents are added to bring all pots to uniform concentration and all other influences are equalized as far as possible. Excessive plant foods are given all pots, water supply is held constant in all cases, soil temperatures equalized, and pedigreed seed from a single mother plant used. After a definite point of tolerance has been established with the type soil and strain of wheat, the black alkali content will be held constant and other factors varied until the influence of concomitant conditions has been analyzed. To facilitate and shorten the time of this work the present equipment for pot culture should be greatly increased.

Considerable difficulty was experienced in getting large samples of soil of desired alkali concentration to be used in these experiments. At first field samples were taken, analyzed, and a wagonload of soil from the selected spot brought to the laboratory. This was dried, mixed by repeated shoveling on a cement floor, the whole passed through a 2 m.m. sieve, again mixed, sampled and analyzed. It was soon discovered that the field samples bore practically no relation to the large sample taken several days later from the same spot. It was, therefore, necessary to take the large samples without preliminary sampling and run the chance of their being usable.

SAMPLING FIELD SOILS

The difficulties of sampling field soils have long been recognized, and Lipman and his associates have shown that single field samples are usually of little value. This is perhaps more true of alkali than any other soil constituent. The movement of alkali in a field is best described as billowy; always in motion, shifting up and down and laterally. During the year we were asked to inspect a farm two miles south of Tucson. Surface appearances and the native vegetation indicated the general presence of black alkali. Samples of the first and second foot taken with the soil auger showed no black alkali, but a fair amount of gypsum, or its equivalent in other black alkali neutralizing salts. The analyses are shown as Nos. 7161 and 7162 in Table I. Since the analysis seemed contrary to field indication, several days later a square yard was marked off in the same field not far distant from the place where the auger samples had been taken. The soil in this yard was removed carefully with trowels in two-inch layers to the depth of two feet, each layer being thrown on a canvas and carefully sampled. The results of the analyses are recorded in Table I, Nos. 7173 to 7184. The surface layer was weakly of the gypsum type, changing into black alkali in the third and fourth inch. The black alkali increased to a maximum at the eighth inch, then decreased and changed back into gypsum type at the sixteenth inch. In very large numbers of samples taken on small areas at the University Farm in connection with field experiments in neutralizing black alkali with gypsum, the most erratic results were obtained from adjacent borings.

TABLE I. COMPOSITION OF 2-INCH SUCCESSIVE LAYERS IN A YARD SQUARE HOLE ON ALKALINE LAND. SAMPLING TEST

Laboratory No.	Depth	Total soluble solids	Chlorides as NaCl	$CaSO_4$ Equivalent	Na_2CO_3 Black alkali
		%	%	%	%
7173	0"- 2"	1.05	.048	.033	...
7174	2"- 4"	0.888	.052	...	.059
7175	4"- 6"	0.780	.050	...	.064
7176	6"- 8"	0.720	.032	...	.102
7177	8"-10"	0.632	.016	...	.093
7178	10"-12"	0.628	.016	...	.076
7179	12"-14"	0.660	.020	...	.034
7180	14"-16"	0.724	.024	...	.013
7181	16"-18"	1.05	.024	.326	...
7182	18"-20"	1.41	.028	.517	...
7183	20"-22"	1.70	.036	.778	...
7184	22"-24"	1.49	.030	.560	...
Soil auger sample near by					
7161	1st ft.	1.86	.056	.511	...
7162	2nd ft.	1.03	.052	.144	...

RECLAMATION OF ALKALI

An experiment in the reclamation of alkaline land on a tract adjoining the Tempe Drainage Ditch adjacent to the Date Orchard was cooperated in by the department. The experiment was planned by Messrs. Goodin and Eder and nearly completed before our cooperation was invited; consequently, certain points were overlooked, the original experiment having had in view the growing of rice rather than the leaching of alkali. The soils were not sampled before leaching began and sampling was delayed several days after leaching closed, probably resulting in rapid rise of alkali from the ground water as seemed to be indicated in a later experiment. An estimate of the original condition of the tract can be based only on the alkali left in high spots which received little leaching and an adjacent unleached tract. Some years ago the land used for the experiment was among the best in the Salt River Valley, but, due to rising water table, had been abandoned to Bermuda grass, which was finally killed out and gave place to saltbush. The Drainage Ditch has reduced the water table four to five and one-half feet below the surface which is not sufficient for effective leaching and permanent reclamation. The results, however, are highly interesting and show among other things the completeness with which white alkali may be leached and the tenacity with which black alkali resists leaching. The higher white alkali shown by Nos. 7359, 7360, and 7361 as compared with Nos. 7383 and 7384 probably marks the rapid rise of alkali in the interval after the first flooding and sampling; the latter samples were taken immediately after the leaching had ceased. The analyses of these soils are given in Table II.

TABLE II.—ALKALI IN SOILS RECLAIMED BY LEACHING

Lab. No.	Description	Depth feet	Total Soluble salts	Chlorides as NaCl	Black alkali as Na_2CO_3
			%	%	%
7359	Irrigated 4 times, one week apart; submerged periods of 10 days each in July and August	0- 4	.408	.044	.216
		4-12	.404	.080	.229
		12-24	.408	.174	.167
7360	Flooded 6 times in June and early July, then submerged 30 days	0- 4	.560	.104	.288
		4-12	.512	.154	.237
		12-24	.320	.126	.161
7361	Same treatment as 7360	0- 4	.464	.072	.233
		4-12	.540	.15	.220
		12-24	.440	.18	.161
7362	Elevated land flooded 4 times during season	0- 4	3.856	2.52	.254
		4-12	2.008	1.26	.110
		12-24	.496	.26	.161
7363	High land; flooded but never kept submerged; representative of original	0- 4	2.16	1.60	.038
		4-12	.320	.072	.135
		12-24	.168	.048	.085
7364	Irrigated twice in season of 1919	0- 4	1.36	.58	.271
		4-12	.752	.32	.186
		12-24	.332	.096	.153
7365	Not irrigated for 2 years;	0- 4	1.52	.88	.322
		4-12	0.369	.12	.191
		12-24	0.256	.06	.169
7383	Same as 7360; resubmerged[1]	0-12	.32	.020	.135
7384	Same as 7361; resubmerged[1]	0-12	.296	.012	.178
7366	Frankenburg ranch ¼ mile distant; similar untreated land[2]	0- 4	.536	.164	.220
		4-12	.736	.288	.178
		12-24	.526	.220	.119
7367	Same[3]	0- 4	1.3	.74	.102
		4-12	0.840	.44	.135
		12-24	0.520	.24	.161
7368	S.E. ¼ of same section[4]	0- 4	.36	.060	.051
		4-12	.52	.236	.169
		12-24	.512	.204	.186

1. The lands represented by samples 7360 and 7361 were again submerged for 21 days, using between four and five acre feet of water. The seepage was much greater than when the treatment was started. 2. Land fallow for six or seven years with exceptions of one or two unsuccessful attempts to grow milo; flooded in winter, 1918; planted to cotton April, 1919; no irrigation during season; fair stand of cotton. 3. Badly run out Bermuda when Bermuda was killed by alkali; new Bermuda transplanted in 1917 and irrigated every ten or twelve days, fair stand by fall; in 1918 Bermuda broken up and planted to cotton, irrigated only after planting, yield one-half bale; heavily irrigated in fall and winter, 1918; planted to cotton in 1919, yield three-fourths bale or more per acre. 4. Cropped continuously in past years, in 1918 yielded one bale cotton and has yielded well; irrigated after last picking and heavily during winter but never during crop season.

COTTON TOLERANCE TO ALKALI IN FIELD

In the Twenty-ninth Annual Report of this Station are reported several analyses of alkaline soil showing different degrees of damage to crops in the field. Similar observations have recently been made by Mr. Catlin on cotton in Salt River Valley. Here again the difficulty of securing soil samples representing the actual conditions under which the crop is growing are almost insurmountable. The results of this investigation will be found in Table III. Other data for alkali resistance by cotton are given by Nos. 7366, 7367, and 7368, Table II. None of the failures can be attributed definitely to black alkali but seem to be due to soluble salts and chlorides. These results in a general way show good cotton produced on soil containing .4 percent soluble salts with low chlorides; stunted, unprofitable cotton on soils containing .4 to .6 percent soluble salts with .1 to .3 percent chlorides; and total destruction of the crop on soils containing upwards of .6 percent soluble salts of which one-half or more was chlorides. The relatively high tolerance on No. 7627 cannot be accounted for; it may have been due to rise of alkali late in the season.

TABLE III.—FIELD TOLERANCE OF COTTON FOR ALKALI, 1919.

C. N. CATLIN

Lab. No.	Description	Total soluble solids	Chlorides as NaCl	$CaSO_4$ or Equivalent	Black alkali as Na_2CO_3
		%	%	%	%
7627	N.W. of Phoenix Indian School; good cotton	.704	.512	...	.051
7628	Same; cotton 3½ ft. high	.424	.092	...	.017
7629	Same; cotton 2 ft high	.412	.08	.044	...
7630	Same; no cotton	.792	.44	.087	..
7631	1 mile south of Tempe; good cotton	.340	.048	.087	..
7632	Same; cotton 1 ft. high	.52	.192	.022	.
7633	Same; no cotton	1.632	.636	.022	..
7634	Redden place, south Date Orchard; good cotton	416	.056	Neutral	...
7635	Same; small stalk of cotton	.608	.228	.022	..
7636	Same; no cotton	.676	.336	.065	
7637	Frank Parker, W. Adams St.; good cotton	.388	.048	.044	.
7638	Same; cotton 3 ft. high	.504	.220	.017	..
7639	Same; cotton 1 ft. high	.588	.352	.102	...
7640	Same; no cotton	.872	.544	.135	...
7641	Bargthold place; fair cotton	.700	.304	.044	..
7642	Same; no cotton	1.212	.576	.220	...
7643	Pickerell estate, 1 mile east of Date Orchard; fair cotton	.400	.144	.017	...
7644	Same; cotton 1 ft. high	.344	.092	.051	...
7645	Same; no cotton	1.336	.832	...	109
7646	Hudson land, 1 mile south of Tempe; good cotton	.368	.060	...	.068
7647	Same; cotton 1 ft. high	.352	.044	...	.034
7648	Same; no cotton	1.308	.676	...	.186

THE TEMPE DRAINAGE DITCH

In 1916 when water began flowing in the Tempe Drainage Ditch, then still under construction, this department began the study of the changes that take place in the character of the drainage water. Monthly samples, with a few omissions, have been analyzed, giving an almost continuous record for more than three years. The analyses have been published in the Annual Reports of the Station. While the composition has varied considerably from month to month, the general tendency has been for the drainage water to become less saline. The first few months, while construction was under way, were marked by excessively salty waters, freshening rapidly as the ditch was extended. The average monthly composition for the three years since the completion of the ditch was as follows:

	1917	1918	1919
Total solids	308	266	262
Chlorides as NaCl	209	182	173

Several times during the interval the character of the water has changed from black alkaline to gypsum (permanent hardness) and back to black alkaline. The monthly analyses for 1919 are recorded in Table IV.

TABLE IV.—MONTHLY VARIATIONS IN COMPOSITION OF WATER FROM THE TEMPE DRAINAGE DITCH, 1919. PARTS PER 100,000

Date	Total solids	Chlorides as NaCl	Hardness (permanent) $CaSO_4$	Hardness (temporary) $Ca(HCO_3)_2$	Alkalinity Na_2CO_3	Qualitative SO_4	Qualitative Ca	Qualitative Mg
Feb.	301.8	199.0	8.7	68.8	...	Mod. Str.	Mod. Str.	Mod. Str.
April	261.2	174.0	3.81	73.3	...	Mod. Str.	Mod. Str.	Mod. Str.
May	224.0	151.0	...	63.5	2.97	Mod.	Mod.	Mod. Str.
June	269.0	180.0	4.35	73.3	...	Mod. Str.	Mod. Str.	Mod. Str.
July (high water)	206.0	145.0	4.35	17.0		Str.	Mod.	Mod. Str.
Aug.	212.0	136.0	Neut.	47.8	Neut.	Mod. Str	Mod.	Mod.
Sept.	211.0	135.0	..	63.8	1.69	Mod. Str.	Mod.	Mod.
Oct.	220.0	136.0	...	29.7	4.66	Mod. Str.	Mod.	Mod.
Nov.	319.0	216.0	Neut.	67.6	Neut.	Str.	Mod.	Mod. Str.
Dec.	392.0	259.0	16.32	66.0	...	Str.	Str.	Str.

Str.—Strong. Mod. Str.—Moderately strong. Mod.—Moderate. Neut.—Neutral.

In the Twenty-eighth and Twenty-ninth Annual Reports there were published analyses of Arizona feeding stuffs, many of them being materials concerning which little information is available. Since data of this sort have considerable value to others and are not likely to be recorded elsewhere, the list is extended here by the addition of recent analyses in Table V.

TABLE V.—COMPOSITION OF ARIZONA FEEDING STUFFS

No.	Feeding stuffs	Condition	Water	Ash	Crude protein	Crude fiber	Ether extract	Nitrogen free extract
			%	%	%	%	%	%
7199	Sorghum silage[1].....	fresh	75.17	2.88	1.13	6.41	.48	13.93
		dry	6.65	10.82	4.27	24.09	1.79	52.38
7200	Feterita silage[1]......	fresh	54.29	2.43	3.92	6.57	1.13	34.07
		dry	6.03	4.74	7.65	12.83	2.20	66.55
7201	Darso silage, some feterita[1]	fresh	57.66	2.82	3.18	6.69	1.04	28.62
		dry	6.75	6.22	6.99	14.73	2.28	63.03
7202	Sorghum and hegari silage, mixed[1]	fresh	69.76	2.44	1.68	6.83	.76	17.52
		dry	4.01	7.75	5.36	21.69	2.40	58.8
7203	Alfalfa hay[1] 1918-19		3.70	8.02	15.73	29.75	1.67	40.59
7204	Cowpea hay[1] 1917-18		3.70	8.07	9.51	29.18	2.16	47.38
7205	Barley[1]		6.70	4.67	1.61	6.37	1.85	68.73
7206	Cottonseed meal[1]....		5.01	6.35	39.87	....	10.62	....
7214	Corn silage[1]	fresh	74.43	1.84	1.89	7.3	0.42	14.13
		dry	5.24	6.82	6.99	27.06	1.57	52.32
7215	Poppies: full flower[2]	fresh	86.99	1.79	2.92	1.40	0.44	6.45
		dry	5.70	13.01	21.16	10.15	3.23	46.75
7228	Woolly foot *(Bouteloua eriopoda)*[3]..	dry	2.80	7.66	5.61	30.31	1.54	52.08
7229	Cotton top *(Panicum lacnanthum)* new growth[4]	dry	2.81	8.46	4.62	32.62	1.36	50.11
7230	Same old growth[4]...	dry	2.47	8.67	4.00	34.33	1.11	50.58
7231	Spruce top grama *(Bouteloua bromoides)*[5]	dry	2.06	6.34	5.63	31.49	1.24	53.24
7232	Tangle top *(Heteropogon contortus)*[6]	dry	1.35	5.06	3.39	33.43	1.07	55.70
7252	*Calycoseris Wrightii*[7]	dry	5.97	11.05	10.47	22.37	5.63	44.51
7253	Poppies: pods[8]......	dry	4.43	6.63	16.28	32.17	12.53	27.96
7254	Indian wheat; whole plants[9]	dry	6.84	15.21	10.26	31.75	1.09	34.85
7255	Indian wheat; seeds[9]		7.83	5.85	12.89	38.75	0.50	34.18
7271	Spanish dagger[10]....	dry	....	....	8.55	....	....	....
7324	*Bouteloua Rothrockii*[11]	fresh	64.56	2.99	2.99	13.03	0.72	16.56
		dry	5.12	8.25	8.25	35.90	1.97	45.63
7325	*Chaetochloa, sp.*[12]....	fresh	75.97	2.69	1.83	9.73	0.37	10.47
		dry	4.27	10.74	7.31	38.76	1.49	41.71
7326	*Bouteloua curtipendula*[13]	fresh	67.16	3.48	3.35	13.22	0.81	13.59
		dry	4.53	10.13	9.75	38.44	2.36	39.52
7336	Elephant grass	fresh	82.82	2.14	1.56	6.52	0.28	6.68
		dry	3.91	12.47	9.06	37.93	1.64	38.90
7536	Cottonseed meal[14]...	dry	5.55	6.44	38.46	12.23	5.94	31.38
7537	Milo maize, threshed, cracked[14]	dry	8.59	1.60	12.13	1.81	1.20	74.67
7538	Hegari; threshed, cracked[14]	dry	10.24	1.44	9.41	1.88	1.76	75.27
7491	Grama grass; old heads and tops[15]..	dry	....	....	3.31	....	....	....
7492	Same; old bottoms[15]	dry	....	....	3.50	....	....	....

1. Feeds used in sheep feeding experiments by Animal Husbandry Department. 2. Full bloom; many seed pods; relatively few buds. 3. Also called wire grama; Santa Rita pasture March 16, 1919; no cattle grazed last year; ¾ 1918 growth, ¼ older, would probably be eaten in this proportion; seeds fallen; stem 6 to 8 inches high. 4. New growth starts on sides of old stems; ¼ lower stems rejected, sample 5 to 7 inches long. Old growth, 2 or 3 years old containing ¼ stem towards roots; 2 to 4 inches long. 5. Fine clean stems; 5 to 10 inches long; all seeds fallen; perhaps one-tenth old stem. 6. Tall and coarse; reddish; one-third 16 inches long, few seeds; one-third 12 inches long, no seeds; one-third 8 inches long, no seeds. 7. Entire plant with roots twisted off. 8. Pods almost mature, containing much pulp. 9. Plants pulled, roots and lower stems cut off; some seeds had fallen; sample would represent average forage about March 16. 10. Pulp of the yucca leaf after the fiber had been removed for commercial purposes. 11. Collected August 9, 1919; in head; knee high; just passing pollen stage. 12. Collected August 9, 1919; waist high; past blooming. 13. Collected August 9, 1919, nearly waist high; past pollen stage. 14. Feeds used in steer feeding experiments by Animal Husbandry Department. 15. Old grama grass from range south of Elgin; stock apparently starving; 7491 heads and tops of stems; 7492 bottom leaves from base of old plants.

THE SALTON SEA

In 1907 the Department undertook, in cooperation with the Desert Botanical Laboratory of the Carnegie Institution, a study of the changes in the chemical composition of the Salton Sea as evaporation took place after the closing of the break in the Colorado River. Annual analyses for ten consecutive years were made, but owing to the pressure of war work and the belief that less frequent anayses from that time would suffice, the eleventh sample was not taken till June 17, 1919. The analysis of this sample has been made by the chemist as time would permit. Since these analyses have developed wide scientific interest and have not been published in collected form since the eighth analysis, they are given here in Table VI.

Several phenomena have been observed and reports published by this Station and the Carnegie Institution. Three substances have been disappearing unmistakably from the water: Calcium carbonate, potassium, and phosphorus. The calcium carbonate has been accounted for in the formation of tufa, notably on mesquite brush that had been submerged when the Salton Sink filled with water. No adequate explanation of the fate of potassium and phosphorus has yet been made. At the suggestion of the writer, Mr. S. W. Griffin undertook a comparison of the potassium and phosphorus content and the potassium-sodium ratio in the tufa on the mesquite with the tufa from the ancient sea at Travertine Point. The ancient tufa contained potassium .20 percent, sodium .16 percent; the recent tufa, potassium .19 percent, sodium 1.27 per cent. It must be noted however, that the mesquite branches bearing the recent tufa were removed from the salty water and dried without rinsing, while the ancient tufa has been exposed to the weather perhaps for centuries. Nevertheless, the potassium-sodium ratio in the recent tufa is 1:6, while the water from which it was removed

TABLE VI.—ELEVEN COMPLETE ANALYSES OF THE SALTON SEA WATER, PARTS PER 100,000

	June 3, 1907	May 25, 1908	June 8, 1909	May 22 1910	June 3, 1911	June 10, 1912	June 18, 1913	June 12 1914	June 8, 1915	June 10, 1916	June 17, 1919
Total solids at 110° C.	364.80	437.20	519.40	603.80	718.00	846.55	1002.56	1179.6	1377.4	1647.2	2614.4
Water of occlusion, etc.	....	....	17.50	22.56	20.84	23.9	32.6	36.2	42.2	47.5	100.4
Sodium, Na	111.05	134.26	160.33	189.28	227.81	270.71	323.08	381.47	441.60	528.9	833.6
Potassium, K	2.30	2.78	3.21	3.53	3.81	3.81	3.45	4.01	5.12	5.71	9.98
Calcium, Ca	9.95	11.87	12.70	13.67	15.62	17.28	19.75	22.22	25.27	29.85	43.5
Magnesium, Mg	6.43	7.63	8.96	9.84	11.68	13.62	16.22	19.03	22.63	27.17	43.5
Aluminum, Al	.030	.035	.062	.040	.089	.100	.125	.140	.032	.034	none
Iron, Fe	.005	.006	.010	.008	.036	.042	.038	.012	.020	.060	none
Manganese, Mn	none	none	none	none	none	none	none	none	none	none	none
Zinc, Zn	none	none	none	none	none	none	none	none	none	none	none
Lead, Pb	none	none	none	none	none	none	none	none	none	none	none
Copper, Cu	....	....	trace	trace	trace	....	....	trace	....	....	....
Lithium, Li	trace	.013	.017	.021	.025	....	....	....	....	....	....
Chlorine, Cl	169.75	204.05	240.90	280.93	339.42	395.44	473.89	559.66	650.95	787.64	1247.0
Sulphuric, SO_4	47.60	56.74	65.87	76.36	91.67	106.83	124.65	148.10	174.47	207.89	337.0
CO_3, (in total solids)	6.58	7.66	7.34	6.38	5.78	....	....	....	....	....	....
CO_2 (total)	....	....	....	....	....	12.09	11.28	10.68	11.92	11.40	11.83
HCO_3, (volumetric)	....	....	....	....	17.14	16.85	15.74	15.22	16.62	16.10	17.08
Silicic, SiO_4	1.41	1.43	1.59	1.55	1.83	1.79	2.18	2.42	1.55	1.21	.70
Phosphoric, PO_4	.009	.011	.01	.013	trace	trace	trace	trace	doubt	doubt	....
Nitric, NO_3	.18	.20	none	none	none	trace	none	none	none	none	....
Nitrous, NO_2	none	trace	.0006	none	none	none	none	none	none	trace	....
Oxygen consumed	.093	.059	.068	.045	.063	.072	.110	.110	.208	.170	....
Boric acid	....	trace	trace	trace	trace	trace	trace	trace	trace	trace	trace
Total constituents	355.39	426.74	501.10	581.67	697.83	....	....	....	....	....	....

showed a similar ratio of about 1:90. There was an unmistakable concentration of potassium in the recent tufa.

With regard to phosphorus estimated as phosphate ion the ancient tufa contained .167 percent and the modern tufa .116 percent. The formation of the tufa was undoubtedly accompanied by the fixation of phosphorus. In the first few years after the filling of the sink a distinct and even weighable precipitate of ammonium phosphomolybdate could be formed from one or two liters of the water, but in 1916 no positive reaction for phosphorus could be gotten by working three liters of the water.

If calcium had concentrated at the same rate as total solids there would have been about 71.34 parts per 100,000 of calcium in 1919 instead of 43.5 parts. Thus, the equivalent of 27.84 parts per 100,000 of calcium has been lost. In like manner the .009 parts of phosphate ion present in 1907 would now amount to .064 parts, whereas all has been lost. There should also be at present 16.49 parts per 100,000 of potassium instead of 9.98 parts; that is, there has been a loss of 6.51 parts of potassium.

An analysis of the tufa being deposited from Salton Sea in 1912 made in this laboratory by Mr. C. N. Catlin and published in "The Salton Sea" (Carnegie Institution of Washington, page 47) gave about 70 percent of calcium carbonate. Assuming that the tufa used by Griffin also contained 70 percent of calcium carbonate, we find the 27.84 parts of calcium lost from the water would require the loss of .115 parts of phosphate ion and .19 parts of potassium. Thus the loss of the entire amount of phosphorus originally present can be attributed to the formation of the tufa, but only about 3 percent of the potassium lost can be accounted for in this way. It appears, therefore, that nearly all the potassium that has disappeared from the Salton water must have been adsorbed. (See Abstraction of Potassium during Sedimentation, J. W. Watson. Thesis, University of Virginia, 1913.) Deep deposits of mud have been thrown up on the flat shore lines along the eastern margin of the sea near Nilands. These muds may contain a large part of the lost potassium.

AGRONOMY

G. E. THOMPSON, R. S. HAWKINS

During the period covered by this report G. E. Thompson has been in charge of the Department of Agronomy. On January 1, 1919, R. S. Hawkins joined the department as Assistant Agronomist, and on October 1, 1919, S. P. Clark joined the department with the title of Extension Agronomist, but with the understanding that one-half his time would be given to the regular work of the department.

The strictly experimental work of the department is organized under projects. These projects cover the various phases of crop work under investigation and are placed in the different agricultural regions in the State but are located principally on the Experiment Farms of the Salt River Valley, the Yuma Valley, the Sulphur Spring Valley, and on the Dry-Farm near Prescott, Arizona. The various projects with a brief history and report of progress are listed below.

I. A CONTINUATION OF STUDIES AT PRESCOTT DRY-FARM.

In the general work of the Prescott Dry-Farm we desire to determine the agricultural practices necessary by means of which the dry-farmer with limited land can make a reasonably good living. Consequently, the work of this farm includes not only the testing of the various crops adapted to the climatic conditions of the Prescott district and the methods of planting, cultivating, and handling these crops, but it also includes the putting up and feeding out of silage, and minor investigations and observations of other farm practices. During the summer of 1919 the farm was divided into five principal fields, the arrangement of the fields permitting a rotation of crops from year to year and permitting the economical handling of farm help, machinery, etc.

No grain yields of importance were secured except from dwarf milo maize. This crop planted in early summer and given good care, made a very satisfactory and profitable grain crop.

From the silage standpoint, Papago sweet corn was the most satisfactory crop grown on the Experiment Farm. The field on which this crop was planted received some run-off water from higher ground above, thus giving it an extra opportunity to produce a larger yield. Weights taken at the time the crop was cut and placed in the silo showed a yield from the best part of the field slightly in excess of 25 tons of silage per acre. The corn matured satisfactorily and from those portions of the field left until maturity seed of good quality was harvested for the plantings of 1920.

A local variety of corn called Bloody Butcher produced some reasonably good corn and approximately 12 tons of silage per acre. Another variety of corn developed in Gila County, Arizona, and for years grown under dry-farming conditions, produced first-class ears and shows considerable promise for this locality. Seed has been saved and the variety will be tested further in 1920.

A considerable number of varieties of sorghums were tested, but of them all dwarf milo maize proved most satisfactory. The varieties tested included red amber, South Dakota amber, Freed sorghum, Darso, feterita, hegari, and sumac. The fact that Prescott has an elevation of approximately 5,300 feet, resulting in cool nights during the summer months and cool weather in the spring and fall, makes this climate better adapted to corn than to sorghums.

The sorghums that did not make a satisfactory grain yield were harvested and stored as silage, thus providing feed and facilities for the Animal Husbandry Department to carry on feeding experiments.

Sudan grass planted in cultivated rows 42 inches apart produced a first-class seed crop and that portion of the field harvested for hay produced two satisfactory cuttings. Sudan grass is well adapted to the region about Prescott and is a satisfactory field crop.

II. A CONTINUATION OF STUDIES OF SULPHUR SPRING VALLEY DRY-FARM.

The purpose and work of the Sulphur Spring Valley Dry-Farm is very similar to that outlined for the Prescott Dry-Farm. Although the conditions are dryer and consequently more severe, resulting in smaller yields, still the results throughout are comparable with the results secured on the Prescott Dry-Farm. However, the growing season is a little longer and sorghum crops are more satisfactory, partly because of lower elevation. Perhaps the best crop grown on the farm under strictly dry-farm conditions was a field of red amber sorghum planted in late March. This field withstood the extremely dry weather of June, July, and August, and when a good rain of early September supplied needed moisture the crop developed rapidly and made considerable silage. Blackhulled kafir planted at the same time under the same conditions made more silage, but did not mature as well; consequently its feeding value was not as good as that of the red amber.

Sudan grass proved a failure in 1919. The small Sudan grass plants died of drouth before they had attained sufficient size to

Fig. 2.—Green manuring with Canada field peas—Prescott Dry-Farm.

establish a good root system. In an average year we believe Sudan grass should be a satisfactory crop. Under dry-farming soy beans, cowpeas, and velvet beans were failures.

III. LEGUMES AND THEIR CULTURE FOR SOUTHWEST CONDITIONS.

Under this project plantings were made on the five farms under control of the University. In all, 12 varieties of vetch were tested, 10 varieties of cowpeas, 4 of soy beans, 3 of velvet beans, 4 of clover. A considerable number of miscellaneous crops were tried out on a small scale. In the Yuma Valley a number of the varieties of vetch were very promising, practically every one of them making a satisfactory growth and producing seed. In the Salt River Valley an unusually sharp frost occurred just after the vetches were up, and every variety, either from this or some unknown cause, died.

Of all the varieties of cowpeas tested, Red Ripper seems the most desirable. Groit stands second. From the standpoint of foliage alone, Brabham is perhaps as desirable as either of the other two. However, the Brabham variety produces seed very sparingly, consequently its usefulness as a field crop is limited. The Taylor variety was good in the Salt River Valley, but Whippoorwill gave only medium success.

As has been the case in previous years, soy beans were not satisfactory; although a good vine growth was secured with most of the varieties, practically every variety, if it produced seed at all, produced a shrivelled and unmarketable bean. This is probably due to the very hot and dry atmosphere, as shrivelled beans were produced regardless of the supply of moisture in the ground. Soy beans cut a little before maturity and allowed to cure in the shock produced a much better quality of beans than those allowed to cure on the vine.

IV. A STUDY OF THE VARIETIES AND METHODS OF CULTIVATION OF INDIAN CORN AND THE VARIOUS SORGHUMS.

In handling this project plantings were made on the five farms under the control of the Experiment Station and on farms of numerous individuals throughout the State. In the Salt River Valley, Mexican June corn or improved strains of it proved the best of all the varieties tested. The large, coarse, and late maturing corns of the eastern states were very unsatisfactory; none of them were able to withstand the hot and dry atmosphere of our valleys.

In the Salt River Valley, milo maize ranked first as a grain-sorghum crop with hegari as a close second. Either of these crops can be planted after a small-grain crop such as wheat or barley, and still have time for complete maturity. Yields in excess of 4,000 pounds of threshed grain per acre were secured with both milo and hegari.

From the silage standpoint, orange sorghum gives promise of being our best variety. Sumac sorghum promises to rank a close second. Honey-drip sorghum and goose-neck sorghum will make larger yields than the two first named, but they are larger, coarser, and more difficult to handle and require a longer growing season.

V. THE CULTIVATION AND FIELD MANAGEMENT OF EGYPTIAN COTTON.

All of the experiments in connection with this project were handled on the Salt River Valley Experiment Farm. The work covered date of planting tests ranging from March 1st to May 15th. It covered a series of fertilizer tests in which acid phosphate, sodium nitrate, cottonseed meal, commercial fertilizer, and barnyard manure were used at various rates and in various combinations. No striking nor conclusive results were secured from the fertilizer tests. The various tests in the spacing of cotton were considerably injured by a severe storm in late August and the results were not conclusive. A few preliminary experiments were made with the topping of cotton. Excellent results were secured in the control of black arm during the seedling stage. Tests were made to determine the effects of planting every third row to cowpeas instead of planting by the common methods. Various inoculating media were used in these tests for comparison with plantings of the same variety without inoculation and the wide spacing of cotton without cowpeas. The largest yield secured from any planting was that from the acre planted in the ordinary manner except that every third row was omitted.

VI. CULTIVATION AND MANAGEMENT OF WINTER AND SPRING GRAINS INCLUDING WHEAT, OATS, AND BARLEY.

Some of the work in this project was carried on on the Salt River Valley Experiment Farm. Plantings of wheat included rate of planting tests, and date of planting tests, as well as variety tests. Early Baart wheat for average conditions proved the best of the varieties tested. Good yields were secured from a locally developed strain of Red Turkey wheat. Kanred, the best hard winter wheat of central Kansas, did not prove the equal of the Early Baart or local Turkey wheat. Durham wheats made a good yield, but are difficult to market, consequently their usefulness is limited.

A very striking and successful demonstration was given in the control of stinking smut or bunt. One plot of wheat planted from untreated seed showed 66 percent of smut infection, while the plot planted with treated seed showed less than one-half of 1 percent infection.

Common six-row barley proved superior to the other varieties tested.

Abruzzi rye made a very large growth of straw and produced a fair quality and yield of rye. Red rust-proof Texas oats were the best oats tested.

VII. EFFECT OF DYNAMITING SUB-SOIL ON FIELD CROPS.

This project was handled on the Sulphur Spring Valley Dry-Farm. During the season of 1919 no difference was found in the yield of sorghum produced on the dynamited or undynamited ground.

VIII. A VARIETAL AND CULTURAL TEST OF GRAIN AND FORAGE CROP AND OF GRASSES AND MISCELLANEOUS CROPS.

Under this project tests were made with Smilo grass, Napier grass, Rhodes grass, Harding grass, rice, flax, and a number of other crops. All of these tests were of a preliminary nature and are incomplete.

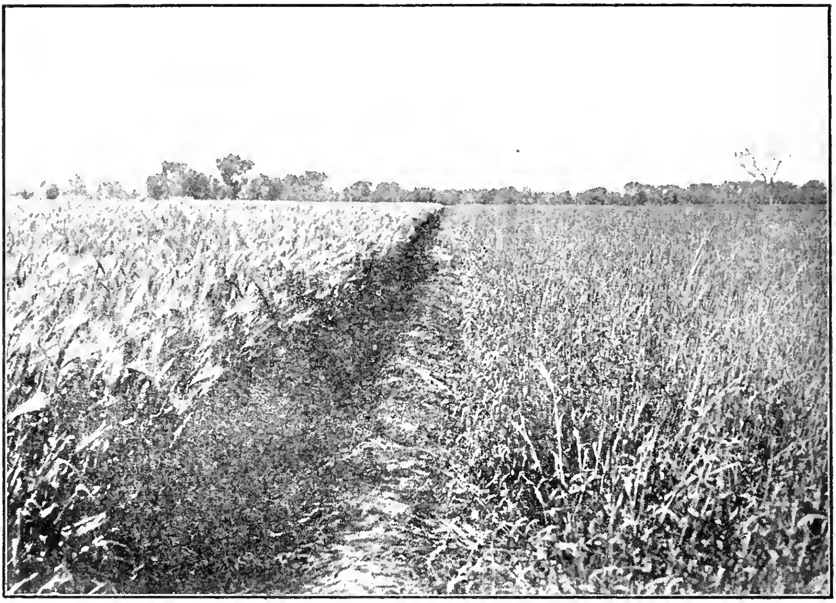


Fig. 3.—Wisconsin barley and Abruzzi rye—State Experiment Station, Mesa.

IX. FIELD STUDIES WITH LEGUMES.

This is a very definite project outlined to answer the two questions: "Is inoculation of legumes necessary in Arizona?" and "Does intercropping of field crops with a legume increase the yield?" Various inoculation materials are used and various crops are tested. This work has been conducted on the Sulphur Spring Dry-Farm, on the Prescott Dry-Farm, on the Mesa Farm, and on the University Farm at Tucson, and will be continued during the season 1920.

X. COOPERATIVE CROP EXPERIMENTS.

In handling this project, the Agronomy Department supplied seeds and planting instructions to various farmers in different sections of the State. Corn, wheat, cowpeas, and the sorghums were the principal crops under investigation. This work will be considerably increased during the season of 1920.

During the fiscal year covered by this report considerable farm machinery was added to the various Experiment Farms. Likewise much time and money were spent in levelling land and improving the irrigation facilities. The department is in much better shape now than at any previous time to handle detailed experimental work.

ANIMAL HUSBANDRY

R. H. Williams

The work in the Department of Animal Husbandry deals with a study of economical methods of producing beef, pork, and mutton. The investigations of the department cover a wide field of search into the factors which have a direct bearing on the industry.

RANGE CONDITIONS THE PAST YEAR

The past fiscal year continued dry throughout the Southwest, and in the southern and eastern parts of the State forage was very inferior. In the northern part of the State the winter was unusually cold and many animals perished. It is doubtful if as many animals died in a single year since the great drouth in 1892-93. A combination of lack of feed, thin animals, deep snow, and extremely cold weather in the northern part of the State, made the winter one of the most trying in the history of the business. The market for animals was inferior and cattlemen have had a setback. Many stockmen situated in the southern part of the State leased fenced pastures in Mexico and thousands of cattle were moved across the line where feed was abundant.

The winter range on the desert was late in coming, but was good after the middle of February. The lamb crop was about normal, losses being light and the price of wool and lambs high, so that the sheepmen have had a prosperous year. The sheep and goat industries in Arizona are on a sound, economic basis.

Commencing the last day of June, 1919, the three years' drouth in southern Arizona was broken. Feed began to grow everywhere; in places where old-timers believed there never would be any revegetation the old palatable species sprang up and showed the unusual revegetative qualities of these grasses.

At the close of 1919 there were undoubtedly fewer cattle in Arizona than at any time since 1890. During the drouth the ranges were overstocked, but with abundant rainfall and the small number of animals to be maintained the carrying capacity should increase. The number of sheep on Arizona ranges is about an average of that of the past five years.

Farmers in irrigated districts have plowed up many acres of alfalfa to plant cotton. The supply of alfalfa is being reduced very materially. Farmers have reduced the number of all kinds of livestock maintained, but there is a tendency for them to increase the number of cattle and sheep finished for market. Farmers on irrigated land are increasing the number of pure-bred Hereford cattle and registered sheep, as they find a good demand for breeding males from range stockmen. Dry-farmers have continued to use livestock as a means for marketing their crops. There is a tendency for dry-farmers to cooperate more with range cattlemen in feeding cattle for market and in carrying range cows over periods of drouth.

INVESTIGATIONS

Four different lines of investigation have been pursued in the Department of Animal Husbandry during the past year. They were:

1. Lambing ewes on feed.
2. Feeding range cows.
3. Hog feeding tests.
4. Range livestock production.

LAMBING EWES ON FEED.

Each winter close to a million sheep are brought from ranges in northern Arizona to winter on the desert ranges in the central part of the State. During seasons of abundant rainfall the sheep do well on the desert. At times, however, feed and water are not available on the desert and it is necessary to feed the sheep or else move them to irrigated valleys to be fed. During the winter of 1917-18 approximately 400,000 ewes were fed on irrigated farms. Little was known regarding the best method of feeding sheep and losses were excessive.

In order to secure some information regarding the best feeds for lambing ewes on irrigated farms, an experiment was conducted during the winter of 1918-19. Two hundred range-bred ewes were selected and placed in dry feed lots on the Mesa Experiment Farm. They were divided into ten different groups of twenty in a lot and fed as follows:

Lot	I	Silage.
Lot	II	Silage ad libitum, one-fourth pound cottonseed meal.
Lot	III	Silage ad libitum, one-half pound cottonseed meal.
Lot	IV	Silage, six pounds; one and one-half pounds alfalfa hay.
Lot	V	Silage, four pounds; two pounds alfalfa hay.
Lot	VI	Silage, four pounds; two pounds pea hay.
Lot	VII	Alfalfa hay, three pounds; whole barley one-half pound.
Lot	VIII	Alfalfa hay, one and three-fourths pounds; pea hay, one and three-fourths pounds.
Lot	IX	Pea hay, three and one-half pounds.
Lot	X	Alfalfa hay, three and one-half pounds.

The sheep were maintained in the feed lots for seven weeks. At the outset they were extremely thin and began to lamb a week after being placed in the feed lots. Complete records were taken regarding the amount of feed consumed, dates of lambing, weights of the lambs and ewes, mortality in the different lots, and the vigor and condition of the lambs. From the flock 170 of the ewes lambed and there were 24 dry ewes. Ninety percent of a lamb crop was raised from the ewes that lambed, or 76.5 percent of a lamb crop raised from the entire flock. As a result of the test, it was clearly demonstrated that thin range ewes require an abundance of good feed to place them in proper condition for lambing. Silage alone made the ewes fat, but was extremely inferior for milk production. The addition of cottonseed meal to the ration increased the milk flow. Pea hay was too coarse for the ewes and not as satisfactory as alfalfa hay. There is no reason why sheep cannot be fed in dry lots in such a way as to maintain the animals in good, vigorous condition for lambing, to have strong lambs at time of birth and raise as good lambs there as on the desert. The ewes, however, if thin at the outset of the test, should be forced to a maximum of their capacity for at least three weeks before lambing. This means that the ewes will require much more feed than that recommended by the feeding standards.

CATTLE FEEDING.

On the Prescott Dry-farm 20 thin, old range cows were selected and divided into four different lots containing five each. The cows in Lot I were fed 30 pounds of silage per day; Lot II, 40 pounds of silage per day; Lot III all the silage they would eat; and Lot IV all the silage they would eat and two pounds of cottonseed meal daily.

This test indicated that 30 pounds of silage was not enough to maintain these cows and probably all would have died on this amount. Forty pounds of silage per cow daily was almost sufficient to maintain them, but they gradually became weaker and probably would not have lived on this allowance. It is believed, however, that if either Lot I or II had been given the freedom of a browse range or dry pasture where they could have secured a small amount of forage they would have done well on 30 pounds of silage per head daily. The cows given all the silage they would take did not make rapid or cheap gains. They became strong and vigorous, taking a good fill the first few weeks, which increased their weight, but after the third week little gain was made. These cows ate about 60 pounds of silage per head daily. Silage alone is not a satisfactory ration to fatten thin range cows.

The cows fed on a combination of silage and two pounds of cottonseed meal made good gains and finished for marketing in about 100 days. It is believed that this ration is a cheap and efficient one for finishing cows for market.

TWO METHODS OF RAISING GILTS.

The five Duroc-Jersey gilts from the same littler have been under inspection another year. These pigs were divided into two groups consisting of two gilts maintained on one farm and three on another. When they were 779 days old, or approximately 25½ months, the two gilts raised on an ordinary farm weighed 175 and 222 pounds, respectively, while the three gilts maintained under good conditions weighed 575 pounds, 610 pounds, and 630 pounds, respectively. The number of pigs raised by the gilts from the two different farms did not vary much. It may be that the pigs from Farm B were too fat and those from Farm A were too thin for the best results. It is planned to exchange two of these gilts from one farm to the other and to study the development of the large ones under inferior conditions and the small ones under good conditions.

FATTENING HOGS ON GARBAGE VS. ROLLED BARLEY.

Eight hogs averaging 122.2 pounds live weight were divided into two lots. Lot I was fed on garbage secured from the University Dining Hall and Lot II rolled barley from a self-feeder. The pigs were fed over a period of four weeks. The garbage cost $25.00, while the pigs fed on rolled barley were given $10.66 worth of feed. These pigs ate an average of 19.04 pounds of rolled barley per day and they weighed an average of 551.4 pounds during the feeding period, so that they consumed an average of 34.52 pounds of rolled barley per thousand pounds live weight.

The pigs in Lot I gained a total of 227 pounds during the four weeks, while those fed on rolled barley gained only 97 pounds. The average daily gain of the pigs fed on garbage was 2.03 pounds per head, while those fed on rolled barley gained only .87 pounds daily. Although the pigs fed on garbage were fed at considerably more expense, yet they made much more rapid gains and cost only $10.73 per one hundred pounds increase in live weight, while those in Lot II, fed rolled barley, cost $10.99. Hogs were selling on the local market during the period while the test was being conducted at 16 cents per pound live weight. The profit secured from feeding the hogs amounted to \$5.27 for the pigs in Lot I, and \$5.01 per 100 pounds gain in Lot II. The pigs in both lots were vigorous and ate their feed with apparent relish.

MARKETING HOGS DRESSED VS. SELLING THEM ALIVE.

Eight pigs weighing a total of 1358 pounds and ranging in weight from 128 to 217 pounds each were offered for sale to local butchers. The highest bid received was 16 cents per pound, or a total of \$217.28 without any deduction made for shrinkage. These pigs were maintained twelve hours without feed or water before killing them. They were then weighed, dressed, and allowed to hang over night to cool. They dressed a total of 1050 pounds, which was sold at 26 cents a pound, yielding a total of \$273.00. A careful record was secured of the actual expense of dressing the hogs, which amounted to \$1.225 per pig. At this rate the gross returns received for dressing the pigs amounted to \$55.72, or \$6.965 per head, or a net return of \$5.74 per head.

On March 21, 1919, four hogs ranging in weight from 148½ to 208 pounds were offered to local butchers for sale. The best bid secured was 16½ cents per pound live weight. As the four pigs weighed 697 pounds, this would amount to \$115.00. The pigs were dressed at a cost of \$1 per pig and the offal. They were then sold at 25 cents a pound for the dressed carcasses, yielding a gross return of \$127.62, or an increase of 12.525 cents for dressing them. This is an average of \$3.156 per pig, or a net profit of \$2.156 per pig for dressing them.

The results of these two tests indicate very emphatically that local farmers would do well to slaughter their hogs and sell the dressed carcasses.

INSTRUCTION AND EXECUTIVE WORK

The office work in the Department has been unusually heavy during the past year. This work has called for the supervision of the livestock, planning new equipment, purchasing new animals, judging livestock at fairs, addressing meetings, and personal conferences with stockmen. Quite a number of articles have been published in technical journals and local periodicals. An initial selection has been made of a Rambouillet buck and four ewes.

NEEDS.

The Animal Husbandry Department has been greatly handicapped due to lack of animals suitable for investigation, lack of land and pasture and forage crops, fences and other equipment for experimental purposes. The Station should have an experimental range consisting of at least ten sections in area, properly fenced and equipped. This range should be located where it will be as representative as possible of range conditions in the State. With such an area properly equipped and stocked, it would be possible to study fundamental problems relating to the production of livestock under range conditions. The methods of determining the cost of production can only be developed through a series of investigations involving herds and flocks maintained on ranges under typical conditions. The study of increasing the carrying capacity of our ranges and the practical management of animals so as to make the best use of the forage grown is of greatest importance to stockmen in the State. The Department is confronted with many questions upon which it has no information, and it is urged that provision be made for land and equipment where long-time experiments may be undertaken to develop cheaper methods of producing animals on Arizona ranges.

BOTANY

J. J. Thornber

The year ended June 30, 1919, was far from being favorable for the grazing industry. The rainfall for this period was considerably below the average throughout the State. This was particularly true of the summer season, the precipitation of which was scant and came mostly in light showers separated by dry, hot spells of from one to three weeks' duration. The rainfall for this twelve-month period at Tucson was 9.58 inches, which was proportionally greater than in many other parts of the State. Of this amount 3.13 inches, or 32.7 percent, came during the summer period, July to October inclusive, and 5.31 inches, or 55.4 percent, during the winter and spring months, November to April, inclusive. The remaining 1.14 inches fell during May and June, 1919, and was not sufficient to increase materially forage growth on the desert ranges. However, on the prairies and in the foothills at altitudes of 3500 to 6000 feet the rains in May were generally good and helped very much the growth of the perennial grasses.

The dry summer of 1918, unfortunately, was preceded by a very dry winter and spring, with the result that conditions on the stock ranges in the winter of 1918-19 were very bad and losses were necessarily heavy. On many of the ranges there was practically no feed during the winter season, and to prevent larger losses it was necessary to ship stock out or feed them. This was noted in part in the Annual Report for the year ending June 30, 1918.

With some exceptions, the winter and spring rainfall throughout the State was nearly up to the average. Though never heavy at any time, the winter rains, mostly in the form of showers, continued more or less regularly from November to May, inclusive. January was the driest month, with but .26 of an inch rainfall; while for the months of November, December, and April the rainfall averaged more than one inch. One-half the winter rainfall came prior to February 1, during which season the temperatures are too low for good winter annual growth, even at the lower altitudes where the climate is mildest. The forage growth on the grazing ranges during the spring months was slightly below the average, but it was very timely. This, together with the favorable rains in May, helped very much to carry stock on the ranges until July 1, 1919, when the summer rainy season set in heavily.

WORK ON POISON PLANTS

The work on poison range plants begun last year has been continued. The commoner poison plants in the southern and central parts of the State have been studied carefully, both in the field and by means of numerous plant collections. Data have been collected relative to their poisonous properties, their seasons of growth, flowering, and fruiting, and conditions favoring or discouraging their growth. Some work has also been done on practical means of eradication. In the instance of loco plants, digging seems to be the simplest method. The plants are invariably killed when cut off at the roots two to four inches below the crown. Even where the plants are moderately abundant on grazing ranges, a considerable area can be cleared by one person in a week's time with a good sharp hoe, or better, a spud. The latter is a tool resembling a hoe, but with a short, straight neck and a stout blade about two-thirds as wide as a common hoe.

On the majority of grazing ranges in southern Arizona the loco plants grow rather scatteringly and are rarely abundant. But even where they are abundant on the range it is recommended that they be dug out. It is only necessary to dig out the larger and more luxuriant growing plants, since these are the ones from which stock eat enough of the loco forage to produce the disease. The smaller and weaker plants will either die out during the year or else grow to be large enough the following year so as to be easily seen. As far as possible, no loco plants should be allowed to mature seed, and to prevent this the cutting or digging should begin either before or by the time that the plants first begin to flower.

Occasional reports of stock poisoning, apparently caused by plants that are not known to be poisonous, have been received from different localities. In some instances stockmen suspect very strongly certain plants as causing the trouble. Some of the plants that are believed to cause stock poisoning, at least at certain seasons of the year, are rayless golden-rod or burro weed *(Bigelowia coronopifolia* and *B. Hartwegi), B. heterophylla, B. Wrightii, Baccharis pteronoides, Lupinus Kingii,* and a species of *Linum.* Work now is being done on some of these plants.

In the vicinity of Dewey, Arizona, during February and March, 1919, stock were poisoned on several different occasions from eating bledo or careless weed *(Amaranthus Palmeri)* hay. This case of poisoning was so apparent that it could not reasonably be doubted. The hay was fed in racks in stock corrals, and the animals were healthy and in good condition. Practically all the animals that ate any quantity of the hay were poisoned, and the ones worst affected died in the corrals 6 to 15 hours afterwards. The writer examined very carefully a sample of the hay weighing 25 pounds and found it to be almost pure bledo or careless weed. There were a few small specimens of other common plants that are not known to be poisonous. These represented altogether less than one percent of the total weight. The Experiment Station chemist made careful analyses to determine if any of the commoner poisonous substances might be found present, but in none of the tests was even a trace of any poisonous substance found. Without more study it is impossible to suggest the cause of this poisoning.

Careless weed is commonly regarded as one of our best summer annual forage plants and is invariably relished by stock, either as dry coarse hay or as succulent green feed. Like alfalfa, occasionally it causes bloat with stock when eaten greedily by hungry animals, or following a rain or heavy dew. Considerable hay is made from careless weed for winter roughage along the Gila, Santa Cruz, and San Pedro rivers in southern Arizona, and, with the exception of the case noted above and perhaps one other at Verde, Arizona, it has not been known to cause poisoning with stock. Careless weed greens are considered a delicacy for the table in summer and are regarded as equal to those of good spinach. In the past the writer has suggested that desirable strains of bledo be selected and grown as a garden vegetable.

In November, 1918, the writer made investigations concerning losses of stock on certain foothill ranges in southern Arizona in the vicinity of Douglas.These losses occur late in the fall and winter seasons usually following cold weather and rains and curiously enough the fattest animals are the ones that are usually found dead. Commonly two or more animals die at a time within a small radius, mostly at places where stock collect to rest. None of the animals show any evidence of struggling or violence, but usually are in positions indicating rest or sleep. Along with stock from other parts of the range, these animals drink from a tank of good water located in a canyon some distance below. The location where nearly all these animals have been found dead is a limestone hill a half mile or so in extent and surrounded by foothills of native rock which is non-calcareous. Similar losses of stock are known to have occurred on this hill for the past eight or ten years. The range in this vicinity is one of the best in southern Arizona, the forage being about equally divided between perennial grasses and browse, and nowhere in the State were stock observed coming through the long droughty period in better condition than here.

Due in part to the character of the soil, some species of plants were growing on this hill that were not observed elsewhere in the immediate vicinity, while still other species were growing in greater abundance than on soils derived from other rock formations. However, the species were not unusual for southern Arizona conditions and none could be suspected of being poisonous to stock. When the writer visited this range no animals had died for some weeks and the plant growth was rather closely grazed. Any poison plants that might have been growing here had been grazed down so as not to be easily recognizable. It was suggested that until such time as a careful study could be made of all the conditions affecting the grazing on this area, at least the lower part of the hill, where the animals die, should be fenced to keep stock off from November until March, inclusive.

The following is a list of the commoner plants growing on this limestone hill, as identified by the writer. The symbols, a, b, c, and d after the plant names, indicate as follows: a signifies abundant; b signifies common; c signifies occasional; d signifies infrequent.

(1) *Opuntia spinosior*........b
(2) *Ceanothus Greggii*.......c
(3) *Cercocarpus paucidentatus* a
(4) *Agave Palmeri* (not grazed, ...b
(5) *Brickellia Wrightii*.......c
(6) *Opuntia Engelmanni*.....c
(7) *Garrya Wrightii*.........c
(8) *Dasylirion Wheeleri*......b
(9) *Andropogon cirratus*. ....a
(10) *Fouquiera splendens*......c
(11) *Rhus coriophylla*.........b
(12) *Viguera cordata* ....b
(13) *Notholaena sinuata* ......b
(14) *Bouteloua curtipendula*...a
(15) *Artistida purpurea* ....b
(16) *Muhlenbergia Vaseyana*..c
(17) *Triodia sp.* ....d
(18) *Eragrostis lugens*........b
(19) *Eupatorium arizonicum*...c
(20) *Andropogon saccharoides* c
(21) *Mentzelia multiflora*......d
(22) *Quercus Toumeyi*........c

Dr. Lon Durham, a government veterinarian, very kindly accompanied the writer on this trip and cooperated in this study. Dr. Durham failed to locate any definite symptoms of stock disease that might be responsible for losses of these cattle and gave it as his opinion that the trouble was due to some poison plant, possibly as yet unknown as such.

NOTES ON PLANT INTRODUCTION WORK

A considerable number of new plant introductions, including trees, shrubs, and hardy flowers were set in the plant introduction gardens at the University Campus and the University Farm. Among those are included the following: *Cupressus Benthami; C. mycrocarpa; C. glabra; C. goveniana; Libdocedrus decurrens; Juniperus sabina; J. phoenicaea; Quercus suber; Pistascia atlantica; P. vera; Ulmas pumila; Elaegnus pungens; Carpenteria californica; Berberis Thunbergii; B. trifoliolata; Ceanothus thrysiflorus; Forsythia suspensa; Sparteum junceum; Sophora japonica; Syringa chinensis sougeana; Phyllostachys quiloi; Diervillea florida; Tamarix algerica; T. parviflora purpurea; Bouvardia triphylla; Hibiscus syriacus; Mesembryanthemum arboreum; Statice arborea;. S. pseudarmeria; Hunnemannia fumariaefolia; Ipomoea mexicana; I. Learii; Pentstemon antirrhinoides; P. centranthifolius; P. cordatus; P. heterophyllus; P. hybridus; P. spectabilis; P. Wrightii, and P. Torreyi.*

A list of trees and other ornamental plants was selected and planted at the Experiment Station dry-farm, Cochise, Arizona, the altitude of which is about 4000 feet. Another list was made for planting at the Tempe Date Orchard, Tempe, Arizona. The plants for the date palm orchard were selected with reference to alkali resistant qualities.

STUDIES OF GRASSES AND GRASS-LIKE PLANTS

The writer gave most of the summer season of 1918 to field studies of our native grasses and other forage plants of the central and northern parts of the State, with a view to secure as much practical information as possible relative to the abundance, distribution, life history, and grazing value of these plants. A part of the fall season was spent in a similar study of the forage plants on the better class of ranges in southern Arizona. This season was peculiarly interesting, since in many localities on account of the shortage of grass, stock were subsisting largely on browse.

During the early months of the school year, one-half of the writer's time was taken up with instruction work, including classes in botany in the University and in physiology and hygiene in the S. A. T. C. Following the abrupt close of the S. A. T. C. work with the signing of the armistice, the writer began a study of the plants of the Juncaceae or Bog-rush family and of the Cyperaceae or Sedge family, both families of which are fairly well represented in our State. This latter was completed with the exception of the genus Carex, the plant collections of Arizona of which are too incomplete to make possible a satisfactory study. Although Bog-rushes and Sedges are not grasses, they resemble grasses and in their growth are usually associated with grasses, and besides they are of economic value to the stockman chiefly because of their forage production.

The remainder of the year, beginning with January, 1919, was divided between instruction in the University, which included two-fifths time, and investigation work in the Experiment Station, including the plant introduction and poison plant work already noted and the beginning of a comprehensive economic study of our grasses.

DAIRY HUSBANDRY

W. S. Cunningham

The Dairy Department was organized about November 1, 1918, the dairy work being separated from the Department of Animal Husbandry at that time. Much of the year was spent in adjusting conditions in the department, so that little experimental work was done.

Records were kept of the milk and fat production for the year and the results are given in Table VII.

TABLE VII.—YIELDS OF DAIRY COWS AT UNIVERSITY FARM, 1918-19

Name of cow		Days dry before calving	Days milk	Yield in pounds		Average % butterfat
				Milk	Butter-fat	
Princess of Chewanbeek	Jersey	29	360	8,294.1	399.5	4.74
Childeberte	"	66	338	6,364.3	366.3	5.75
*Gipsy Draconis.........	"	77	365	9,452.8	418.3	4.42
Myrtle of Nogales.....	"	53	260	6,481.3	267.8	4.13
Arizona s Butter Girl...	"	...	260	4,676.4	275.3	5.88
Average		...	316	7,053.8	345.5	4.89
Belle Liscomb de Kol 2d	Holstein Friesian	77	365	10,344.3	330.2	3.19
Josephine Arizona Maid	" "	89	365	14,136.3	408.7	2.88
Moensje Jesse Aspirante	" "	88	365	13,423.2	416.5	3.10
Theresa Belle, 3rd......	" "	66	264	11,350.2	362.0	3.19
Josephine Ariz. Maid II	" "	0	360	7,458.4	241.0	3.23
Madison Martha, 2d....	" "	65	349	11,679.0	336.3	2.89
Miss Pell Pietertje....	" "	131	365	10,750.8	392.4	3.65
Johanna Madison Pauline	" "	113	365	11,106.5	287.8	2.59
Theresa Belle De Vrier	" "	58	365	11,066.9	357.2	3.22
†Molly Artis Pontiac Mercedes	" "	...	363	6,275.2	189.2	3.01
Theresa Belle Monona..	" "	0	282	3,820.1	130.1	3.40
Average		...	...	10,128.3	313.8	3.09

*Died December 29, 1919.
†Sold.

DAIRY CATTLE FEEDING EXPERIMENT

In the spring of 1918 an experiment was conducted to determine the value of cottonseed cake as a supplement to alfalfa hay and silage, for milk production. The results of that experiment were not what was expected since the most unbalanced ration of alfalfa hay and cottonseed cake gave the best results, both in quantity of milk produced and in net profits.

Another experiment was planned and conducted along the same line so as to be a check on the first experiment. Some few changes were made in that cottonseed meal was substituted for cottonseed cake and the amounts of all feeds were increased. In addition to the regular ration of alfalfa hay, silage and cottonseed meal, rolled barley was given to those cows producing more milk than was provided for in the regular ration.

RATIONS

All of the rations were figured so that each lot received the same nutrients according to the amount of milk produced.

The rations used were as follows:

Ration 1. Alfalfa hay, 22 lbs. Silage, 45 lbs.

Ration 2. Alfalfa hay, 30 lbs. Cottonseed meal, 4 lbs.

Ration 3. Alfalfa hay, 15 lbs. Cottonseed meal, 4 lbs., and silage, 45 lbs.

In addition to the above rations, the Holstein cows were fed one pound of rolled barley for each three pounds of milk produced over 30 pounds daily, while the Jerseys were fed one pound of rolled barley to each three pounds of milk over 25 pounds.

COWS

Nine cows were used in the test. All of these cows were giving a fairly good flow of milk and none of them was about to go dry. They were divided into three lots of three cows each. The lots were balanced as well as possible in regard to breed, period of lactation, and quantity of milk given. To overcome any differences in the above points and in individuality, the lots were changed to different rations each month. In interpreting results, the rations and production have been calculated for three periods collectively and no attempt has been made to draw conclusions for any one period.

The cows were divided into lots as follows:

Lot 1	Lot 2	Lot 3
Margaret De Kol Johanna	Miss Pell Pieterje	Madison Martha II
Johanna Madison Pauline	Pelle Liscomb De Kol II	Arizona Maid 2nd
Arizona Butter Girl	Gipsy Draconis	Princess

PLAN OF FEEDING

The plan of feeding was as follows:

1st period	Lot I	was	fed	Ration	1
	Lot II	"	"	"	2
	Lot III	"	"	"	3

2nd period	Lot I	was fed Ration 2
	Lot II	" " " 3
	Lot III	" " " 1
3rd period	Lot I	was fed Ration 3
	Lot II	" " " 1
	Lot III	" " " 2

DURATION OF TEST

The test was divided into three periods of four weeks each. One week was allowed between each period for the changing of rations.

The first period began November 18th, A. M.
The first period ended December 15th, P. M.
The second period began December 23rd, A. M.
The second period ended January 20th, P. M.
The third period began January 28th, A. M.
The third period ended February 25th, P. M.

The summary of milk and butterfat produced by cows while on each of the three rations is given in table:

SUMMARY OF MILK AND FAT PRODUCED

Rations	Total milk yield *Pounds*	Total fat yield *Pounds*	Number days in test
Ration 1................	6084.8	238.05	84
Ration 2................	6776.2	237.95	84
Ration 3................	6675.1	250.07	84

During the 84 days of the test, the production for ration 1 was 6084.8 pounds of milk and 238.05 pounds of fat; for ration 2, 6776.2 pounds of milk and 237.95 pounds of fat; and for ration 3, 6675.1 pounds of milk and 250.07 pounds of fat. Ration 2 caused the largest production of milk while ration 3 produced the most fat.

The following table shows the feed cost of milk and fat produced with feeds at the prices prevailing at the time the experiment was started, and the profit over feed-cost obtained from the milk valued at 30 cents per gallon:

COST OF PRODUCTION AND PROFIT OVER FEED COST

Rations	Cost of feed *Dollars*	Feed cost per gallon of milk *Cents*	Feed cost per pound fat *Cents*	Value of milk @ 30c gallon *Dollars*	Profit over feed *Dollars*
Ration 1	115.44	16.6	48.3	212.22	96.78
Ration 2.......	123.84	16.1	54.4	236.34	112.50
Ration 3.......	126.21	16.8	51.7	232.83	106.62

Feeds were priced as follows: Alfalfa hay, $25 per ton; silage, $9 per ton; cottonseed meal, $45 per ton; barley, $60 per ton.

Ration 2 consisting of alfalfa hay and cottonseed meal proved to be the most economical ration for milk production while ration 1 consisting of alfalfa hay and silage proved to be the most economical producer of fat.

With milk valued at 30 cents per gallon ration 2 gave $15.72 more profit over feed cost than ration 1 and $5.88 more than ration 3.

The results of this test would indicate that for short periods of time a very narrow ration can be fed with satisfactory results. However, on account of the common opinion among stockmen that rations containing a great excess of proteins affect the breeding qualities and general health of animals if fed to them for a long period of time, such narrow rations as alfalfa hay and cottonseed meal should be fed with caution.

ENTOMOLOGY

C. T. VORHIES

The chief activity of this department during the summer and autumn months of the year 1918-1919 lay in continuing the investigations planned and begun the previous year on grazing range rodents, with special reference to the Large Kangaroo Rat, *Dipodomys spectabilis*. The chief base of operations for this work is on the U. S. Range Reserve on the northwest slope of the Santa Rita Mountains. Difficulties in securing some of the fencing materials needed, and also in securing labor when wanted, owing to war conditions, delayed the completion of the fences for the experimental areas until late autumn. It was expected, when plans were made, to have these fences finished by July, 1918, in time for the summer growing season. However, the summer rains of that year were so scanty that practically no grass growth occurred on the selected areas, but the delay in fencing did not affect the course of the experiments, which were in many phases postponed one year by the unfavorable season. Life-history and ecological studies of the Large Kangaroo Rat, and to some extent of the Merriam Kangaroo Rat *(Dipodomys merriami)*, and of the jack rabbits and occasionally of other rodents, were continued throughout the year, resulting in the securing of considerable valuable data.

The fencing was finally completed in November, 1918, with the assistance of two University professors while the University was closed on account of the influenza epidemic. Approximately eight hundred dollars were expended by the Forest Service in materials and construction of these fences under the cooperative agreement whereby the U. S. Forest Service, the U. S. Biological Survey, the Carnegie Institution, and the University of Arizona Experiment Station are working on this grazing range project.

As opportunity offered, the department also carried on the work of building up the collection of Arizona insects. Two steel cabinets containing four dozen Schmitt boxes were secured in which to house the collection. Some investigation of the distribution of the Arizona wild cotton *(Thurberia thespesioides)* and of the native boll weevil which lives upon it was conducted during the year. This was undertaken with reference to the possible future bearing of the results upon the extension of the area of cultivated cotton up the Santa Cruz and Rillito valleys.

In April, 1919, specimens of a small beetle were received from Mr. C. J. Wood of the Mesa Experiment Farm with the report that they were destroying cotton by feeding just below the surface of the soil on the seedlings as they were emerging from the ground. So large a percentage of the cotton in one experimental half-acre was thus destroyed as to make replanting necessary. This particular half-acre was being tested with cottonseed meal as a fertilizer, and the assumption was that the fertilizing material was attractive to the beetles. The pests were most numerous in this plot and a quantity was taken for feeding tests. These tests, while not conclusive, indicated the probable correctness of the above assumption. The beetles fed readily on crushed cotton seeds and particularly on the lint remaining with the seeds before any seeds had germinated or where no young plants were present. When young plants appeared they seemed to attack them only in part and as a sort of change or variation of diet. Irrigation of the affected area of soil was effective in preventing damage to the replanting, and is therefore suggested as the proper control measure. This pest is a small dark brown to black beetle, oblong, and between three-sixteenths and one-fourth of an inch long. It is provisionally classified as *Blapstinus pimalis.*

The corn stalk borer mentioned in the Twenty-ninth Annual Report has been identified as *Diatraea lineola*, a species not hitherto recorded as an economic insect. It is, however, so closely allied to the larger corn stalk borer of the East *(Diatraea zeacolella)*, and its habits and life history appear to parallel that pest so closely, that for all practical purposes it may be regarded as the same.

During the year the department moved into new quarters in the Agriculture Building, thus securing adequate space for its present activities, but with only the most meager equipment. Funds for this fiscal year did not permit the immediate remedying of this weakness, and while in the end the change will result in great benefit to our work, it placed a certain temporary handicap thereon, which it is expected will be largely removed in the next fiscal year.

HORTICULTURE

F. J. Crider, A. F. Kinnison

The activities of the Department of Horticulture in matters of the Experiment Station have consisted largely in foundational work on projects as outlined in last year's report and in broadening the general scope of work so as to better serve the horticultural interests of the State. It is believed that good progress has been made and that conditions are favorable for greater growth and service. The lines of work pursued fall naturally into three main divisions—Pomology, Olericulture, and Ornamental Gardening.

POMOLOGY

A ten-acre orchard composed of 400 varieties of the leading fruits was started at the Salt River Valley Experiment Station Farm during the past spring and a three-acre orchard at the University Farm. Also additional plantings were made at the Yuma Date Orchard and Horticultural Station. These plantings are for the purpose of determining the relative value of varieties and to serve as a basis for experimentation in other phases of orchard culture. The trees have made a remarkably good growth, and in the case of the fig and jujube have set a few fruits. The older plantings at the Yuma Date Orchard and Horticultural Station and at the Prescott and Cochise Stations have reached a stage of growth where they should in a short time give some results, particularly in the matter of variety comparison. It is planned to enlarge the orchards at these stations next year.

DATES

The behavior of varieties of dates during the past season was interesting as compared with the previous year in that the weather conditions were entirely different. The season of 1918 was almost ideal for date ripening, which made it possible for every bearing variety to mature a maximum crop, whereas the rainy weather of the past season developed the fact, as has been shown in previous years, that there is a great variation in the adaptability of varieties to moist conditions. At the Tempe Orchard the Rhars variety was almost a total failure due to souring, which was brought about by the wet weather. The Deglet Noor was very badly affected by fungus spots at the Tempe Orchard, but at the Yuma Orchard where the rain was less a reasonably good quality date was produced. Even in the Yuma Valley, however, there is too much moisture present to- produce ideal dates of this variety. The Hayany maintained its established record for withstanding adverse weather conditions; also Bentkabala, Nesheem, Nazl al Bacha, Tennessim, and Tadala suffered very little damage.

In this connection it is believed that other districts of the State having less rainfall and lower humidity would prove better adapted to date production. For further experimentation along this line plantings will be made on the Yuma Mesa (where the relative humidity is probably lower than in any other part of the State) and in portions of the Salt River Valley next to the foothills.

In view of the detailed statement in the Twenty-ninth Annual Report of yields at the Tempe and Yuma Orchards, it is thought that this feature might be eliminated and only the total number of trees, yields and returns given, as indicated in Table VIII.

TABLE VIII.—YIELDS AND RETURNS FROM THE TEMPE AND YUMA DATE ORCHARDS

Orchard	No. bearing trees	Total yield in pounds	Avg. yield per tree in pounds	Total returns	Avg. returns per tree
Tempe	307	17,107	55	4531.16	14.77
Yuma	120	8,938	62	3000.00	20.77

In the case of rooted palms used in filling vacancies at the Tempe Orchard last year, a rather large percentage have started into growth. This is interesting from the fact that the soil here is extremely alkaline and it was feared that the young offshoots could not survive such a condition. As a precaution against the action of salts, however, about a cubic yard of sweet soil was placed in the tree holes at the time of planting and a heavy straw mulch applied on the surface to prevent the rise of alkali. It is believed that the entire setting of offshoots would otherwise have been lost.

The results in propagating the date have not been as satisfactory as was anticipated, but it is thought that the difficulty has been located and that future efforts will be atended with greater success. It is planned to propagate the present available offshoot crop from both the Tempe and Yuma Orchards on the Yuma Mesa, where the conditions of climate and soil are most favorable for such work.

CITRUS

Citrus investigations in methods of culture, including fertilizer and orchard cover crop tests, have been conducted as outlined in last year's report. While no definite results have been secured, quite a difference in the behavior of summer orchard cover crops was noted on the Yuma Mesa. The lack of a sufficient water supply prevented the planting of large areas, but small plots of cowpeas, garavanza, tepary beans, peanuts, and velvet beans were used. The cowpeas proved far superior, making a larger growth and withstanding drouth to a greater degree than any of the other crops. In the matter of ground-cover during summer the peanuts ranked next to the cowpeas. The velvet beans made very little growth during summer, but grew rapidly in early fall, climbing onto the trees to the extent of precluding their use as an orchard cover crop. A notable feature in connection with the experiment is the fact that the orchard cover crops grew on absolutely virgin soil, the land between the tree rows not having been cultivated or irrigated previous to the planting of the crops.

Variety plantings of citrus were made at the Salt River Valley Farm and the Yuma Date Orchard and Horticultural Station during the past spring; also plantings to determine the best methods of pruning the Washington Navel Orange and Marsh Seedless Grapefruit.

With the added land and equipment for citrus investigation that is now available it will be possible to broaden the citrus investigational work very materially next year.

NEW FRUITS

With a view towards testing the value of fruits other than the standard sorts, a number of the newer kinds that show promise are being tested at the Salt River Valley Farm, the University Farm, and at the Yuma Date Orchard and Horticultural Station. Among these are white sapote, jujube, feijoa, avocado, guava, paw paw, and hovenia dulcis. The sapote, feijoa, and jujube made a most satisfactory growth during the past season, having withstood a winter temperature of twenty degrees at Tucson. The avocado trees were badly acected by the hot, dry weather of summer and another attempt will be made to grow them by supplying temporary shade during the season of severest heat.

In this connection an introduction garden has been established at the Yuma Date Orchard and Horticultural Station where new varieties of fruits, vegetables, and ornamental plants from the Department of Agriculture and other sources will be tested.

OLERICULTURE

Effort was made to maintain an all-the-year family garden at each of the sub-stations except the Tempe Date Orchard, where soil conditions are not satisfactory for general gardening.

Best results along this line were attained at the Yuma Date Orchard and Horticultural Station where it was found possible to produce vegetables throughout the entire winter as well as a few during the hottest portion of summer. Among the less frequently grown vegetables that are being tested are roselle, Chinese cabbage, Chinese mustard, and chayote.

IRISH POTATO

During the year plantings of one of the standard varieties of potatoes, the Early White Rose, were made at intervals of every two weeks at the Yuma Date Orchard and Horticultural Station to determine the best time of planting. The highest yield was from plantings made the middle of January and the second highest yield from plantings made the first of February. November and December plantings were very promising until the plants were killed by a cold spell of weather in January.

Potatoes planted at Yuma during the latter part of the summer were a failure, the seed having rotted in the ground due to high soil temperature. However, the same variety, the Lookout Mountain, at Tucson gave promising yields for the season. Table IX shows the result of this test.

TABLE IX.—LATE SUMMER PLANTINGS OF THE LOOKOUT MOUNTAIN VARIETY OF POTATO

Planting date	Average yield per hill	Yield per acre
June 1	.24 lb.	3528 lbs.
July 6	.33 lb.	3857 lbs.
August 1	.32 lb.	4704 lbs.
September 16	.27 lb.	3969 lbs.

A variety test with some of the leading varieties of Irish potato was made at the Yuma Date Orchard and Horticultural Station. The yields secured in this test are shown in Table X. All the varieties were planted on the same date, February 5th.

TABLE X.—VARIETY YIELD OF IRISH POTATO

Variety	Average yield per hill	Yield per acre
Mammoth Pearl..........	1.00 lb.	14,508 lbs.
Early Six Weeks........	1.12 lb.	16,611 lbs.
Rural New Yorker.......	.79 lb.	11,539 lbs.
Earliest of All...........	.60 lb.	9,905 lbs.
Flagstaff Red	.70 lb.	10,613 lbs.
Producer.................	.53 lb.	7,8[illegible] lbs.
Early Rose	.50 lb.	7,438 lbs.
Bliss Triumph	.60 lb.	9,759 lbs.
White Rose	.65 lb.	9,672 lbs.
Downing	.75 lb.	11,157 lbs.
Burbank	.87 lb.	13,109 lbs.
Pride of Multanomah....	.37 lb.	5,586 lbs.
Snow	.83 lb.	12,465 lbs.
Hoosier	.22 lb.	3,163 lbs.

Storage tests as outlined in last year's report were continued in an effort to find a satisfactory method of carrying the spring crop of potatoes through the summer. Best results were secured from the method in which the potatoes were spread out thinly on the ground under an open shed, and next to this the method in which the potatoes were spread out in thin layers in slatted bins. The percentage of loss in the first-named method did not exceed 5 percent; in the latter method the loss was about 10 percent. Sound potatoes from these tests will be used for planting next spring. The potato studies will be broadened next year to include fertilizer and spraying tests in the potato districts of northern Arizona. Also seed potatoes produced in the northern part of the State will be tested for yield and quality in the other potato districts.

SWEET POTATO

Commercial storage tests with the sweet potato were conducted in which adobe houses were used as a means of storage. Two houses were utilized for the experiment, one constructed especially for storage purposes, and the other an old adobe converted into a storage house. Five thousand pounds of potatoes were placed in each house and an effort made to maintain a temperature of 85 to 90 degrees during the first two weeks of storage and 55 to 60 degrees during the remainder of the storage period. On the whole, the results were very satisfactory. In one house, where a uniform size potato was used and where the temperature was allowed to vary but little from the standard set, no spoilage whatever developed. In the other house, where the potatoes were not graded (extremely large and very small sizes being mixed together), a rather large percentage of spoilage resulted. While these tests will be continued, it is believed that, by the exercise of care in grading and handling and the regulation of temperature, the adobe house will prove a most satisfactory method of commercial sweet potato storage.

SPINACH

Cultural tests with spinach, as outlined in last year's report, were conducted at the Yuma Date Orchard and Horticultural Station which included variety tests, methods of planting and different planting dates. The results are shown in Tables XI and XX.

TABLE XI.—YIELD PER VARIETY WITH REGARD TO TIME OF PLANTING

Planting date	Varieties			
	Victoria	Savoy	Long Standing	Prickly Winter
Oct. 15...........	139 lbs.	212½ lbs.	140½ lbs.	169 lbs.
Oct. 29...........	89½ lbs.	127¾ lbs.	114½ lbs.	94½ lbs.
Nov. 12..........	68 lbs.	124 lbs.	109 lbs.	170½ lbs.
Nov. 26..........	27¾ lbs.	96½ lbs.	61 lbs.	131½ lbs.
Dec. 10...........	84½ lbs.	151 lbs.	105 lbs.	130 lbs.
Dec. 24...........	90 lbs.	204½ lbs.	117½ lbs.	176½ lbs.

TABLE XII.—YIELD PER VARIETY WITH REGARD TO METHOD OF PLANTING

Method of planting	Varieties			
	Victoria	Savoy	Long Standing	Prickly Winter
Level row........	155 lbs.	261½ lbs.	175 lbs.	322 lbs.
Furrow	200¾ lbs.	314¼ lbs.	266½ lbs.	286½ lbs.
Bed	143 lbs.	340½ lbs.	206 lbs.	263½ lbs.

TOMATO

Tests with twenty-six varieties of tomatoes were conducted at the Yuma Date Orchard and Horticultural Station with a view towards determining the bearing season and yield. The results are shown in Table XIII.

TABLE XIII.—VARIETY TEST WITH TOMATOES SHOWING BEARING SEASON AND YIELD

Variety	Bearing season	Season of greatest ripening	Yield per acre
June Pink	June 12-Aug. 1	July 5-July 23	37,338
Tex-Seed Black Land	June 16-Aug. 7	June 30-July 14	34,873
Burbank	June 24-Aug. 1	June 30-July 18	26,480
Acme	June 30-Aug. 16	July 5-July 18	24,767
Redfield Beauty	June 24-Aug. 7	July 14-July 25	24,592
Clark s Triumph	June 24-Aug. 16	July 9-July 13	24,342
Stone	June 30-Aug. 7	July 5-July 18	22,487
Chalk's Early Jewel	June 24-Aug. 16	July 5-July 14	22,225
Livingston's Coreless	July 5-Aug. 16	July 14-July 28	21,348
Truckers' Favorite	July 5-Aug. 16	July 9-July 18	21,336
Tex-Seed Beauty	June 30-Aug. 16	July 9-July 19	21,336
Texseed McGee	June 16-Aug. 16	July 30-July 14	21,336
Spark's Earliana	June 16-Aug. 7	July 5-July 16	20,446
Livingston's Globe	July 16-Aug. 16	July 16-Aug. 1	19,402
Bonny Best	June 24-Aug. 16	July 9-July 16	16,891
Trophy	June 24-Aug. 7	July 9-July 18	16,002
Golden Ponderosa	July 5-Aug. 16	July 14-July 28	16,002
Matchless	July 5-Aug. 16	July 18-July 28	15,897
Red Rock	July 5-Aug. 16	July 14-July 28	15,897
Ponderosa	July 9-Aug. 7	July 14-July 25	15,365
Earlibell	June 24-Aug. 16	July 5-July 9	12,157
Livingston's Dwarf Stone	June 30-Aug. 7	July 9-July 16	12,157
Dwarf Champion	June 24-Aug. 26	July 5-July 14	11,379
Phoenix Special	July 14-Aug. 16	July 16-Aug. 1	7,948
Early Detroit	June 30-July 25	July 9-July 14	6,078

ORNAMENTAL GARDENING

Plans have been prepared for beautifying the grounds at the different branch stations and execution of the designs begun at the Tempe Date Orchard, Cochise Dry-farm, Salt River Valley Farm, and Yuma Date Orchard and Horticultural Station. These plantings furnish opportunity for determining the adaptability of various species of shade trees, shrubbery and flowers to conditions in the different sections of the State. The new greenhouse and adjacent grounds on the University Campus will furnish additional opportunity for work in ornamental gardening.

MISCELLANEOUS

Considerable time was required of the Horticulturist in the general supervision of work at the Tempe Date Orchard and the Yuma Date Orchard and Horticultural Station as well as in starting the citrus investigational work on the Yuma Mesa. It was also necessary for both the Horticulturist and Assistant Horticulturist to spend a rather large portion of their time in the interest of horticultural extension. In addition to regular project work in extension service, numbers of trips were made to different parts of the State to assist in special field problems. More than five hundred letters were written in answer to inquiries concerning different phases of horticultural work.

Very valuable service was rendered the department during the year by the foremen of the different branch stations in the careful execution of work as outlined.

IRRIGATION INVESTIGATIONS

G. E. P. Smith. W. E. Code

In November, 1918, this office was strengthened by the appointment of W. E. Code as Assistant Engineer. The position had been vacant for eighteen months, owing to the Great War. In June, 1919, H. C. Schwalen was added to the staff in order to assist in the extensive investigations in the San Simon Valley and to carry on extension service work relating to pumping for irrigation.

THE CASA GRANDE VALLEY

Conditions have been favorable for continued study of the groundwater supply. Unusually heavy rainfall has aided in the investigations of recharge and the large acreage under pump irrigation, 5200 acres, has made possible definite conclusions on the effect of pumping on the groundwater table. The rapid development of the valley agriculturally has added interest in the conclusions to be drawn from these studies.

Surface runoff measurements have been made with more precision than in any previous year. The river discharges at Tucson for the year 1919 were 42,200 acre-feet for the Rillito and 28,700 acre-feet for the Santa Cruz. The discharge at Sasco was 57,200 acre-feet, 10,500 acre-feet of which was from the Robles Wash. The loss, therefore, by seepage between Tucson and Sasco was 24,200 acre-feet plus the flow from Canada del Oro and a few small tributaries. Of this flow, 6,800 acre-feet reached the Southern Pacific Railroad at Eloy and 7,900 acre-feet at Lirim and Maricopa, representing a loss of 42,500 acre-feet between Sasco and the railroad.

A large percentage of the water that passed Eloy did not reach the Gila River. On two occasions when floods of considerable magnitude passed Eloy the water did not reach to the main highway leading east from Casa Grande.

The Santa Rosa Wash which drains a large area to the south, debouches upon the Casa Grande Valley at a point 14 miles southwest of Casa Grande. The waters of this wash spread over the valley and the flow crosses the Southern Pacific Railroad near Maricopa. The flows are intermittent and usually of short duration, but it is thought that they have some value in replenishing the ground waters on the western side of the valley. During dry years the run-off is practically negligible.

The U. S. Indian Service, through the agency of an employee, has been keeping flood data at Cockleburr for several years. During 1919 there were three summer floods and one winter flood. It is estimated from the records that not over 6,000 acre-feet entered the valley and from records taken at the railroad culverts it is thought that about one-sixth of this amount passed the railroad.

Water table fluctuations have been greatest along the north margin of the valley, representing the extensive recharge due to floods in the Gila River. Considerable variations of water level have been found in the vicinity of areas irrgated by flood waters from the Gila, and some effects noted have been due to seepage from the Florence Canal. Some erratic fluctuations of the water table west of Casa Grande can be explained by the character of the buried topography, which includes a long flat hill of volcanic rock.

The depression of the water table due to pumping operations has been most marked between Casa Grande and the Casa Grande Ruins, the greatest being near the Tweedy and W. S. Prouty ranches. The average depression for the season was about one foot. The recovery during the fall and winter has been complete over about two-thirds of the area of depression.

A group of water-table records is shown in Fig. 4. The Vasquez well is situated about three miles south of Casa Grande, the Elliott well two miles west of Casa Grande, the Ward well just below the Florence reservoir, the Bigelow well near the center of the main pumping area, and the Munk well a mile south of the Gila River.

Some determinations of the quality of the well waters have been made for comparison with former records. In some cases the alkalinity has changed slightly, but in general the composition of the soluble contents has remained practically constant.

Progress has been made on the negotiations with the United States Department of the Interior with a view to storing and utilizing the floodwaters of the Gila River. It is hoped that the project of the United States Indian Service for building a diversion dam at Sacaton will be abandoned in favor of the proposed diversion dam fourteen miles upstream from Florence. The Sacaton dam would be very costly, would be difficult to maintain, and would serve a comparatively small acreage. The Florence dam would be only one-fifth as long as the Sacaton dam, would be tied to bedrock except for about 200 feet in mid-channel, and would serve the lands of both Indian and American farmers equally well.

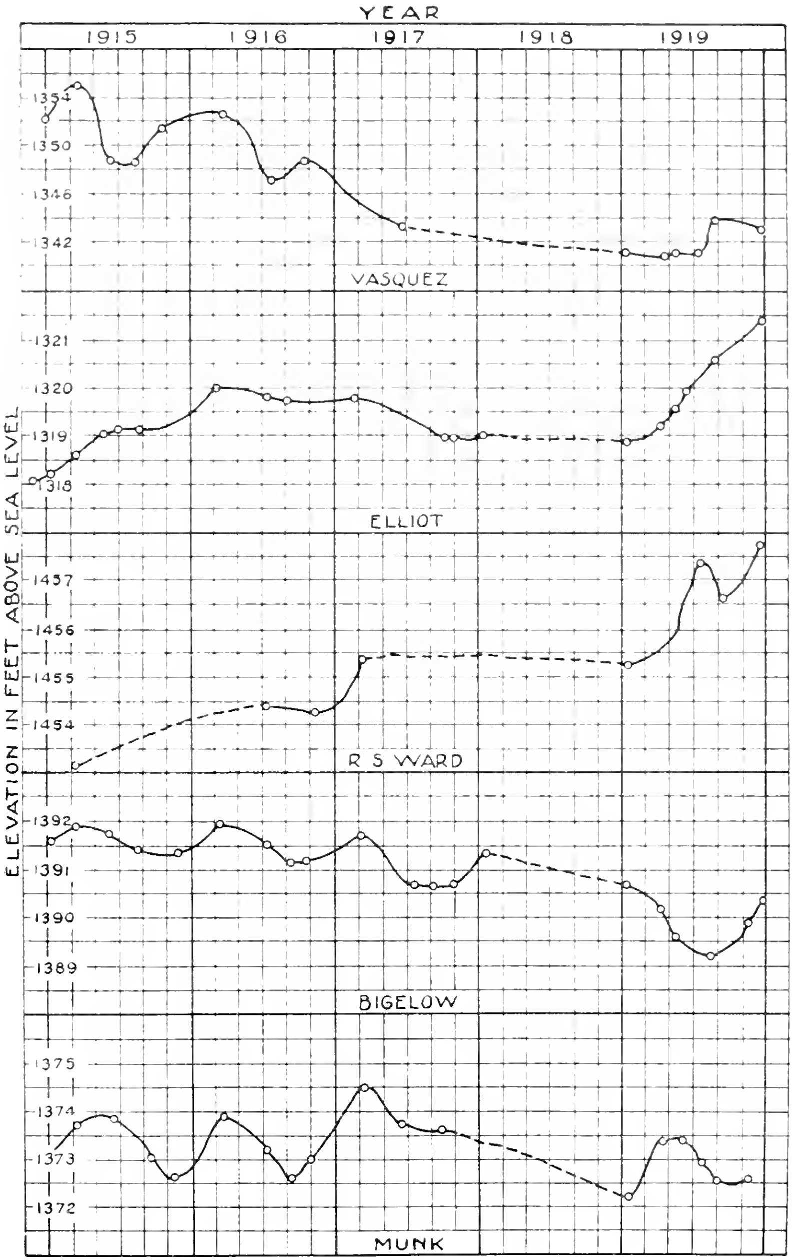


Fig. 4.—Water table fluctuations in the Casa Grande Valley over a period of five years. The dotted curves are for periods when no records were obtained.

The stream flow records to 1917 have been published in previous reports. Table XIV completes the record to 1920.

TABLE XIV.—RUN-OFF RECORDS FOR SANTA CRUZ AND RILLITO RIVERS, 1917, 1918, AND 1919

Month	Santa Cruz at Tucson	Rillito near Tucson	Santa Cruz at Sasco	Culverts near Eloy	Culverts near Lirim	Culvert at Maricopa
1917						
January	0	1,720	262	0	0	0
February ...	0	274	0	0	0	0
March	0	8	0	0	0	0
April	0	0	0	0	0	0
May	0	0	0	0	0	0
June	0	0	0	0	0	0
July	8,500	5,110	19,800	.....	362	528
August	10,500	2,840	11,200	455	...	172
September ..	9,410	643	8,290	454	0	0
October	0	0	0	0	0	0
November ..	0	0	0	0	0	0
December ..	0	0	0	0	0	0
TOTAL ..	28,500	10,595	39,552	909	362	700
1918						
January	0	0	118	0	No record	...
February ..	32	7	0	0	No record	...
March	14	*7,820	0	0	No record	...
April	0	0	0	0	No record	...
May	0	4,200	0	0	No record	...
June	78	488	0	0	No record	...
July	225	147	915	182	No record	33
August	4,620	7	5,610	279	No record	423
September ..	0	0	1,050	0	No record	...
October	22	39	0	0	No record	...
November ..	0	6	0	0	No record	...
December ..	79	5	106	4	No record	...
TOTAL ..	5,070	12,779	7,799	465		456
1919						
January	0	13	0	0	0	0
February ...	0	815	0	0	0	0
March	0	332	0	0	0	0
April	0	658	0	0	0	0
May	0	0	0	0	0	0
June	0	0	0	0	0	0
July	15,500	31,000	37,900	4,920	1,510	6,600
August	9,920	4,160	12,300	1,470	1,360	3,960
September ..	2,190	467	2,210	84	0	0
October	0	0	312	0	0	0
November ..	592	2,010	3,790	292	1,700	†
December ..	480	2,770	726	46	1,770	†
TOTAL ..	28,682	42,235	57,238	6,812	6,340	....

*Estimated.
†No record.

THE SAN SIMON VALLEY

By special act of the Fourth Legislature, an appropriation was made for water supply investigations in Cochise County. The largest item in the appropriation is for an artesian test well in the San Simon Valley; and inasmuch as the artesian water supply is closely related to the other sources of supply, it seemed wise to concentrate the investigations in that valley until the principal problems were solved.

The artesian wells of the valley have been visited, and the pressures and discharges have been measured for comparison with previous measurements. Attention has been given also to the shallow-well water supplies. The valley and surrounding mountains have been searched for reservoir sites, and the two best locations so far found have been surveyed with a view to their use as storage reservoirs.

In order to study the surface run-off, gaging stations have been established on San Simon Creek, and on six of the creeks issuing from the Chiricahua Mountains.

The drilling of the artesian well has been deferred, partly in the hope that the well of the U. S. Oil & Refining Co. would progress rapidly and would indicate the formations likely to be encountered in the State test well, and partly in the belief that the price of well casing would be reduced. Specifications for the test well have been prepared and bids for drilling the well will be asked at once.

THE STATE WATER CODE

As a sequel to Circular No. 11 of the College of Agriculture, Circular No. 26, entitled "Water Storage and the Water Code," was published in December, 1918. This circular pointed out the available lines of irrigation water supply development in Arizona, and emphasized the dependence of future development on the adoption of a water code similar to the codes of the other irrigated states.

A state water code bill prepared by this department was introduced in the Fourth Legislature, and its provisions and purposes were explained in detail to the members of the Legislature. The bill was passed on March 13, 1919, and is now in full effect. The most important feature of the law is the provision for the determination of all existing water rights, taking an entire watershed at one time, and the fixing of titles of these water rights, so that every water user may know his exact status with respect to every other water user. The establishing of these water rights makes it possible to determine the extent of the unappropriated floodwaters and to design engineering works for storage. Proposals for private undertakings and for federal projects will no longer be confronted with the impossibility of determining the extent of the available water supply, and several large projects may be expected to go forward rapidly.

The state water code, in addition, makes it necessary for appropriators to obtain a permit from the state water commissioner before diverting water from a stream. The effect of this provision is to protect those now using water in their rights. No water user with established rights need fear that some new settler or project will divert his water to other lands. The commissioner is given authority with police powers to distribute the waters of the State to those entitled to use them. Plans for dam and canal structures must be submitted to the commissioner for approval, and he is given authority to examine and inspect the construction, with a view to securing safety of life and property on the lands below such structures.

A special appropriation is provided for the adjudication of water rights in the Gila River watershed.

CEMENT PIPE

The results of the investigations on cement pipe made during the past three years are now available in Bulletin 86. This treatise covers not only the manufacture and characteristics of cement pipe, but also reports of tests, analysis of pipe failures, discussion of applicability of cement pipe to various uses, and the design of pipe lines and pipe-line structures.

DURABILITY OF CEMENT PIPE

Since the publication of the bulletin, the author has had the opportunity to participate in the testing by the U. S. Bureau of Standards of eight-inch cement tile of twenty different varieties that had been buried in a drain in alkaline soil near Yuma for six years. In most cases four tile of a series were tested. The tile were excavated and were tested to destruction immediately in an external pressure machine to determine the loads required to break the tile. The broken segments were then examined for evidence of injury by the alkali. Other specimens of the same series had been removed from the ground and tested in 1914, 1915, and 1916. The tests of 1919 showed practically the same or increased strength as compared with the earlier tests and in no case was there evidence of any disintegration. However, there was a marked difference in the appearance of the fractured surfaces, the more porous tile appearing damp or wet and showing more or less alkali salt in the fracture, while the denser tile were dry and absolutely free from any signs of alkali. The densest and strongest tile were those that had been mixed with quaking or wet consistency, and the tests have established definitely that drain tile for strongly alkaline soil should be mixed wet. One series of tile had been dipped or painted with cement grout; the grout was intact in its original condition. Tar coating was less effective than the grout, and ferrous sulfate in the mixing water was shown to be of no value. Both hand-tamped and machine-made pipe were among those tested, and both classes showed definitely that dense concrete is not affected by alkali. This conclusion is substantiated by information received concerning tests on similar series of drain tile buried in alkali soil in other Western states and tested by the U. S. Bureau of Standards.

It can be stated, then, that hand-made drain tile of wet consistency*, or high grade machine-made pipe is entirely safe for drainage projects in Arizona. The reason why such pipe should be used in preference to clay tile is because of the great saving in cost.

USE AND WASTE OF IRRIGATION WATER

Bulletin 88, under the above caption, was published in May, 1919. It is the result of observation and study relative to methods of irrigation during the past fifteen years. It discusses the useful function of irrigation (transpiration), and classifies the various losses to which irrigation supplies are subject, offering many suggestions for reducing the losses to a minimum.

The efficiency of irrigation is defined as the ratio of that portion of the water actually utilized by the crop to the total quantity applied to the land. It is the farmer's province to make this ratio as high as possible.

The bulletin was written particularly for those districts in Arizona like the Salt River Valley where the water table has risen to dangerously high levels, and for the pump irrigators, whose water supplies are so costly that the water must be conserved to the utmost limit.

THE CONTINENTAL RUBBER PLANTATION

The report, on the basis of which the rubber plantation was located at Continental, near Tucson, was made by the Irrigation

*See Bulletin 86, Arizona Experiment Station, page 91. Much cement pipe of this class is being made in the Salt River Valley at the present time.

Engineer in 1916. Since that time the Irrigation Engineer has designed the general layout for the 4000 acres of irrigable land, the water-supply development, the distribution system, the works for flood protection, and various minor agricultural engineering works. This connection has provided the opportunity for demonstrating many ideas advocated by the irrigation department, and has made possible the preparation of Bulletin 86, which is the first general treatise on cement pipe.

WATER SUPPLY FOR YUMA MESA EXPERIMENT STATION

A water-supply system for the irrigation of the Citrus Investigations Station on the Yuma Mesa has been designed, and all material required has been ordered. Much care has been given to making this an ideal system; and, according to the custom in the past in connection with water-supply development on Experiment Station farms, a description of the system will be made a matter of record.

The water supply is derived from the east main canal in the Yuma Valley and is elevated to the Mesa by pumping through a long pipe line. Power is available from the Somerton transmission line by means of a branch line one mile in length. An Allis-Chalmers direct-connected pumping unit, consisting of a 5 inch, Type S, double-suction pump and a 40 horsepower, 440-volt, 3-phase, 60-cycle, 6-pole motor will be set in a dug pit 45 feet from the canal and slightly lower than the water level in the canal, so that the pump will always be primed. The switchboard and starting box will be on the ground floor above the pump. The suction pipe is of 8 inches diameter and there will be an 8-inch gate-valve on each side of the pump. The combined efficiency of pump and motor is guaranteed to be 63 percent. The over-size motor is required by the location in a pit and in a hot climate.

The pipe line to the Mesa is 1050 feet long. Standard spiral steel pipe with flanged joints was first selected, but later the design was changed to use redwood machine-banded stave pipe. The steel pipe would have several advantages, ease of installation, freedom from troubles, and high salvage value, but the stave pipe is of lower first cost and will give direct opportunity to study the behavior and life of this type of construction. On account of the short supply and high cost of steel, it would be of great moment if the characteristics of wood pipe were such that it could be recommended for water lines, particularly those under high head or subjected to water hammer, while for lines under low head, cement pipe is by far the most advisable to use. The pipe line is 10 inches in diameter and the head due to friction will be less than eight feet. A check valve is to be placed in the line 135 feet from the pump.

At the edge of the Mesa the water will be delivered through a circular standpipe into a 14-inch cement pipe and will flow by gravity to the citrus orchard.

WATER TANK AND TOWER

The subject of an elevated water tank for the Mesa Experiment Farm has been studied, and plans and specifications for a tank have been prepared.

PLANT BREEDING

G. F. Freeman, W. E. Bryan, E. H. Pressley

ALFALFA

Alfalfa studies during the past year have been confined, first, to the field plots one-fourth acre in size; second, to plot rows, each of which was planted from seed taken from a single mother plant; and, third, to a study of variation from the recognized type in both Hairy Peruvian and the common types.

Of the twenty field plots of variety tests at the Salt River Valley Experiment Farm, four were selected for future increase and testing by farmers in different parts of the State, in order to test their yields in the different alfalfa sections. By referring to last year's report (p. 157) it will be seen that the French variety (No. 41) was the highest in yield of these plots, and that the yields of its summer cuttings were relatively high. For these reasons No. 41 (French) and a plot each of Hairy Peruvian, Algerian, and Turkestan alfalfas were saved last summer for seed. The other sixteen plots of this series were discontinued. A rather light seed crop was matured on these plots last season, but on the day (August 24) they were cut for seed, a severe storm occurred and so scattered and mixed the varieties that none of the seeds could be used. For this reason another season at least will be necessary to obtain the final seeding for this series.

Of the 61 pedigreed races grown in rows last season, 36 were selected for increase and testing in field plots. These selections were made on the basis of yield and quality of hay. The quality of the hay was based on a high percentage of leaves and relatively small size of stems. Sufficient data on these characters have been accumulated to permit a number of the best selections to be made and seed will be taken from these next season.

In connection with alfalfa seed certification in this State, the question of type of plant has become important. For example, in a so-called Hairy Peruvian field, are the various forms usually found the result of normal variation within a pure line, or do these forms come about as a result of mixtures or of cross-pollination? In an attempt to secure data which will answer this question, the following line of work has been planned and begun at the Salt River Valley Experiment Farm.

Beginning on the west side of Border E 68, ten rows of common alfalfa extending the entire length of the border were planted; next, ten rows of Hairy Peruvian with seed coming from a field in the Yuma Valley certified as commercially pure; next, one row each of No. 41 (French), Siberian (35), Turkestan (27), Algerian (24), Arabian (22), Common (17), Variegated (11), one selection from Hairy Peruvian (39), and one row of Baltic. The remaining four rows of the border were planted to Hairy Peruvian from the same source as the ten rows mentioned above.

Work with these alfalfas has been planned as follows: Each variety will be thinned to one typical plant in a place, with two feet of space between the plants in the row. Some of the plants of each variety will be covered with screen wire cages during the flowering stage in order to secure self-pollinated seed. Seeds will also be taken from plants of each variety which have grown in the open and been exposed to cross-fertilization by insects. The seed grown from self pollinated plants under cages and seed from plants grown in the open from each of the above varieties will be planted in adjacent rows for the purpose of studying the variation of plants grown from self-pollinated seed and that of plants from seed grown in the open. This comparative study will be made through at least three seed generations. In addition to furnishing data for the determination of the extent of cross-pollination by insects in an open field of alfalfa, those pure races from self-pollinated plants will furnish good material for the study of variation within the same pure lines of alfalfa. It is believed that pure lines may be established by the time three successive seed generations have been taken from self-pollinated plants.

BEANS

Work with beans during the past year was confined to testing a number of varieties introduced by the Department of Agriculture. Eighty-nine varieties from foreign countries having climatic conditions more or less like those of Arizona were planted. Owing to the small space available for these plantings, only a single short row could be planted to each variety. Along with these foreign introductions were planted the Pink, Bates, Bayou, Hansen, and Pinto beans. The entire lot was planted in the early spring and came into bearing about mid-summer. The yield from each of the native beans was very low, and in the case of the Bayou and Hansen no pods at all were set. On the other hand, some of the introductions set numerous pods which were well filled. Eleven varieties from these introductions were selected for further testing.

WHEAT

Work with wheat during the past year has included a comparative field test of fifteen hybrid races and six pure races, including Early Baart, two selections from Arizona 39, 36-51, Kanred, and a Macaroni selection (1 E-88); and the selection and the growing of the second plant generation of the Turkey-Sonora cross which was made in the spring of 1917.

The comparative field tests of hybrid and pure races were located at both the Yuma Horticultural Station and the Salt River Valley Experiment Station. Table XV gives the yield of hybrid and pure races.

TABLE XV.—YIELD OF HYBRID AND PURE RACES OF WHEAT

Number	Size of plot	Yield per acre
	Feet	*Pounds*
Hybrid 615	12.5 x 596	2772
Hybrid 650	12.5 x 596	3515
Hybrid 625	12.5 x 596	2678
Hybrid 713	12.5 x 596	2731
Hybrid 1088	12.5 x 596	2099
Hybrid 1090	12.5 x 596	2807
Early Baart	16 x 576	2921
Arizona 39 (5)	16 x 576	1883
Arizona 39 (9)	16 x 576	2545
36-51	16 x 576	2993

The yields of some of the hybrids exceeded that of the Early Baart. These hybrids have been produced from a cross between Sonora and Algerian Macaroni wheats made in the spring of 1913. This was the first year these hybrids have been grown on a field scale, and while the yield is rather high and the baking tests (see Table XVI) show a good quality of gluten, there appeared in each of these plots a number of different types of plants. For this reason these wheats at present would not be satisfactory for general field planting, and it will be necessary to repedigree each of these hybrids by head selections.

Early Baart, as usual, gave a rather high yield. No. 36 51, a Turkey selection, also produced well. Mr. C. J. Wood, foreman of the Salt River Valley Experiment Farm, placed a sample of this wheat (36-51) on display at the recent Kansas City Dry-Farming Exhibition, where it took second prize as a hard winter wheat in competition with all hard winter wheats displayed. The Arizona 39 wheats were low in yield this year. This is partly due to a severe attack of smut which destroyed nearly half the heads.

Milling and baking tests were made from these wheats and the results are given in the following tables:

TABLE XVI.—BAKING TESTS*, CROP OF 1919

Arizona Exp. Station No.	Hybrid 615	Hybrid 625	Hybrid 713	39A-5	Patent flour Kansas hard	St. grade flour Kansas hard
Loaf No.	13	14	15	16	17	18
Absorption	64.3	65.0	65.7	60.3	58.3	59.1
Time of fermentation	194	192	209	215	241	235
Maximum volume of dough	2050	2075	2050	2000	2175	2125
Oven rise	5.25	4.05	4.50	3.05	5.15	4.60
Weight of loaf	525	527	540	525	510	517
Volume of loaf	1980	1830	1900	1740	1910	1880
Color of crumb	92	93	93	91	91	93
Texture of crumb	94	92	94	87	95	95
Bread quality factor	95	92.16	94	88.3	94.16	94
Rank	3	10–11	5–6	16–17	4	5–6

*The baking test, analyses of wheat and flour, and milling tests reported in the following tables were made by the Milling Department of the Kansas State Agricultural College.

TABLE XVI.—*Continued*

Arizona Exp. Station No.	34-16	36-51	39A-5	39A-9	Wizard	D. F. Sonora
Loaf No.	1	2	3	4	5	6
Absorption	62.0	59.7	59.7	60.0	57.7	63.7
Time of fermentation	212	194	220	206	220	219
Maximum volume of dough	2100	1875	2050	2225	1800	1975
Oven rise	5.5	5.35	4.55	4.05	2.45	3.85
Volume of loaf	2005	1920	1875	1850	1680	1760
Weight of loaf	507	524	508	513	506	526
Color of crumb	94	92	92	92	89	91
Texture of crumb	96	93	93	92	92	90
Bread quality factor	96.75	93.67	92.90	92.16	88.30	89.67
Rank	1	7	9	10–11	16–17	15

TABLE XVI.—*Continued*

Arizona Exp. Station No.	Irr'g'd Sonora	Kanred	1E-88	H-650	H-1088	H-1090
Loaf No.	7	8	9	10	11	12
Absorption	63.3	61.3	71.7	63.3	70.0	63.3
Time of fermentation	210	214	200	196	199	188
Maximum volume of dough	1925	2125	1975	2000	1925	2075
Oven rise	3.6	4.25	4.45	5.05	1.35	5.45
Weight of loaf	514	522	556	520	550	522
Volume of loaf	1825	1860	1810	1920	1545	2015
Color of crumb	92	91	92	92	87	94
Texture of crumb	92	92	92	92	80	95
Bread quality factor	91.75	92	91.5	93.3	81.4	96.58
Rank	13	12	14	8	18	2

TABLE XVII.—ANALYSIS OF WHEAT, CROP OF 1919

Arizona No.	Moisture	Ash	Acidity	Phos-phorus	Protein
34-16	9.47	1.908	.423	.395	14.65
36-51	9.17	1.674	.396	.343	17.54
39A-5	9.92	1.782	.401	.376	17.78
39A-9	9.45	1.304	.297	.244	13.68
Wizard	9.24	2.078	.495	.439	13.11
D. F. Sonora	8.24	1.940	.531	.409	16.36
Irrigated Sonora	8.58	1.530	.351	.294	13.38
Kanred	8.28	1.706	.459	.370	14.48
IE-88	8.24	1.728	.414	.371	18.84
Hybrid 650	8.63	1.516	.441	.336	15.29
Hybrid 1088	8.08	1.886	.522	.434	16.07
Hybrid 1090	8.68	1.776	.468	.416	15.39
Hybrid 615	8.69	1.484	.396	.318	16.27
Hybrid 625	8.67	1.672	.495	.388	15.36
Hybrid 713	8.68	1.766	.518	.408	15.45
39A-5 Mesa	9.50	1.672	.450	.380	10.86

TABLE XVIII.—MILLING OF WHEAT, CROP OF 1919

Arizona No.	Test weight	Temper-ing	Flour %	Feed %	Scouring loss %	Milling loss %
34-16	62.3	5.0	65.88	33.92	1.48	#1.28
36-51	60.0	6.5	70.28	31.72	1.84	#3.84
39A-5	52.4	5.0	65.84	34.24	2.60	#2.68
39A-9	57.2	5.0	68.76	31.60	2.08	#2.24
Wizard	58.7	5.0	66.16	34.04	1.52	#1.72
D. F. Sonora	60.6	5.0	59.12	41.12	1.56	#1.08
Irrigated Sonora	63.8	5.0	68.72	32.04	1.48	#2.24
Kanred	61.0	7.0	74.00	27.52	1.92	#3.44
1E-88	59.6	7.0	69.32	32.36	2.00	#3.68
Hybrid 650	61.1	5.0	65.32	34.44	2.00	#1.76
Hybrid 1088	63.3	7.0	75.28	26.28	1.96	#3.52
Hybrid 1090	62.1	5.0	62.92	36.68	2.28	#1.88
Hybrid 615	62.3	5.0	65.68	35.12	1.72	#2.52
Hybrid 625	61.3	5.0	59.08	40.92	2.20	#2.20
Hybrid 713	63.0	5.0	62.52	38.56	1.92	#3.00
39A-5 Mesa	60.0	5.0	70.88	30.44	1.04	#2.36

TABLE XIX.—ANALYSIS OF FLOUR, CROP OF 1919

Arizona No.	Moisture	Ash	Acidity	Phosphorus	Protein	Wet gluten	Dry gluten
34-16	12.35	.408	.176	.092	12.01	36.77	12.98
36-51	12.56	.448	.144	.103	15.62	53.17	15.57
39A-5	12.85	.430	.176	.098	15.49	44.92	15.22
39A-9	12.26	.428	.126	.076	11.60	37.12	11.78
Wizard	12.16	.448	.131	.084	10.97	40.65	12.37
D. F. Sonora	11.18	.640	.167	.114	14.39	50.79	16.15
Irrigated Sonora	11.40	.496	.144	.099	11.51	38.17	12.50
Kanred	12.47	.482	.153	.106	12.67	42.45	13.15
1E-88	12.55	.706	.212	.154	17.10	53.49	17.20
Hybrid 650.	11.72	.482	.162	.094	12.65	38.39	13.10
Hybrid 1088.	12.52	.834	.270	.183	14.08	43.67	14.05
Hybrid 1090.	11.50	.402	.171	.103	12.80	42.57	14.94
Hybrid 615.	11.92	.448	.176	.105	14.28	47.07	15.72
Hybrid 625.	11.35	.544	.180	.108	12.63	44.15	14.69
Hybrid 713.	11.61	.472	.162	.109	13.00	45.24	15.04
39A-5 Mesa.	12.24	.496	.140	.097	9.46	27.84	9.73

The second plant generation of the Turkey-Sonora cross gave some very interesting results last season. One of the main objects sought in this cross is to produce an early wheat having the gluten quality of the Turkey. In other words, an attempt is being made to place the Turkey wheat grain on the early Sonora plant. Of the 4910 second generation plants which were grown, 66 were as early as the Sonora. Of these 66 plants, 12 had grains all as hard as the Turkey parent. These 12 hard-grained plants and other later hard-grained segregates will be used as the foundation stock for establishing an early hard wheat. In these hybrids there seems to be a marked positive correlation between fertility, as indicated by number of grains per spikelet, and earliness. These plants were all grown in rows one foot apart and four inches between plants in the row, so as to provide the same amount of space per plant. Table XX shows this correlation.

CORRELATION (r) BETWEEN THE RATIO OF GRAINS TO SPIKELETS AND DATE OF FIRST HEAD IN 366 F_2 PLANTS, FAMILY 1771-1. CROP 1919

DATE OF FIRST HEAD

RATIO OF GRAINS TO SPIKELETS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	
0.25																							1	1		1	3
0.35								1								2			1			3					7
0.45													1	1		1			2			1	1				7
0.55									1			1	2			2			5		2	1					14
0.65														2		1			4								7
0.75											2		1	1		1		2									7
0.85				1			1	1		2	1	2	3	3		4		2	2		1						23
0.95								1	1	1	3	1	3	1		3		1	2		1	1					.19
1.05									1	1	5	3	2			6		1	1		1						21
1.15								2	2		10	2	6	6		6		2	2								38
1.25						3		3	4	1	1	2	1	2		3		2	3								25
1.35				1	3		1	2	1		4	5	5	1		1		1							1		26
1.45					2		3	1	2		1	3	2	2		2											18
1.55			1		1	5	3	2	6	3	2	3	3	2		3		1	2								37
1.65			1	1	5	1		4	1	3	4	7	3														30
1.75			3	1	2	2		3	2	2	2	1	2	1		2											23
1.85	1				2	1	2	2		4	4	2	4	2		2											26
1.95				1		2	2	3	4		1	2	1														16
2.05					2	1		1	1			2	2														9
2.15							1		1	2		2															6
2.25																											
2.35				1	1						1																3
2.45																											
2.55						1																					1
Totals	1		5	6	18	16	13	26	27	19	41	38	41	24		39		12	24		5	6	2	1	1	1	366

DATE OF FIRST HEAD

Coef. of Var. $= 37.993\% \pm 1.0749$

Mean $= 11.989 \pm .1605$

Std. Dev. $= 4.555 \pm .113$

RATIO OF GRAINS TO SPIKELETS

M. $= 1.258 \pm .0163$

Std. Dev. $= 0.461 \pm .0115$

C. $= 36.883\% \pm 1.0362$

r, $= .5846 \pm .0232$

POULTRY HUSBANDMAN

FRANCIS R. KENNEY

The Poultry Department was created February 1, 1919, and has been in existence only during the last five months of the present fiscal year. The Poultry Husbandman has spent most of his time in getting the poultry plant on the campus stocked with desirable birds and in securing equipment and housing facilities for the proper functioning of the department. The poultry yards and buildings and all of the brooders, incubators, and other equipment and appliances have been prepared for use.

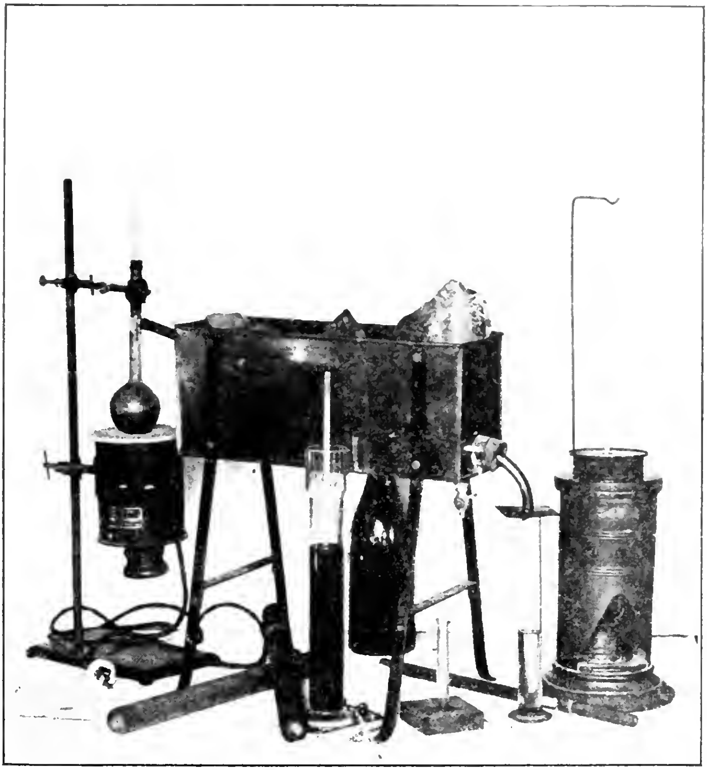
A few good breeding birds have been purchased and several hunred chicks hatched out. There are now on the plant several good pens of Single Comb Rhode Island Reds, Barred Plymouth Rocks, Single Comb White Leghorns, and Single Comb Anconas.

The five months during which this department has existed this year have been used almost entirely in preparation for the next year's work, and no projects have been completed.

The University of Arizona College of Agriculture

Agricultural Experiment Station

Bulletin No. 92



Distillation apparatus, flash-point tester, and hydrometer in the laboratory of the Agricultural Experiment Station.

THE SUPPLY, THE PRICE, AND THE QUALITY OF FUEL OILS FOR PUMP IRRIGATION

By G. E. P. Smith

Tucson, Arizona, November 15, 1920

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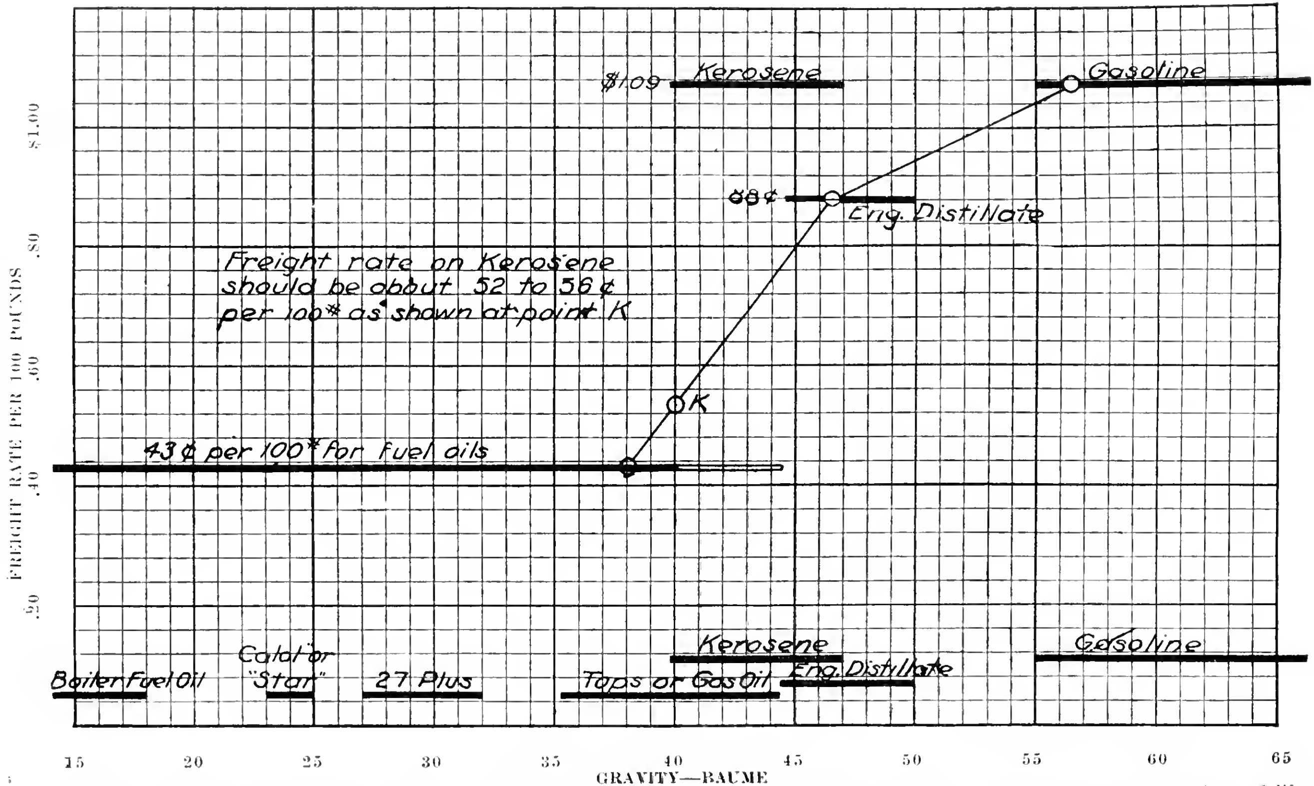

Fig. 1. Diagram showing relationship between gravity of various petroleum oils and the present freight rates from southern California refineries to Tucson. It is obvious that the rate on kerosene is too high relatively, from the standpoint of volatility and danger in transportation, as well as from the standpoint of value.

The Supply, the Price, and the Quality of Fuel Oils for Pump Irrigation

By G. E. P. Smith

INTRODUCTION

The year 1920 has been an unfortunate one for pump irrigators of Arizona. With high prices for fuel oil, with unusually light rainfall, and with dull markets and low prices for crops, there has been little or no profit in most cases.

The Arizona Agricultural Experiment Station has served in a consulting capacity for pump irrigators for the past fifteen years, and has studied the related problems of groundwater supply, wells, power, and fuel oils. This bulletin is the result of studies of fuel oils. The studies are not complete, but the publication is hastened in the hope that it will be available in time to be of service in contracting for the fuel oil supply for 1921.

HISTORY OF PUMP IRRIGATION IN ARIZONA

Although pumping water for irrigation was common in California before 1900, only a few unsuccessful attempts had been made in this State, the earliest being at the Hartt ranch in Pima County in 1889. The development in California was due to the stimulus of an abundant supply of gasoline at five to seven cents per gallon, while Arizona had no available fuel oil supply at low cost.

Between 1900 and 1910, many small pumping plants were installed, most of them in Pima County; but they were confined to shallow-water areas, the pumping lift being from ten to forty feet. For many of these plants the power was derived from wood-burning steam boilers; a greater number employed gasoline engines burning engine distillate No. 1, which was an excellent fuel, almost the equivalent of the gasoline of today. Electric power was used in a few plants. These early plants were described, with tests of their operation, in two bulletins of this Station.* The distillate plants possessed a great advantage over the steam plants in the cost of attendance, an item which in the small steam plants outweighed the difference in fuel costs. In 1910 it appeared that the most feasible power for pumping was to be obtained from central power plants burning boiler fuel oil.

The available gasoline supply was quickly absorbed by the rapid increase in the number of automobiles and motor trucks. The standard of commercial gasoline was reduced from 68° Baumé to 60° Baumé and consequently the supply of engine distillate or its quality had to be reduced. California engine distillate dropped from 55° B. to 50° B., and has since been reduced as low as 43°. California pump irrigators have continued to use the refined distillate to the present day, partly because of their comparative proximity to the refineries and consequent light freight charges.

In 1912, it was found that the cheap, abundant distillates of 37° to 44 Baumé gravity, costing 2¾ cents per gallon in carloads, f.o.b. Los Angeles and nearby points, could be utilized for fuel by slight modifications of the fuel mixers of the standard gasoline engines. The modifications consist of preheating the air or a part of the air and introducing a small amount of hot water into the fuel mixture. Strong, high-tension magnetos, also, have a great advantage over low-tension magnetos or wet batteries in burning this fuel, and another aid to good combustion that has been used to some extent is lengthening the connecting rod so as to increase the compression pressure. The cheap distillates were obtained at first by "topping" heavy crudes in order better to fit them for use in locomotives; this process gave a low flash point to the "tops". Later, somewhat similar oils were obtained as straight cuts in the refining process. These products were called tops or gas oil, and were adopted widely in Arizona. Being unrefined, they have always taken the same freight rate as boiler fuel oil and other unrefined fuel oils. Under the stimulus of the cheap tops or gas oil, pump irrigation has grown by leaps and bounds since 1912. It is probable that the number of plants has increased ten-fold and the amount of water pumped a hundred-fold. The area of pump irrigation has spread

*Bul. 49, Cost of Pumping for Irrigation, and Bul. 64, Groundwater Supply and Irrigation in the Rillito Valley, Chapter VII. Since 1910 two additional bulletins for pump irrigators have been issued: Bul. 71 on Care and Operation of Gasoline Engines and Bul. 74 on Oil Engines for Pump Irrigation and the Cost of Pumping.

to include some lands where the lift is a hundred feet and more, and it is probable that the average pumping lift for Arizona is now over fifty feet, with consequent large power requirements and heavy investments for wells and machinery. If gas oil suitable for the type of pumping engines now in use ceases to be available at moderate cost, hundreds of pumping plants will be put out of service, at least until some other and cheaper form of power can be obtained. If pump irrigation becomes impracticable from any cause, it will result in the abandonment of hundreds of improved farms.

THE PRICE ADVANCE OF FEBRUARY, 1920

Until the present year, tops or gas oil has been obtainable from California refineries in ample quantity, and at very low prices. In December, 1919, contracts were being made for gas oil of 38° to 40° B. gravity at 5¾ cents per gallon. As late as January 22, a twelve-month contract was made at 6½ cents. About the end of January, without warning, gas oil was withdrawn from the market. Those communities which had not arranged contracts for the year's supply became alarmed and made strenuous efforts to protect themselves. In March one community sent a representative to California to find oil. After a long search he contracted with a jobber for 60 carloads at 11 cents a gallon; only seven carloads were obtained on this contract, however, and by mistake they were billed as kerosene, making the freight charge about six cents per gallon.

Thus the price was practically doubled in one advance. Additional advances during the summer brought the price to 14½ cents in August. But the seriousness of these advances is not measured in cents. A motorist uses only one or two gallons of gasoline per day, and hence a slight advance in price of gasoline is not a crucial matter. A farmer with a 1000-gallon pump requires from 50 to 150 gallons per day, depending on his vertical lift, and an advance of eight and a half cents per gallon in price means an additional expense of $4 to $13 per twenty-four hours. Allowing the freight charge of 34½ cents per 100 pounds and allowing a vertical lift of 60 feet, the cost of gas oil per acre irrigated, for land in alfalfa or any double-cropped land, is increased from $6.75 to $13.40 per year. The cost of pumped water is necessarily high. To the cost of fuel there must be added the fixed charges of depreciation, interest, and taxes; also, the cost of lubricating oil, attendance, and repairs. There are many ranches from which the net returns in the past have been meagre, and with the increased cost of irrigation the balance sheet can show only a loss. During the past summer many ranchers have irrigated much less than was needed, on account of the high cost of fuel, and the lack of water was reflected in the low crop yields.

The cause of the advance in price of gas oil is not understood clearly. The production of crude oil in California in 1919 was 101,-000,000 barrels, and the production in 1920 has been approximately the same amount. The amount of gasoline derived from the crude oil in 1919 (by conventional atmospheric refining methods) was approximately 418,000,000 gallons, which is almost exactly ten percent of the crude oil produced.

During the present year some of the largest oil companies have added largely to the gasoline supply by a process of "cracking" heavier distillates—a process of increasing the yield of low boiling hydrocarbons by heating the distillates while under high pressure. The plan of the largest companies, it is understood, is to crack the "cut" between gasoline and kerosene to make gasoline, and to crack the cut between kerosene and lubricating oil to increase the supply of kerosene. If the smaller companies follow this plan, as is probable, it will do away with all California fuel oils suitable for the ordinary farm engines, except kerosene and gasoline.

Price advances in boiler fuel oil and in gasoline, also, occurred last winter, but these advances were of small moment. In reply to an inquiry by the Railroad Commission of California, the Standard Oil Company stated that considerations of profits did not enter into their price advance; that their action was designed to protect the fuel oil and gasoline supply by stimulating production and by checking consumption.

Increased demand doubtless was the largest factor in the price advance of gas oil. However, the largest refiners have not manufactured any gas oil for some time, and the small refiners are not equipped to convert gas oil into products of higher value. The law of supply and demand is very sensitive if it can account for the price advance of 150 percent, mostly in three winter months.

FREIGHT RATES ON FUEL OILS

For many years the rates from southern California refineries to Tucson were 83 cents per 100 pounds for gasoline and kerosene, 66 cents for engine distillate, and 30 cents for unrefined oils. As a war measure, 4½ cents per hundred was added to each of those rates. Recently all freight rates in the Western district have been advanced 25 percent. The new rate for fuel oil is 43 cents. Fuel oils are figured at 7¾ pounds per gallon, and refined oils at 6.6 pounds. The advance from 30 cents to 43 cents is, therefore, an increase from 2⅓ to 3⅓ cents per gallon, an increase of minor importance when compared with the change in price at the refineries. Some fuel oil users protested against the recent advance in letters to the Arizona Corporation Commission, but interstate rates are outside the jurisdiction of that Commission.

There is excellent reason for lowering the rate on kerosene. Kerosene is equivalent to a medium or low-grade tops for use in internal-combustion engines, and in case tops is unobtainable, as was threatened several times during the past year, kerosene could be used, at least to mature crops already planted. Rates on the various oils should be governed in part by the values of the oils; the value of kerosene at shipping points is about one-half that of gasoline. The application of the same rate to both oils is an anachronism, dating back to the time when kerosene was the more valuable of the two oils. Furthermore, gasoline has a flash point below, and kerosene has a flash point above, ordinary air temperatures, so that gasoline is dangerous to transport, while kerosene and gas oils are not. The relative densities and freight rates are shown graphically in Fig. 1. In that figure kerosene is shown to be of the same density as gas oil, while its freight rate is equal to that of gasoline.

FUEL OILS AVAILABLE IN ARIZONA

At the present time (November) the fuel oil market is much easier than it was in midsummer. This is due in part to the slowing down of industries, and in part to the diminution in export, caused by the present rates of exchange. These causes are transitory; the shortage next summer probably will be as great as it was this year.

Arizona is situated much closer to the California oil field than to any other, and freight rates are lower from the west than from the nearest field to the east. Nevertheless, since midsummer of 1919 most of the gasoline shipped into Arizona has come from Texas, Oklahoma, and Wyoming, and during the past year most of the kerosene has come from those fields. Also beginning in August, considerable gas oil for pumping engines has been shipped from Ranger, Texas, to Casa Grande, Elfrida, McNeil, and Willcox.

With gasoline retailing at 35 cents, engine distillate at 23, and kerosene at 23½, these oils are too costly for pump irrigation. The demand for gasoline will increase still further with the increase in number of automobiles and motor trucks, but with the installation of more plants for cracking lower grade distillates into gasoline, the supply is likely to keep pace with the demand for some years. The recent opening of government oil lands in California to lease, also, is helping to increase the supply.

Despite the frequent lurid accounts of newly discovered cheap fuel substitutes, it can be stated that neither denatured alcohol nor any other substitute can compete in price with mineral oil.

TOPS OR GAS OIL

This is the fuel oil on which the present development of pump irrigation, exclusive of a few localities in which electric power is available, has been founded. The consumption of gas oil in Arizona for pump irrigation in 1920 has been approximately 1,300,000 gallons. Had not a large part of this been contracted in advance, the cost to Arizona farmers would have been over $200,000.

The California gas oils of six years ago were of about 44° B. gravity, but the quality has been forced down gradually to 38°. During the war some 37° oil was used, but it was found unsatisfactory in most engines.

In March, 1920, shipments of gas oil running between 35° and 36° were received at Higley, Casa Grande, and Tucson, and samples were forwarded to the Experiment Station for testing. These oils were burned with the greatest difficulty, engines smoked badly and carbonized rapidly. One experienced operator stated that five gallons of gasoline were required to warm up a cold engine, though previously with a good gas oil only a gill had been used. It was stated, also, that three gallons were required to do the work of two gallons of good gas oil. Owing to the vigorous protest, no more oil of so poor quality was shipped at that time, but later in the summer several shipments of unsatisfactory gas oil were received. Many farmers who obtained oil from these shipments purchased gasoline also to mix with the gas oil.

It is believed that the California supply of gas oil will be further reduced by the extension of plants for cracking, and there is no indication that the price will be lower next season than it has been in 1920. Furthermore, the quality of gas oil that is now being offered to inquiring local dealers and consumers is inferior to the quality on which buyers have insisted in the past.

While the farmers of Arizona were installing engines designed to burn tops, it was not foreseen that a method would be found for converting California tops into gasoline, and that the supply would be required for that purpose.

At present, only one company in Texas is shipping gas oil to Arizona. This oil is proving satisfactory to the users in the Casa Grande Valley and in the Sulphur Spring Valley. Its gravity is 42° B. and its flash point about 110° F. The present price is 10½ cents at Ranger, Texas. The freight to Tucson is 4.5 cents per gallon and the rate to Casa Grande is 5.1 cents. If additional refiners can be interested in the Arizona market, the Texas oils may prove to be a more reliable supply than the California oils. It is essential to keep both supplies available.

The Whitewater Cooperative Co. at Elfrida, Arizona, purchased a carload of Ranger, Texas, gas oil of 38° B. gravity, in the belief that this oil would be of the same quality as 38° California tops. None of the engines in the vicinity could burn the oil and much of it is still unsold. Texas oils should be 4° B. higher in gravity than California oils in order to have the same volatility. This rule is quite general and is important; it should be followed by purchasers of North Texas oils.

The relation of gas oil suitable for electric-ignition engines to the other petroleum fuel oils is illustrated by the accompanying chart showing the refining process at an Oklahoma refinery. The processes at other refineries are similar in principle but differ in details.

		Gravity °B.	Percent of crude.
Crude......	Crude naphtha..........	53.5	14.4
	(Cut at 46°B.)		
	Kerosene stock..........	40.6	17.0
	(Cut at 37°B.)		
	Heavy gas oil..........	35.0	18.0
	(Cut at 32°B.)		
	Lubricating stock..........	30.1	19.5
	(End of distillation)		
	Residuum	16.5	28.0
	Loss		3.1
			100.0

In the above process, the crude oil is first separated into five parts. As heat is applied, the crude naphtha is distilled first. When the gravity of the distillate is down to 46° B., the valves in the piping are changed and the distillate is run into the crude kerosene stock tank. When the gravity is down to 37° B., the distillate is "cut" to tanks holding heavy gas oil. (This is not the gas oil ,or tops, that is familiar to pump irrigators throughout Arizona.) The crude naphtha is refined again, yielding gasoline, and a residue which is piped to the kerosene stock tanks. The kerosene stock is distilled again, yielding a distillate which is treated with acid and becomes kerosene, and a residue which is piped to the heavy gas oil tanks.

It is the crude kerosene stock which approximates California tops in quality.

TWENTY-SEVEN PLUS OIL

Considerable California oil of a grade called "27-plus" has been brought into Arizona for use in semi-diesel engines. One sample of 27-plus found at Phoenix tested 32° B. The largest refiners, however, have ceased to make this oil, and it is found to be an excellent oil for cracking. Also, the semi-diesel engines have not become popular on account of their higher cost, their unsuitability for farm conditions, and their need of close attention. Therefore, 27-plus is not an oil of importance. Its present price f.o.b. Tucson is 15 cents per gallon. It appears possible that a large supply of cheap gas oil of about 34° B. is to be available in the North Texas field. This oil is approximately equivalent to 27-plus from California. If it is probable that such a supply will be available for many years, it will tend to increase the use of semi-diesel engines, in which case those engines having compression pressures of about 250 pounds per square inch should be preferred to the ordinary semi-diesel engines having compression pressures less than 200 pounds.

24 BAUMÉ OIL

Oil of 24° B. was formerly sold under the trade name of Star Fuel Oil; it is now called Calol diesel engine oil, at least by one company. It is the ideal oil for engines of the diesel and Hvid, or Brons, types, with the exception of small Brons engines, less than 20 horsepower, for which gas oil is used. While such engines can burn heavier oil for short periods of time, it is wiser to use 24° oil for steady opera-

Footnote. As this bulletin goes to press, there is increasing evidence that Arizona will have to look to Texas for fuel oils for the coming year. Prices of petroleum oils in Texas have been greatly reduced, while in California there has been no decrease in prices.

tion. The price of this oil is about \$2.80 a barrel (42 gallons) at California refineries and \$4.20 a barrel at Arizona main line points.

BOILER FUEL OIL

In the refining of asphalt base oils, the greatest bulk of the crude oil is left as boiler fuel oil after the more valuable constituents have been removed. In Arizona, boiler fuel oil is used almost exclusively as fuel for steam plants. It is tried occasionally in diesel and Brons engines, but it is poor judgment to use this oil in any internal-combustion engine. The gravity runs from 14° to 18° B. Its cost at the present time is about \$1.85 to \$2.00 a barrel (42 gallons) at California refineries, and \$3.40 a barrel in Arizona.

Much boiler fuel oil has been shipped into Arizona from Texas during the past two years, depending on the relative prices in Texas and California.

Mexican oil is received at Galveston and reshipped. It will be an important factor in steadying the price of Texas oils. Mexican crude is heavy, usually about 14° B., and contains a very low percentage of light oils.

One disadvantage to the purchaser in buying heavy oil is the difficulty of handling it. A carload of 18° B. oil received recently at Casa Grande was so viscous that it required 98 hours of pumping to unload the oil, and the cost of unloading was over \$150. Had steam for heating the oil been available, the cost could have been reduced.

TESTS

The qualities of petroleum oils for which tests are applied ordinarily are as follows:

1. Gravity
2. Flash point
3. Burning point
4. Boiling range
5. Solidifying point
6. Sulphur content
7. Water and sand content
8. Thermal value

GRAVITY

There are two scales in use for expressing gravity, the Baumé scale and the standard decimal scale. In the former the gravity of pure water is taken at 10°, in the latter at unity, that is, 1.000. Gasoline in the Baumé scale is about 56° to 60°, in the decimal scale it is about .750, showing that gasoline is about three-fourths as heavy as water.

The gravity of oils is measured commonly on the Baumé scale. The formula for conversion is as follows:

$$\text{Specific gravity (decimal)} = \frac{140}{130 + \text{Baumé value}}$$

Specific gravity is obtained readily by means of a hydrometer, a small instrument costing one or two dollars. Each farmer or community of farmers should own one. A hydrometer with range from 35° B. to 70° B. is recommended, since this range includes gas oils, kerosene, and gasoline, and is found on one of the standard commercial hydrometers.

While taking the specific gravity, the temperature of the oil should be obtained also. A correction can be applied to reduce the specific gravity to what it would be at 60° F., the standard temperature. Approximate rules for this correction are as follows:

For gasoline, allow 1° Baumé for each 10° F.

For tops and similar oils of about 40° B., allow 1° Baumé for each 12° F.

For Calol diesel fuel oil and similar oils of about 25° B., allow 1° Baumé for each 15° F.

The correction is to be added to the reading of the hydrometer if the temperature of the oil is below 60° F. when tested, and subtracted if the temperature is above 60° F.

There has been considerable condemnation of the specific gravity test by some oil companies, on the ground that it does not show the fitness of an oil for engine service. The test is of great value, however, and it is the easiest test to make, and should be used generally. The ultimate and best test is the experience with an oil in actual service. So long as oils come from the same field, as, for example, the southern California field, then the average volatility, and the fitness of a shipment are indicated usually by the specific gravity. That is, having had experience with gas oils of various densities, a purchaser can take the specific gravity (and perhaps the flash point) and then know whether or not the oil is satisfactory. When oils come from an untried field, then further tests are necessary, either the distillation test or the test of actual service.

FLASH POINT

The flash point is the temperature at which vapor is given off in such quantity that it flashes when exposed to an open flame. The flash point indicates the ease or difficulty of starting a cold engine. A moderately low flash point, say below 115° F., is desirable for electric-ignition engines.

Many different patterns of apparatus are in use to determine the flash point, and the results obtained vary considerably. The Arizona Agricultural Experiment Station uses the Elliott or New York State tester, which is semiclosed.*

Large purchasers of oil, such as farmers' oil associations, should own and use a flash-point tester. There is an advantage in using the same type of testing apparatus as that used at the Experiment Station, inasmuch as comparisons can then be made with Experiment Station records.

BURNING POINT

The burning point is the temperature at which the "flash" becomes permanent. This point is obtained with the flash-point tester. After the flash point has been obtained, the temperature is raised further until the flash continues as a steady flame.

BOILING RANGE

The distillation or boiling-range test is made by heating the oil in a small still, and noting the temperature at which the first drop and successive fractions of the oil are carried over into the cup in which the distilled oil is caught. The U. S. Bureau of Mines† recommends that the temperature be noted for the first drop, and each successive ten percent up to ninety percent, and also for ninety-five percent and the dry point.

The American Petroleum Institute distinguishes between "dry point" and "end point" in the following manner. The dry point is usually stated to be the point at which the bottom of the distillation flask becomes dry, and frequently this is indicated by a puff of smoke leaving the bottom of the flask. The end point is determined by continuing the heating until the column of mercury (thermometer) reaches a maximum and then starts to recede consistently. For light oils, the end point, or maximum boiling temperature, can be obtained quite accurately and consistently. For heavy oils, not much dependence can be

*In a recent private communication from the U. S. Bureau of Mines, the Tag closed tester is recommended for oils having specified limits less than 150° F., and the Pensky-Martens closed tester for fuel oils flashing above 150° F. These instruments will be obtained and tried by the Experiment Station at once.

†Bureau of Mines Technical Paper 214, "Motor Gasoline; Properties, Laboratory Methods of Testing, and Practical Specifications."

placed on either the dry point or the end point, on account of the rapid cracking which occurs at high distillation temperatures.

The distillation test is undoubtedly the best index of the suitability of an oil as an engine fuel. It is difficult to make, requiring considerable technique, and only the largest buyers of oil can be expected to provide themselves with apparatus. The Experiment Station can make a limited number of tests for users within the State, when conditions justify the expenditure of time. In the Station laboratory a standard 100 c.c. Engler flask and electric heater are used. The thermometer belonging with the apparatus as received has an upper limit of 270° C. After some kerosenes had been run, another thermometer with a limit of 350° C. was secured. It is found necessary to provide the flask with asbestos insulation for oils heavier than gasoline.

The boiling range usually distinguishes between straight refinery gasoline and blends with casing-head gas or "cracked" gasoline.

SOLIDIFYING POINT

This is not of importance with ordinary light oils. Benzene, from coke ovens, however, despite its high volatility, freezes at a relatively high temperature, about 40° F.

With boiler fuel oil the solidifying point is important in the winter season, as steam coils are required to give the oil sufficient fluidity to flow in pipes.

SULPHUR CONTENT

Sulphur and sulphur compounds in oils are objectionable. Various tests for sulphur are in use in laboratories. One of the tests for sulphur in aviation gasoline is the evaporation to dryness of 100 c.c. of gasoline in a copper dish. The bottom of the dish must not be colored gray or black.

The presence of sulphur leads to corrosion and pitting, particularly of exhaust valves. Not over .20 percent should be allowed in gas oil, or .75 percent in diesel engine oil.

WATER AND SAND CONTENT

Sand from the oil wells and water are seldom found in light oils, but frequently in heavy oils. Obviously they are objectionable. They are detected easily in light oils, both water and sediment sinking to the bottom of a container. To make the separation in the case of boiler fuel oils, a centrifuge has been much used. If the oil emulsion is quite viscous or if great accuracy is required, the water content should be determined by distillation. For this purpose 100 c. c. of the oil is mixed with 100 c. c. of solvent, and the distillation is carried to a point where the water in the receiving cup cannot be further increased.

Salty water is very corrosive in diesel engines.

THERMAL VALUE

The thermal or calorific value measures the theoretic power in fuel. It is stated in British Thermal (heat) Units (B.T.U.) per pound of fuel. Each B.T.U. is equivalent to 778 foot-pounds of work. The thermal value is determined in bomb calorimeters.

Coal varies so widely in quality that determinations of the calorific value become almost a necessity. Petroleum oils, however, vary but slightly. California fuel oils have about 19,000 B.T.U. per pound. Although the calorific value per pound decreases with the density, this is overbalanced by the fact that oils are bought by volume and the weight of a unit of volume increases faster than the calorific value decreases. A gallon of gas oil has about 8 percent more potential power than a gallon of gasoline.

OTHER TESTS

Additional tests that are applied to gasoline are color, odor, and acidity. A test for acidity is to shake the residue after distillation with distilled water and to add a little methyl orange. For heavy oils tests are made for coke residue, free carbon, acid and alkaline content, resin, paraffin, and asphaltum. For lubricating oils the viscosity is of great importance, and is best made in an Engler viscosimeter.

California oils and most of the Texas and Oklahoma oils are of the so-called asphalt base type. Pennsylvania oils and much of the oil from the mid-continent field are of the paraffin base type.

TESTS OF FUEL OILS AT THE AGRICULTURAL EXPERIMENT STATION

During the early years of the use of gas oil very few tests were made, because the shipments were satisfactory to the users. Even the low gravity gas oils contained sufficient gasoline to give low flash points. Records of most of the early tests were not preserved. Since 1917 tests have been made on many oils, often at the request of the local dealers or the users. Specific gravity and flash and burning-point tests are listed in the accompanying table.

TABLE I. TESTS OF MOTOR FUEL OILS AT THE UNIVERSITY

Year	Oil	Source	Specific gravity	Flash point	Burning point	Remarks
			°B.	°F.	°F.	
1914	No. 1 Tops	Kellogg Oil Co.	32	93	120	
	2 "	"	39	108	135	
	" "	"	40	58	84	
	Tops	Union Oil Co.	40			
	"	"	27			
	Union Gas Oil	"	44.6			
	Special Gas Oil	Standard Oil Co.	44	59	77	
	Star Fuel Oil	"	24	195	245	
	Solar Oil	Texas Oil Co.	37.5	200	238	
	Kerosene		47	115		
1917	Star Fuel Oil	Casa Grande	24.3	154		
	Tops	Willcox	38.0			
	"	"	41.3			
	"	"	38.1			
1918	"	Rillito	37.5	159	182	
	"	"	37.9	146	161	
	Special	Tucson	43.5	84	90	
	Tops	University Farm	37.1	160	165	
	Gasoline	Standard Oil Co.	56.4			
	"	Texas Oil Co.	59.2			
	Engine Distillate	Standard Oil Co.	44.5			
	Gasoline	"	56.0			
	Kerosene	"	42.9			
	"	Union Oil Co.	43.0			
	Gasoline	"	55.0			
	Tops	University Farm	41.6			
	Engine Distillate	Union Oil Co.	45.5			
	Tops	Richfield Oil Co.	40.0			
	Gasoline	Standard Oil Co.	56.2			
	"	Union Oil Co.	55.6			
	Engine Distillate	Union Oil Co.	46.8			

TABLE I.—*Continued.*

Year	Oil	Source	Specific gravity	Flash point	Burning point	Remarks
			°B.	°F.	°F.	
	Tops	Tucson Transfer Co.	37.0			
	"	Higley	39.0	119	167	Wine-red
	"	University Farm	38.3	94	127	
	"	"	37.9	107	119	
1919	"	A. Steinfeld Co.	37.7	107	125	
	"	University Farm	38.7	100	138	
	"	Tucson Transfer Co.	37.0	107	126	
	"	"	38.1	95		
	"	"	37.4	108		
	"	"	37.9	103	127	
	"	"	41.5	104		
	"	"	40.0	90		
	"	Texas Oil Co.	35.9	94		
	"	Higley	41.0	72		Strong odor
	"	Tucson Transfer Co.	41.7	86		
	"	Texas Oil Co.	37.6	120		
	27-plus	E. R. Post Co.	31.0	194		
	Tops	Tucson Transfer Co.	38.3	96	104	
	Gasoline	Texas Oil Co.	58.9			
	"	Standard Oil Co.	56.1			
1920	"	"	56.0			
	Tops	Pacific Petr. Co.	35.5			
	"	Higley	35.6	135		Acidity-none
	"	"	35.7	134		Acidity-none
	"	General Petroleum Co.	35.2	142		
	"	University Farm	36.9	118		Reddish brown
	Kerosene	Texas Oil Co.	41.7			
	"	Standard Oil Co.	40.1			
	Tops	Tucson Transfer Co.	38.3			
	"	"	37.9			
	"	Higley	37.5	122		

TABLE 1.—*Continued.*

Year	Oil	Source	Specific gravity	Flash point	Burning point	Remarks
			°B.	°F.	°F.	
1920	Tops	Tucson Transfer Co.	37.8	90		
	Distillate	Continental	42.5	59		
	Gasoline	Standard Oil Co.	56.0			
	"	Phoenix	59.7			
	"	"				
	Gas oil	Tucson Transfer Co.	41.5	104		Acidity-none
	Kerosene	Standard Oil Co.	39.8	120		Acidity-none
	"	Texas Oil Co.	41.8	130		Acidity-none
	Gasoline*	Tucson	62.8			Acidity-none
	"	Texas Oil Co.	58.3			
	Kerosene	Union Oil Co.	40.8	109		Acidity-slight
	Gas oil	White Eagle Pet. Co.	37.0			Odor of CS_2
	"	Imperial Ref. Co.	44.5	Below 65	94	
	"	General Petr. Co.	37.8	90		Amber
	"	Imperial Ref. Co.		106	142	Yellow straw
	"	"		97	134	Amber
	Distillate No. 2	Ventura Ref. Co.	42.5	Very low		Deep amber Odor CS_2
	Gasoline	Wichita Falls	58.3			
	27-plus	Tucson Transfer Co.	28.1	183	210	Dark amber
	24-plus	Tuc. Gas Elec. Lgt. & P. Co.	23.0	217		Black
	Gas oil	Richfield Oil Co.	36.7	112	140	Light amber
	"	Imperial Ref. Co.	42.1	110	139	Light amber
	"	Imperial Ref. Co.	37.4	131	182	Light amber
	16°-18° oil	Gilmore Petroleum Co.	18.9			Black viscous
	27-plus	General Petroleum Co.	26.5	132	194	

*Mexican aviation gasoline.

Most of the oils tested were what might be termed regular as to color, odor, and other qualities. Occasionally a carload of freakish oil is received, and usually such oils give much trouble. As an example, a sample of oil was received from Higley in June, 1919, which had been shipped from the refinery as a "special fine oil". The oil had a flash point of 72° F. and a specific gravity of 41° B., but it possessed a strong odor suggestive of turpentine, and contained much flocculent material which settled slowly after shaking, flaky particles sticking to the sides of the bottle and more granular particles sinking to the bottom. The rancher who submitted the sample stated that repeatedly the feed-pump became clogged so that the engine could not get any oil, and a black deposit settled on the cylinder. He had tried filtering, but that "only held back the coarse stuff and let the dissolved" matter pass. The oil necessitated an undue amount of water with the charge, but, strangely, the exhaust was not smoky. With such apparatus as was available at the University at that time, a distillation test was run. The oil began to boil at 167° F. but no distillate was caught until the temperature reached 257° F., suggesting casing-head gas. At 347° F. 56 percent was distilled and at 446° F. 82 percent. Further heating yielded only a few drops of thick oil. The residue, about 18 percent, was almost black and contained solid particles. Upon mixing some of this residue with acetone, most of the solids dissolved, indicating asphalt. On examination twelve hours later, a thin coating resembling vaseline was found on the bottom of the beaker. This was probably paraffin. Upon mixing some of the residue with carbon bisulfid, most of the solids dissolved, leaving a small amount that appeared to be dirt. This oil may have been a product of cracking or it may have been a light-gravity distillate that had decomposed in storage, to which some improper heavy oil had been added so that it might be classified as fuel oil in shipment.

Another freakish oil, received in Pima County in September, 1920, tested 42.5° B. The flash point was very low, less than 59° F. But on distillation it was found to have a wide boiling range with a high end point, and in use it was very troublesome, causing engines to smoke badly.

During 1920 many oils have been tested for boiling range in the standard Engler apparatus described above. These tests have been made at atmospheric pressure of about 27.6 inches, which should cause the samples to be somewhat more volatile than if tested at sea level. Some selected boiling range curves are exhibited in figures 2 to 6.

In Fig. 2 are shown the boiling ranges of three gasolines. No 1 curve is for an aviation gasoline; No. 2 is for a sample from the yard of the Standard Oil Co. at Tucson; and No. 3 is for gasoline from the Texas Oil Company's yard at Tucson. Commercial gasoline has a boiling range of from 100° to 400° F., and about 50 percent is distilled at a temperature of 250° F.

Tests of three samples of gas oil or tops are shown in Fig. 3. No. 1 is high-grade gas oil, excellent for farm pumping plants and

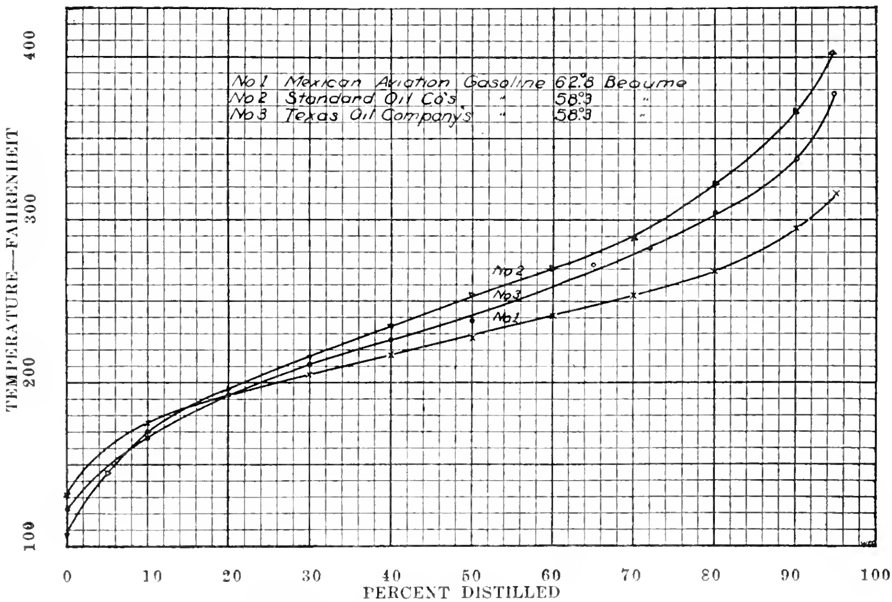

Fig. 2. The boiling ranges of three gasolines, one an aviation gasoline and the others commercial gasolines in use principally as automobile fuel.

usable for low-speed tractors; No. 2 is a low-grade tops which would be usable in large stationary engines that are in good condition; No. 3 is too low in volatility, and was found to be unfit for continuous service, even in large engines that were specially designed to burn tops.

No. 1 and No. 2 of Fig. 3 are shown as dotted lines in Fig. 4 as a background for three curves showing the boiling ranges of kerosenes. The Union kerosene is seen to be equivalent to a fair

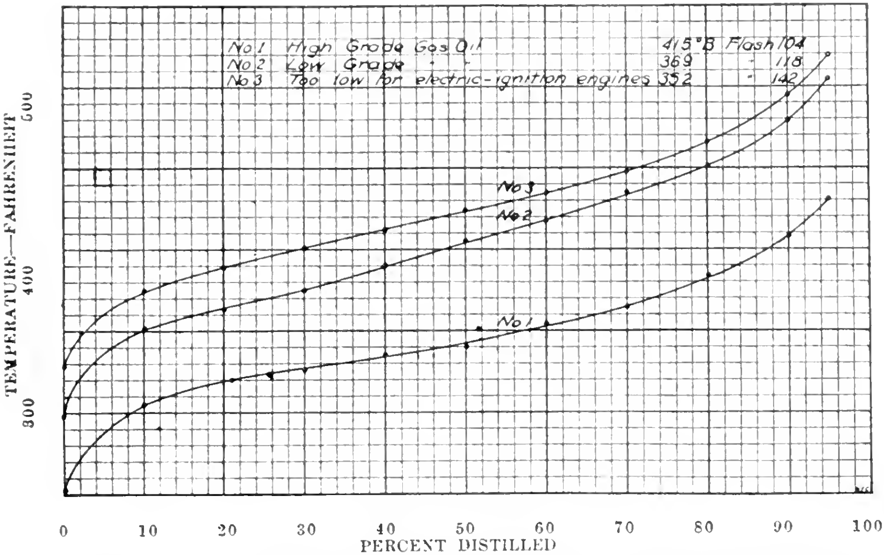

Fig. 3. The boiling ranges of three different shipments of California tops, or gas oil. The lowest curve represents the best of the three oils. The oil began to distill at 250° F. and the distillation was 50 percent complete when the temperature reached 343° F. Curve No. 2 represents a gas oil, the volatility of which was near the lower limit for the ordinary electric-ignition engines in common use thruout Arizona. No. 3 was an oil which was very troublesome in use.

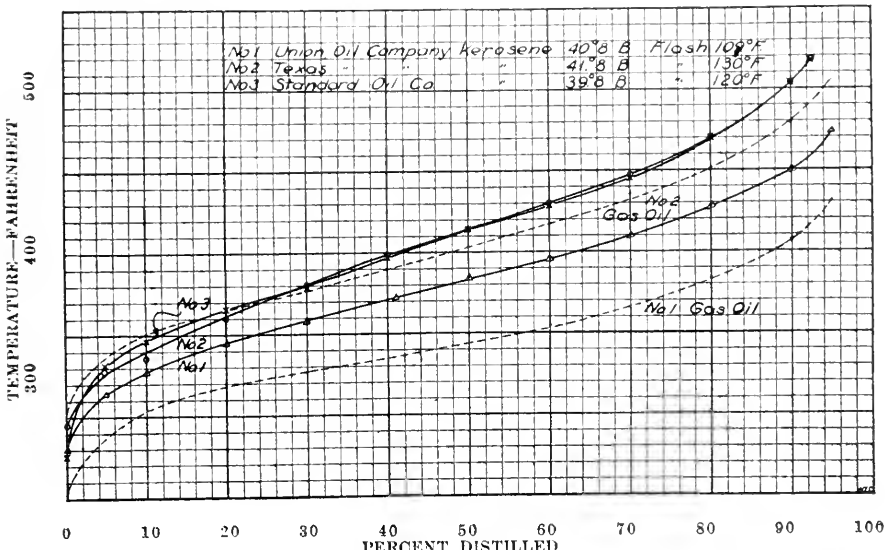

Fig. 4. The boiling ranges of three samples of kerosene. The curves of No. 1 and No. 2 gas oils are shown (in dotted lines) for comparison. The kerosenes in the Tucson market are approximately of the same volatility as a low-grade tops, or gas oil.

grade of gas oil, while the two other kerosenes are inferior to the low-grade gas oil. Any one of these kerosenes would be improved for engine service by the addition of from five to ten percent of gasoline. Of the three kerosene samples only the Union kerosene was from California. Both samples of gas oil were from California. It is apparent that oils from the east must be from 2° to 5° B. higher in gravity than the California oils in order to have equal volatility. This characteristic is confirmed by other tests.

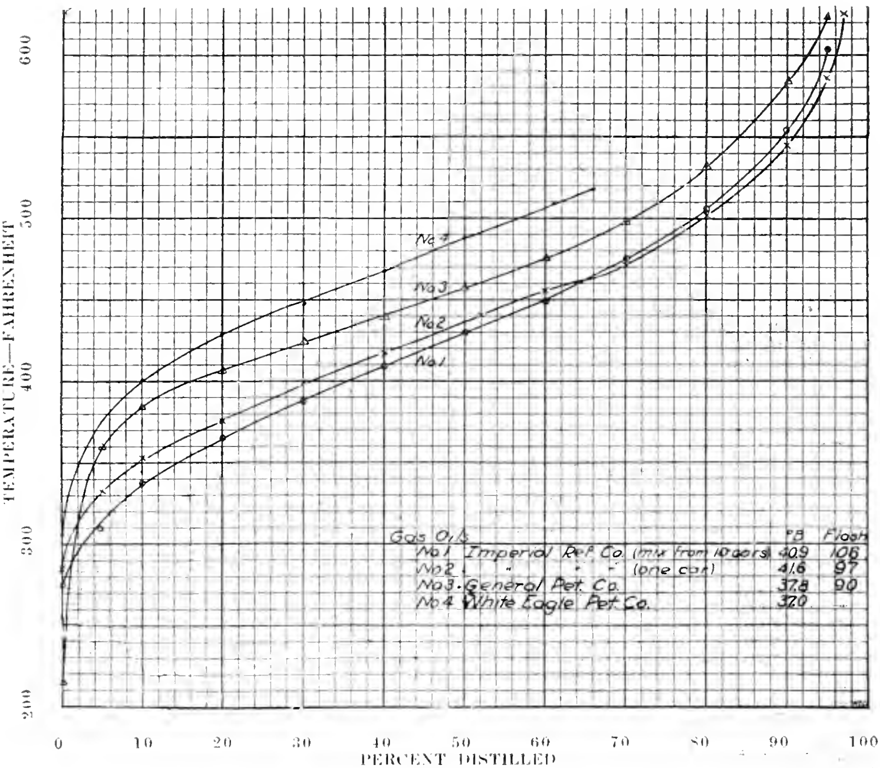

Fig. 5. The boiling ranges of miscellaneous gas oils. No. 1 and No. 2 were from Ranger, Texas, and were quite satisfactory in use in the Casa Grande Valley in 1920. No. 3 and No. 4 were unsuitable for electric-ignition engines. Therefore, No. 2 can be taken as a limiting line for fuel oils for engines of that type.

In Fig. 5 are shown the results of four tests: No. 1 and No. 2 samples were from the Imperial Refining Company, the oil being from a refinery at Ranger, Texas; No. 3 was a sample of unsatisfactory California gas oil; and No. 4 was a sample from the White Eagle

Petroleum Company's Augusta, Kansas, refinery. The Ranger oil is said to be giving fair service at Casa Grande. The California tops (Curve No. 3) was troublesome to the users. Only a sample of the Kansas oil was received. On account of the low volatility the offer of this oil was rejected by the local dealer. Doubtless the oil would be very troublesome to farmers. Comparing the curve of the Kansas oil with No. 3 curve of Fig. 3, the 35° B. California gas oil is shown to have much higher volatility than the 37° Kansas oil, despite its lower gravity.

Fig. 6 shows the corresponding curves for a 27-plus oil, a 24-

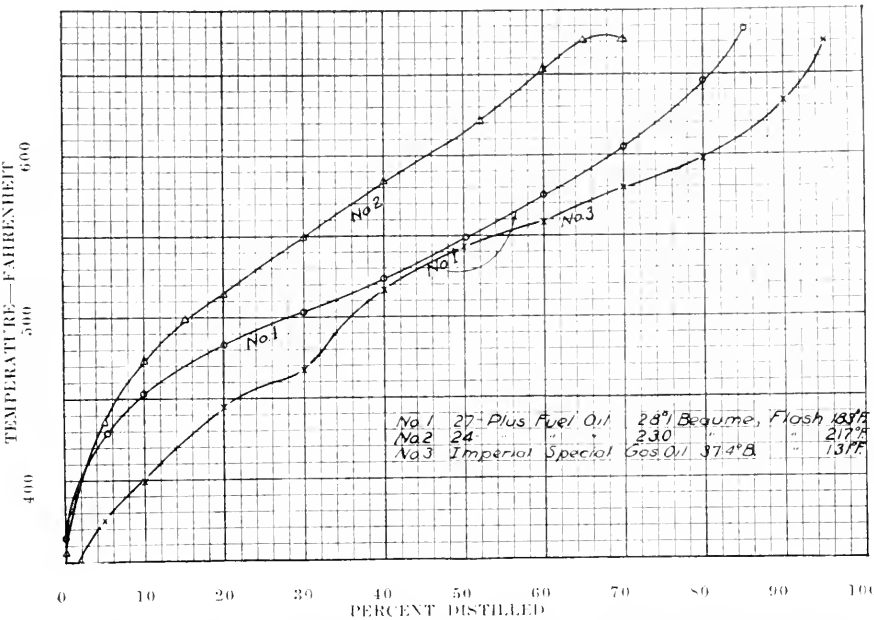

Fig. 6. The boiling ranges of 27-plus oil, 24-plus oil, and a gas oil that was made up to fill a special order from Elfrida, Arizona. The last named oil was found quite impossible to use in the internal-combustion engines in the vicinity of Elfrida.

plus oil and a very low grade Texas gas oil. The first is in use at some of the Tucson city pumping plants and the second is used in the diesel engines of the Tucson Gas, Electric Light and Power Co. The third was found at Elfrida, a carload of it having been purchased under a misapprehension; the cooperative company handling it was practically out of the oil business, since none of their customers purchased the oil but once.

A rough comparison between the light oils may be noted as follows: 50 percent of the gasoline distills before the temperature of 250° F. is reached; in the case of gas oils 50 percent distills below temperatures of from 350° F. to 410° F. and, for the kerosenes found in the Tucson market, the corresponding temperatures are 380° F. to 415° F.

A low initial boiling temperature indicates a low flash point, and is a feature tending to make easier the starting of a cold engine. A high end point indicates the presence of hydrocarbons lacking in volatility. An oil with a high end point is likely to leave unburned residues, which interfere seriously with lubrication, especially so in worn engines in which the compression pressures have been reduced.

SPECIFICATIONS

It is possible, from the above tests, together with a knowledge of the action of the various tested oils in use, to formulate specifications for gas oils. Such specifications must change necessarily from time to time. The following are suggested as a basis for gas oil contracts for the year 1921. They apply more directly to California oils. For Texas and Oklahoma oils, some modifications are required, including a higher Baumé limit and a wider boiling range. Additional knowledge of Texas oils will probably be obtained in 1921. Color and odor are not specified, being of little importance in the case of gas oil, although color deeper than light amber or an unusual odor should lead to the tests indicated in the specifications.

SPECIFICATIONS FOR CALIFORNIA GAS OIL FOR PUMPING ENGINES OF THE FOUR-CYCLE ELECTRIC-IGNITION TYPE

Specific Gravity

The specific gravity shall be above 38° Baumé.

Flash Point and Burning Point

The flash point shall not be over 120° F. and the burning point not over 150° F.

Acidity

The oil shall not contain a measurable quantity of acid, either free or liberated during evaporation.

Volatility

When distilled in a standard 100 c.c. Engler flask, by the method given in U. S. Bureau of Mines Technical Paper 214,

1. The temperature, when 20 percent is distilled, shall not be over 375° F.

2. The temperature, when 90 percent is distilled, shall not be over 500° F.

3. The temperature, when 50 percent is distilled, shall not be over 410° F., nor over the average of the temperatures for the 20 percent and the 90 percent points.

Foreign Substances

The oil shall not contain any water or sand or paraffin wax or free carbon, or any visible solid substance, and shall not contain over .20 percent of sulphur.

The general requirements for gas oil, as compared with gasoline and diesel engine fuel oil, are shown in the accompanying table.

TABLE 11. LIMITING REQUIREMENTS FOR CALIFORNIA FUEL OILS

Test	Gasoline	Gas oil	Diesel oil
Color, above	None	Amber	
Odor	Slight		
Acidity, not over	None	Trace	Trace
Sulfur, under	1 [illegible] percent	.20 percent	.75 percent
Water, under	None	None	1 percent
Solid substances	None	None	None
Specific gravity, above	56° B.	38° B.	23° B.
Flash point, under		120° F.	200° F.
Volatility:			
20 percent point, under		375° F.	
50 " " "	200° F.	400° F.	
90 " " "		500° F.	
80 " " "			600° F.
Asfaltum, under	None	Trace	25 percent
Solidifying point, under			32° F.

It is exceedingly important to contract for the year's supply during the early winter. Pump irrigators cannot afford to take any chances, either as to shortage in the supply or as to quality or price. The contract should be made before the ground is seeded, even better, before the ground is plowed. The farmer may contract with a responsible local dealer, but the dealers or associations of farmers should contract with oil refining companies. Contracts with jobbers are less dependable. Farmers' oil associations are advisable, since they eliminate one profit. It is a good investment for a farmer to install a 3000 or 5000-gallon tank, sunk in the ground, near his pump-house, and to fill it in the winter when work is slack. The winter is the dull season for the refiners, oil stocks are accumulating, and lower prices can be obtained.

There is a belief prevalent in some communities that oil becomes stratified in storage, the lighter oils rising to the top. To test this question, equal parts of gasoline and kerosene were mixed and allowed to stand twenty-four hours, when it was found that the upper third, the middle and the lower third were of exactly the same gravity. While unloading a car of gas oil, six samples were taken and tested. They were exactly the same except the last sample which represented the last oil to be drawn out. This was very slightly heavier than the others. In another test, a hydrometer jar was half filled with gas oil, and the remaining space was filled with gasoline very carefully so that the line between the two oils was distinct. Diffusion proceeded slowly, but was quite complete in two weeks. Several times when gas oil of poor quality has been distributed, farmers have found it necessary to purchase gasoline to mix with the gas oil. In such cases the gasoline should be piped to the bottom of the tank or some agitation may be required.

THE OUTLOOK FOR PUMP IRRIGATION

One purpose of this bulletin is to give a look ahead to pump irrigators and those contemplating new or enlarged pumping plants.

The reports of the U. S. Geological Survey show clearly that consumption of petroleum oil is increasing much faster than supply. Exports are decreasing; imports are increasing. In September, 1920, consumption reached the high record figure of 48,670,000 barrels, while the production stood still at 38,000,000 barrels. California is the largest producing state and Oklahoma stands second. For the Pacific states, it is stated in the Standard Oil Bulletin, the production for 1920 will be 101,000,000 barrels and the consumption is estimated at 110,000,000 barrels, the difference being drawn from reserve stocks, which were already very low at the beginning of the year.

It does not appear that fuel oils will be obtainable again at low prices, at least for some years. Can irrigators continue to pay present or increased prices? The cost of pumping depends, not only on the cost of fuel oil, but also on the lift and on the general efficiency of the plant. For the average individual pumping plant, the cost, on a basis of 80 acres under irrigation, in alfalfa or double-cropped, with gas oil at 18 cents a gallon, including fixed charges, is $18 per acre on a 40-

foot lift and $34 per acre on an 80-foot lift.* The cost for cotton is about three-fourths of these amounts, and for single-cropped land about one-half of the amounts. These figures state the cost of the pumped water and do not include the cost of distributing and applying the water.

It may be of value to compare these costs with the cost of water under gravity systems. For the year ended October 1, 1920, the charges on the Salt River project were $3.90 per acre for 3 acre-feet and $4.90 per acre for 4 acre-feet. The corresponding figures for the current water year are $6.40 and $7.40, including a special assessment. To these figures should be added about $4 per acre to cover the interest on the capital invested in the project. (In the case of the Salt River and other Reclamation Service projects this interest is remitted.)

It appears that pump irrigation, where the pumping lift (that is, the depth to water level plus the drawdown) does not exceed 40 feet, can compete measurably well with gravity irrigation. Undoubtedly pump irrigation with low lift can continue without interruption through a period of price depression in farm crops. But where the pumping lift is much above 40 or 50 feet, it is apparent that there must be a fairly wide margin of profit in farming to make pumping profitable with the common type of plant. This statement must be modified somewhat in the case of plants already in operation; for it may be better to operate a high-lift plant to a limited extent through a period of low prices, devoting the land to the higher-priced crops, than to suffer the loss of the investment already made. With citrus fruits, grapes, melons, lettuce and some other crops, the value of which is high, the cost of the labor of production exceeds the cost of irrigation; the cost of fuel oil, therefore, may not be the controlling factor in the case of crops of high value. With a wide margin of profit in farming, there is opportunity for pumping on high lift. There is a personal equation involved also; under the same controlling factors, some farmers who are thrifty and possess good business ability, and are not hampered by lack of capital, can show a profit where other farmers fail.

ALTERNATIVE SOURCES OF POWER

With gas oil at 18 cents a gallon, it is well to study the alternative sources of power for pumping.

*The basis and method of computing pumping costs, and the assumptions required, are stated in detail in Bul. 74 of this Station, and therefore are not repeated here.

Semi-diesel engines burn lower grades of fuel, the grade called "27-plus" being well adapted to that type. The outlook for an abundant supply of that grade of oil, however, is not encouraging, and the cost is not much lower than that of gas oil, not enough lower to offset the greater cost of the engines and of attendance.

Diesel engines are not built in small units. Large diesel engines are preeminent for central power plants, and central plants have been advised strongly for pump irrigation districts. Fuel oil for diesel engines costs five-ninths as much as gas oil and the consumption per unit of power is only one-half as much, but the losses in generator, transformers, transmission line, and motors aggregate about one-third of the power generated, and the additional investment in high-priced engines, electrical equipment, and transmission line is so high that the power economy of the central plant system is partly nullified. The convenience and ease of operation of motor-driven pumps is an important argument for the central power plant, but the experience in Arizona has been that the power goes off the line frequently, sometimes several times a day, and many transformers have been burned out during the summer rainy (and electrical) season. From the standpoint of fuel conservation and the public's interest therein, the diesel engine central plants should be built wherever the irrigated district is large enough to require 400 horsepower and is fairly compact in area.

For central plants, steam power cannot compete with diesel engines. Engines of the Hvid or Brons type have not been tested by the writer as to fuel economy and reliability, and no judgment can be expressed. It is hoped to investigate this type of engine in the near future.

Another possibility of great promise is that of hydro-electric power. Good water-power projects are not situated in close proximity to the pumping districts of southern Arizona. The Sabino Canyon project is the only one in Pima County that is known to be feasible. There is no proved water-power project in Cochise County or Yuma County. In central and northern Arizona there is much undeveloped water power. Power will be developed in connection with the San Carlos project, and one or two additional power plants can be built in the Gila Cañyon when the flow of water becomes equalized. Much more development is possible on the Salt and Verde rivers. In the Grand Canyon of Arizona there is almost unlimited latent water power; the length of a transmission line necessary to reach the Casa Grande-

Florence district is only 225 miles, and to reach the heart of the pumping district in Pima County 300 miles. At the present time the only cheap electric power in Arizona is the hydro-electric power of the Salt River Valley. It is believed that hydro-electric power in this State will be increased greatly as soon as capital becomes available at a moderate rate of interest.

CONCLUSIONS

SUPPLY

1. An adequate supply of gasoline and kerosene appears to be assured, at least for a year. Long time forecasts are impossible.
2. Engine distillate, gas oil, and twenty-seven-plus—the oils most used for pump irrigation—are being withdrawn from the market in California. A new source of supply, of much promise, is the north Texas and Oklahoma field.
3. Contracts for the year's oil supply should be made during the winter by each dealer and by each farmer.

PRICE

1. The price of gasoline will fluctuate constantly with changes in the demand and in the production.
2. Kerosene likewise will fluctuate in price, but it should be cheapened somewhat by a reduction in the present freight rates.
3. Gas oil is likely to remain at about the present price level. Any further increase is sure to curtail the volume of oil used in pump irrigation, and this will tend to maintain a stable price.
4. The price of diesel engine fuel will always approximate that of boiler fuel oil and will be considerably less than prices of the lighter oils.
5. Steam power plants, using boiler fuel oil or coal, cannot furnish power at a cost low enough for pump irrigation districts.

QUALITY

1. With increasing demand, the tendency is to force the quality downward in gravity to the heaviest grades that the respective engines can burn.
2. Fuel oils should be purchased with specifications. The specifications given on page 418 are recommended for California gas oils for the present. Specifications for diesel fuel oil can be based on the data in the table on page 419.
3. Heavy users of fuel oil should have testing equipment. The Agricultural Experiment Station will continue to make tests for farmers to a limited extent.

The University of Arizona
College of Agriculture

Thirty-First Annual Report

of the

Agricultural Experiment Station

For the Year Ended June 30, 1920

This Report constitutes Part III of the Annual Report of the Board of Regents of the University of Arizona, made in conformity to Article 4483, Title 42, Revised Statutes of Arizona, 1913.

Tucson, Arizona, December 31, 1920

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Ex-Officio

HIS EXCELLENCY, THE GOVERNOR OF ARIZONA

THE STATE SUPERINTENDENT OF PUBLIC INSTRUCTION

Appointed by the Governor of the State

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JOHN J. THORNBER, A.M....................Botanist
ALBERT E. VINSON, Ph.D....................Agricultural Chemist
CLIFFORD N. CATLIN, A.M....................Associate Agricultural Chemist
†HOWARD W. ESTILL, M.S....................Assistant Agricultural Chemist
S. W. GRIFFIN, M.S....................Assistant Agricultural Chemist
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W. E. CODE, B.S.C.E....................Assistant Irrigation Engineer
H. C. SCHWALEN, B.S.M.E....................Assistant Irrigation Engineer
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E. H. PRESSLEY, B.S....................Assistant Plant Breeder
RICHARD H. WILLIAMS, Ph.D....................Animal Husbandman
†C. U. PICKRELL, B.S.A....................Extension Animal Husbandman
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S. P. CLARK, B.S....................Assistant in Agronomy
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†N. L. HARRIS....................Extension Poultry Husbandman
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ETHEL STOKES....................Secretary Agricultural Experiment Station
F. H. SIMMONS........Foreman, Yuma Date Orchard and Horticultural Station
C. J. WOOD....................Foreman, Salt River Valley Experiment Farm
T. L. STAPLEY....................Foreman, Tempe Date Orchard
LESLIE BEATY, B.S....................Foreman, Prescott Dry-Farm
M. H. WOODY....................Foreman, Sulphur Spring Valley Dry-Farm
J. R. REED....................Foreman, University Farm

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*On leave.
†Resigned.

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Thirty-First Annual Report

ADMINISTRATION

D. W. Working

This report covers the first full year of service of the present administrative head of the College of Agriculture and Agricultural Experiment Station, and therefore furnishes occasion for a general statement of purposes and accomplishments. Such a statement, under appropriate headings, will appear in the following pages. This report also gives opportunity for the Dean and Director to acknowledge his obligations to the President of the University for hearty and effective support and to his associates for the fine spirit of cooperation they have manifested. It has been a pleasure and it continues to be a source of satisfaction to work with men and women who have so little need of leadership or direction. We have worked together in frank recognition of the fact that we are partners in doing the special part of the work of the University that has been intrusted to the College of Agriculture. We are in the service of the State of Arizona in order that agriculture may be advanced and that life in the country may be made more wholesome. This is done by those who teach in college classroom as well as by the men and women who with equal dignity and faithfulness carry the message of the College to the people of all parts of the State.

THE PURPOSE OF THE COLLEGE OF AGRICULTURE

THE ORIGINAL IDEA

As developed during a little more than a half century, the American College of Agriculture is a unique institution. It is a college to teach college subjects according to college standards; but it has a special command to "teach such branches of learning as are related to agriculture and the mechanic arts.". The words just quoted are from the Act of Congress of July 2, 1862, donating public lands to the several states to "provide colleges for the benefit of agriculture and the mechanic arts." The idea that the new kind of college was to have a definitely industrial bent was emphasized by the Act of August 30, 1890, which provided for "the more complete endowment and support of colleges for the benefit of agriculture and mechanic arts" established under the provisions of the earlier act. In 1907 another Act of Congress provided additional funds for "the more complete endowment and maintenance of agricultural colleges now established." This amendment contained a new item authorizing the colleges to "use a portion of this money for providing courses for the special preparation of instructors for teaching the elements of agriculture and the mechanic arts."

THE NEW IDEA

The new idea came as an afterthought. At this late date any one might say that the first need was to prepare teachers. But the colleges did prepare teachers, even before they had well learned the art of teaching the students who flocked to the classrooms and laboratories of the institutions of learning dedicated to the promotion of the "liberal and practical education of the industrial classes" in the various pursuits and professions. The work of systematically preparing instructors to teach the elements of agriculture in common and high schools has only fairly begun. The Arizona College of Agriculture gave the first systematic courses for this purpose during the college year just ended. But it has begun the work with the experience of other colleges as a guide, and there is good reason to believe that within a few years it will be able to prepare enough teachers to supply at least the high schools of the State with instructors in vocational agriculture.

THE RESEARCH IDEA

Before the colleges of agriculture had seriously thought of their special opportunity and duty to train men to teach agriculture, they became conscious of the fact that their own instruction was based on a very inadequate foundation of definite agricultural knowledge. It was realized that fundamental research should have preceded the organization of a system of agricultural colleges. Congress met the situation by passing the Act of March 2, 1887 (the Hatch Act), establishing "agricultural experiment stations in connection with the agricultural colleges of the several states, and appropriating $15,000 a year for the support of each." Nineteen years later this act was supplemented by another (the Adams Act) appropriating an equal amount. Under these acts the Agricultural Experiment Station, which forms an organic part of the University of Arizona College of Agriculture, was organized and continues to do its investigational work.

The Legislature of Arizona has liberally supplemented the appropriations made by Congress, and the result has been that the present Director of the Experiment Station was able to take up a work well supported. The work done in the past has more than justified the liberality of the State and is accepted as a promise of continuing generosity on the part of the State.

THE EXTENSION IDEA

When the Colleges of Agriculture seemed to be well organized to teach their students and to do the research work necessary to keep college teaching abreast of accumulating facts and principles, it was keenly realized that the demands of agricultural people were not being met. In truth, the original purpose of the Act of 1862 was being accomplished only in part. Education was being promoted; high-grade research was in progress; publications were being sent to a limited number of people; college and station men were lecturing at farmers' institutes as opportunity offered; and, on the whole, very valuable results were being accomplished. But the colleges were not reaching their special constituency as effectively as seemed desirable. Then came the agricultural extension idea. This called for teaching by special methods wherever a sufficient number of persons might be found willing to receive instruction; it included the enlargement of the plan of giving information and instruction by means of publications of a more popular character than those previously issued by the colleges and experiment stations; it made necessary the organization of special classes; the holding of meetings to discuss a few subjects or even a single subject; and it led to a special adaptation of the method of correspondence teaching. The special advantage of the extension method is that it enables the College to reach a much larger number of people than can be brought to its campus for the more intensive instruction there given.

THE EXPERIMENT STATION FARMS

The Experiment Station conducts much of its investigational work at its branch stations or farms. These are situated in several typical regions of the State and enable our workers to make studies with special application to various climatic and soil conditions. In the Salt River Valley, near Mesa and Tempe, the Salt River Valley Experiment Farm and the Date Orchard give excellent opportunity to study the problems of our most important irrigated area; at Yuma, the Date Orchard and Horticultural Station and the new tract on the Yuma Mesa enable us to study citrus and other fruits, as well as vegetables and a few farm crops, under conditions of extreme heat and aridity; at the Prescott and Cochise dry-farms we are able to make studies where conditions are fairly representative of the dry-farming areas of the State; and the University Farm near Tucson serves the Experiment Station in many ways and serves also as a demonstration farm for use in college teaching.

It is worthy of special note that the Fourth Legislature made an appropriation for the purchase of additional land for the Yuma Station and for special investigations of citrus fruits. The Station was fortunate in securing a twenty-acre tract adjoining the Date Orchard at Yuma. This has been leveled and otherwise improved, and makes a very valuable addition to the old tract. A quarter-section of mesa land, was set apart for our use by the Department of the Interior. This has already been partially improved by the installation of a pumping plant and pipe line, the planting of citrus trees, and the construction of temporary buildings. The report of the Department of Horticulture gives details regarding these improvements.

CHANGES IN PERSONNEL

The College of Agriculture has been fortunate in being able to retain the services of strong men for many years. Three heads of Experiment Station departments have been connected with the University from fifteen to twenty years. Three others have been in service from five to seven years. Too much emphasis can not be placed on the importance of keeping high-class men. The State of Arizona is to be congratulated on supporting a University policy that enables the administrative officers of the University to secure strong men and to keep them after they have learned Arizona conditions so well as to be of maximum service to the State.

One reason why we are able to keep men of ability is found in the fact that the Regents have pursued a liberal policy in regard to salaries. Another reason is found in the opportunity Arizona gives strong men to do their best. High-grade scientific men need freedom in their work and the kind of support that will give them outlet for their energies and ambitions. They need tools and materials to work with. So that the workers of the College of Agriculture may continue to work most effectively, it is necessary that the State pursue its established policy of providing liberal financial support.

RESIGNATIONS

Notwithstanding the liberal policy of the Board of Regents, a number of valuable men have left us to accept positions offering higher salaries. Most of the losses have been from the Extension

Service. Director E. P. Taylor resigned to accept an important commercial position in Chicago, his service ending with the close of the fiscal year, June 30, 1920. Mr. W. M. Cook, who had been County Agent Leader for about three years, was chosen to succeed Director Taylor July 1. Mr. Leland S. Parke, who had served as Club Leader since 1915, resigned at the close of the year, as did Miss Agnes A. Hunt, who had been Assistant Club Leader since 1917. Other resignations were effective as follows: August 31, 1919, H. W. Estill, Assistant Agricultural Chemist; October 31, 1919, W. W. Pickrell, County Agricultural Agent, Pima and Santa Cruz counties; February 1, 1920, N. L. Harris, Extension Poultry Husbandman; March 15, 1920, C. K. Wildermuth, County Agricultural Agent, Pinal County, and C. U. Pickrell, Extension Specialist in Animal Husbandry; June 30, 1920, Mrs. Louise Sporleder Shelley, Home Demonstration Agent, Cochise County.

APPOINTMENTS

On January 1, 1920, Mr. Heber H. Gibson was appointed Professor of Agricultural Education to succeed Professor Homer Derr, who had been employed jointly with the State Department of Vocational Education. During the year, the Regents established a Department of Plant Pathology in the College of Agriculture and appointed Professor J. G. Brown of the Department of Biology of the University to take charge of the new department on July 1. Professor Brown will devote most of his time to Experiment Station investigations of plant diseases, particularly those of cotton and dates. Other appointments were as follows: July 1, 1919, E. H. Pressley, Assistant Plant Breeder; September 1, 1919, S. W. Griffin, Assistant Agricultural Chemist; October 1, 1919, S. P. Clark, Extension Agronomist; January 1, 1920, R. N. Davis, Assistant Dairy Husbandman; January 15, 1920, D. W. Albert, Assistant in Horticulture; June 15, 1920, E. B. Stanley, Instructor in Animal Husbandry.

In addition, Mr. M. H. Woody was appointed foreman of the Cochise Dry-Farm to succeed Mr. F. H. Simmons, who was transferred to Yuma; and Mr. Leslie Beaty was oppointed foreman of the Prescott Dry-Farm on March 15, 1920, to succeed Mr. T. F. Willcox, whose resignation took effect on that date. On July 1, 1919, Mr. F. H. Simmons assumed the foremanship of the Yuma Date Orchard and Horticultural Station to succeed Mr. D. C. Aepli, who had resigned as of June 30, 1919.

On May 1, 1920, Mr. J. R. Reed became foreman of the

University Farm to succeed Mr. G. J. Darling whose resignation was effective at that time.

LOOKING AHEAD

In a growing State a College of Agriculture needs to grow—must enlarge its usefulness or fail to serve the State as it should. It may be assumed that the college teaching of agriculture will be taken care of in connection with providing for the support of university teaching. It seems necessary to emphasize the special needs of the Agricultural Experiment Station and the Agricultural Extension Service.

THE AGRICULTURAL EXPERIMENT STATION

The Experiment Station is a group of trained investigators organized to do research work. They study problems fundamental to the agriculture of the State. When well organized and suitably equipped, they are able to be of great service. They discover new facts; they study agricultural crops and practices; they investigate diseases of plants and animals; they search for new crops adapted to special regions; they even develop new varieties of plants and test their adaptation to particular sections of the State; and they serve as a source of information regarding agriculture for the farmers of the State.

As the agriculture of the State becomes more varied, and as new problems arise, it becomes necessary to provide additional resources and employ additional men to meet the new demands. The new department to investigate plant diseases is only one of the several new departments needed. We have been giving attention to production problems. This is not enough. Attention needs to be given to the problems of management. We need a department of Farm Management. Attention needs to be given to the problems of marketing. We need to study our own marketing problems and practices. This means that early provision should be made for a Department of Farm Marketing. When these needs are appreciated, it is certain that the Legislature will provide the necessary funds.

THE EXTENSION SERVICE

It is only within the past ten years that the Extension Service has become the publicity agency of the College of Agriculture. The disappearing custom was for the College and Experiment Station to have more direct contacts with the farmers and their problems. There were advantages in the old method. But the new method has its own special value. The men and women who give all or most of their time and effort to extension activities know best how to reach the public with the message of the College and Experiment Station. They know also the need of keeping in close touch with the college and experiment station workers in order to be sure of the soundness of their teaching. The Agricultural Extension Service is the College of Agriculture and the Agricultural Experiment Station teaching the people. In this State the Extension Service needs to have increased financial support in order to meet the pressing demands of the farm people for more effective service.

PUBLICATIONS

While the number of publications has not been large, the quality has been high. Several of the bulletins were of exceptional merit. Following is a list of numbers, titles, and authors. The number of copies of each publication is given in parenthesis.

Bulletin No. 89, "The Yuma Mesa," by A. E. Vinson, F. J. Crider, and G. E. Thompson. August, 1919, (5000).

Bulletin No. 90, "Growing Cotton in Arizona," by G. E. Thompson and C. J. Wood. December, 1919, (7000).

Thirtieth Annual Report, December 31, 1919. By the Station Staff, (2000).

Circular No. 27, "Chick Troubles," by Francis R. Kenney. September, 1919, (3000).

Circular No. 28, "A Successful Grain and Cattle Farm in Southern Arizona," by R. W. Clothier. November, 1919, (3000).

Circular No. 29, "Culling the Non-Producing Hen," by Francis R. Kenney. November, 1919, (2000).

Circular No. 30, "Corn as a Trap Crop for the Cotton Bollworm," by A. W. Morrill. March, 1920, (6000).

The demand for our publications is steadily increasing.

TECHNICAL ARTICLES

Rot of Date Fruit. J. G. Brown, "The Botanical Gazette," Vol. LXXIX, No. 6, June, 1920.

Some Reforms Needed in Testing Concrete Pipe, G. E. P. Smith, "Concrete," Vol. 13, No. 5, p. 156, November, 1918.

Concrete Pipe Failures Caused by Unequal Expansion in Shell, G. E. P. Smith, "Engineering News-Record," Vol. 83, No. 3, July 17, 1919.

PROJECTS

AGRICULTURAL CHEMISTRY

A. E. VINSON, C. N. CATLIN, H. W. ESTILL, S. W. GRIFFIN

Alkali Soil Studies: Concomitant soil conditions that affect the toxicity of black alkali, and means for the amelioration of the effects of alkali on soil and plant (Adams fund).

The colloidal swelling of soils and the correlation of colloidal swelling to other soil properties (Adams).

Chemical analyses: miscellaneous (Hatch fund).

Meteorological observations (Hatch).

Effect of weather conditions on processing and pasteurizing dates (State and Hatch funds).

Reclamation of alkali land at the University Farm (State).

AGRONOMY

G. E. Thompson, R. S. Hawkins, S. P. Clark

Continuation of studies at the Prescott Dry-Farm (State).
Continuation of studies at the Sulphur Spring Valley Dry-Farm: This project and the preceding one include variety tests, rate and date of seeding tests, method of planting tests, inoculation of legumes; tests to determine whether dry-farming to raise feed for stock is feasible (State).
Legumes: Variety and cultural tests to determine the worth of the various legumes and varieties of legumes for Southwest conditions (State and Hatch funds).
Corn and sorghums: Variety tests and cultural methods (State and Hatch funds).
Cotton: Date of planting, irrigation tests, thinning methods, intercropping with legumes (State and Hatch funds).
Winter and Spring Grains: Culture and management of winter and spring grains, including wheat, oats, barley, and rye (State and Hatch funds).
Dynamiting: Effect of dynamiting subsoil on the succeeding field crops (State).
Grains, forage crops, and grasses, and miscellaneous crops: Varietal and cultural tests (State).
Cooperative crop experiments: Seeds of various crops have been furnished farmers in order to make comparative tests with each other and with the varieties already being grown (State).
A Study of Indian agriculture (State).
Seed certification (State).

ANIMAL HUSBANDRY

R. H. Williams, C. U. Pickrell, E. B. Stanley

Fattening range steers for market (State and Hatch).
Fleshing thin cows (State).
Use of garbage for hogs (State).
Study of two methods for maintaining sows (State).
The toxic properties of rayless goldenrod (In cooperation with the Botany Department) (Hatch).
Two methods of raising Hereford heifers (State).

BOTANY

J. J. Thornber, J. G. Brown

Grass-like plants and miscellaneous forage plants, economic study of (Hatch).
Jujube fruits: Adaptability to the Southwest (Hatch and State).
Mulberries: A study with reference to fruit production (Hatch and State).
Pistach trees: Practicability of growing pistach trees in the Southwest (Hatch and State).
Poison range plants, economic study of (Hatch).
Range improvement through fencing, a study of (Hatch).
Resistant native stocks for grafting (Hatch and State).
Tamarisks: Their growth in alkaline soils (Hatch and State).
Trees and shrubs for ornamentation, an economic study of (Hatch).
The toxic properties of rayless goldenrod (In cooperation with Animal Husbandry Department (Hatch)

DAIRY HUSBANDRY

W. S. Cunningham, R. N. Davis

Rations for dairy cows: A comparison of alfalfa hay, supplemented by wheat bran, silage and cottonseed meal, with cane fodder supplemented by silage, cottonseed meal and wheat bran (Hatch and State).
Milk substitutes for feeding calves (State).

ENTOMOLOGY

C. T. Vorhies

Rodent control: A study of grazing conditions (Adams).
Insect collection: Collecting and arrangement of economic insects (Hatch and State).

HORTICULTURE

F. J. Crider, A. F. Kinnison, D. W. Albert

Date: Culture and management of date orchards with special reference to the improvement of the yield and quality of fruit and the rooting of offshoots (State).
Citrus investigations: Effect of cultural and environmental factors on tree growth and fruit production (Hatch and State).
Olive: Effect of different methods of orchard management and pruning upon the yield and size of the fruit; also sterility studies (Hatch).
Water requirements of fruits: As affected by pruning and special cultural methods (State and Hatch)
Pruning: Effect of different methods of pruning upon the growth, productivity, and the general welfare of trees (State and Hatch).
Walnut and pecan: Adaptation of cultivated varieties to propagation on native Juglans and Hicoria stocks with a consideration of environmental factors (State and Hatch).
Potato: Study of conditions affecting the production of potatoes in Arizona (State and Hatch).
Sweet Potato: Study of cultural and storage methods (State and Hatch).
Spinach: Study of spinach as a market garden crop for southern Arizona (State).
Variety studies: Type and varietal adaptation of fruits, vegetables, shade trees, shrubbery, flowers, and nursery stock (State).

IRRIGATION

G. E. P. Smith, W. E. Code, H. C. Schwalen

A study of the relation of the evaporation rate to the duty of water and of the factors controlling evaporation (Adams).
Pumping machinery: A study to determine fundamental facts relating to the action and efficiency of various types (Adams).
Groundwater studies: Recharge, movements, losses, and rates of yield; effects of transpiration; relation of yield to artesian pressure (Adams and State).

PLANT BREEDING

W. E. Bryan, E. H. Pressley

Alfalfa: Breeding for yield and quality (Adams and State).
Bean: Biological analysis of genus *Phaseolus* (Adams and State).
Wheat: (a) To produce a wheat which will be productive and at the same time maintain a high average of bread-making qualities under Arizona conditions; (b) to make a biological analysis of the unit characters of wheat varieties (Adams and State).

FINANCES

Table I following gives a complete statement of receipts and disbursements for the College of Agriculture, including the Experiment Station and the Agricultural Extension Service. It does not include amounts spent by the Federal Department of Agriculture in partial support of cooperative agricultural extension workers. These items are shown in detail in the separate report of the Extension Service. Table II shows receipts and expenditures for the Agricultural Experiment Station as reported to the Director of the Office of Experiment Stations of the United States Department of Agriculture. Table III gives in detail the several appropriations by the State Legislature for the two years following the year covered by this report.

TABLE I.—SHOWING RECEIPTS FROM ALL SOURCES AND DISBURSEMENTS FOR ALL PURPOSES ON ACCOUNT OF THE COLLEGE OF AGRICULTURE FOR YEAR ENDED JUNE 30, 1920

Fund	Balance	Receipts	Total	Disbursements	Balance
College of Agriculture—Maintenance	$.........	$ 15,093.51	$ 15,093.51	$ 15,093.51	$.........
Morrill	....	6,335.44	6,335.44	6,335.44	....
Farm Maintenance	....	12,500.00	12,500.00	12,500.00	....
Farm Improvement	....	6,050.00	6,050.00	4,001.05	2,048.95
Printing	....	4,500.00	4,500.00	3,321.14	1,178.86
Improvement	....	6,527.28	6,527.28	6,527.28	....
Plant Introduction	*1.00	4,260.00	4,260.00	3,363.83	896.17
Tempe Date Palm Orchard Fund	*17.90	3,175.00	3,175.00	3,174.95	.05
Yuma Date Orchard Horticultural Station	....	5,925.00	5,925.00	5,925.00	....
Dry-farming fund	....	4,500.00	4,500.00	3,524.70	975.30
Prescott Dry-farm Fund	....	6,090.00	6,090.00	4,705.97	1,384.03
Salt River Valley Farm	*4.59	16,510.00	16,510.00	16,283.03	226.97
Sulphur Spring Valley Farm	*16.74	4,490.00	4,490.00	4,475.96	14.04
Surface Water Investigation	*19.69	3,000.00	3,000.00	2,986.21	13.79
Underflow Water Investigation	....	2,400.00	2,400.00	2,292.15	107.85
Experiment Farm Sales	*241.44	24,851.44	24,851.44	16,000.94	8,850.50
University of Arizona Farm Sales	1,006.23	11,732.70	12,738.93	10,044.01	2,694.92
Hatch Sales	590.29	525.72	1,116.01	419.84	696.17
Adams	....	15,000.00	15,000.00	15,000.00	....
Hatch	....	15,000.00	15,000.00	15,000.00	....
Student Fees	†53.12	588.00	588.00	645.55	‡57.55
Smith-Lever	....	17,433.71	17,433.71	17,433.71	....
State Extension	....	25,160.00	25,160.00	24,976.63	183.37
County Extension	3,506.86	12,441.65	15,948.51	15,301.47	647.04
Cooperative Agricultural Extension	....	7,433.71	7,433.71	7,433.71	....
Citrus Investigation	....	10,000.00	10,000.00	9,606.05	393.95
Date Palm Orchard and Horticultural Station Land and Improvement Fund	....	12,500.00	12,500.00	10,599.72	1,900.28
Cochise County Water Investigation Fund	....	10,000.00	10,000.00	3,240.64	6,759.36
Total	5,103.38	264,023.16	269,126.54	240,212.49	28,971.60
					—57.55
					28,914.05
Grand Total	$269,126.54			$269,126.54	

*Returned to State Treasurer.
†Returned to University General Fund.
‡Overdraft.

TABLE II.—SHOWING EXPERIMENT STATION EXPENDITURES BY FUNDS AND SCHEDULES FOR THE YEAR ENDED JUNE 30, 1920

Abstract	State fund	Sales fund	Hatch fund	Adams fund	Total
Salaries	$ 12,299.66	$ 1,492.92	$ 12,798.39	$ 11,505.66	$ 38,096.63
Labor	18,204.54	1,958.27	280.35	296.35	20,739.51
Publications	3,321.14	....	50.00	....	3,371.14
Postage and stationery	332.56	153.11	233.59	150.79	870.05
Freight and express	551.79	392.93	30.48	47.87	1,023.07
Heat, light, water and power	291.21	8.00	64.00	....	363.21
Chemicals and laboratory supplies	....	....	99.33	275.38	374.71
Seeds, plants, and sundry supplies	3,579.96	1,201.87	398.40	159.36	5,339.59
Fertilizers	368.46	456.33	51.05	....	875.84
Feeding stuffs	1,022.88	678.35	....	....	1,071.23
Library	....	....	2.04	2.10	4.14
Tools, machinery, and appliances	4,735.59	1,473.71	3.60	226.99	6,439.89
Furniture and fixtures	419.16	220.00	12.55	135.55	787.26
Scientific apparatus and specimens	7.50	....	109.09	736.53	853.12
Livestock	2,077.40	4,445.50	....	....	6,522.90
Traveling expenses	2,436.94	1,196.44	793.45	750.80	5,177.63
Contingent expenses	53.36	38.45	....	1.40	93.21
Buildings and lands	17,570.35	2,704.96	73.68	711.22	21,060.15
Balance					
Returned to State Treasurer	1,993.41	....	....	....	1,993.41
Forward to 1920-21	3,905.23	9,546.67	....	....	13,451.90
	$ 73,171.14	$ 25,967.45	$ 15,000.00	$ 15,000.00	$128,508.59

TABLE III.—SHOWING STATE APPROPRIATIONS FOR THE TWO-YEAR PERIOD BEGINNING JULY 1, 1919

Fund	1919-20	1920-21
Maintenance	$ 16,950.00	$ 16,950.00
Improvements	8,150.00	8,150.00
University Farm Improvement	6,050.00	2,250.00
University Farm Maintenance	12,500.00	12,500.00
Dry-Farming Supervision	4,500.00	4,500.00
Printing	4,500.00	4,500.00
Citrus Investigation	10,000.00	5,000.00
Plant Introduction and Breeding Investigations	4,260.00	4,260.00
Prescott Dry-farm Maintenance	6,090.00	5,690.00
Prescott Dry-farm Improvement	2,000.00	1,500.00
Salt River Valley Experiment Farm	16,510.00	12,510.00
Sulphur Spring Valley Dry-farm	4,490.00	4,540.00
Tempe Date Orchard	3,175.00	2,575.00
Underflow Water Investigations	2,400.00	2,400.00
Surface Water Investigation	3,000.00	3,000.00
Yuma Date Palm Orchard Maintenance	5,925.00	4,825.00
Yuma Date Palm Orchard Improvement	12,500.00	....
College of Agriculture Extension	18,000.00	18,000.00
Cooperative Agricultural Extension	7,433.71	10,000.00
	148,433.71	$123,150.00

AGRICULTURAL CHEMISTRY

A. E. Vinson, C. N. Catlin, S. W. Griffin

A report of the work of the Department of Agricultural Chemistry for the first six months of the period covered by the Thirty-first Annual Report was made in the Thirtieth Annual Report. Consequently the present report covers the six months ended June 30, 1920.

ADAMS FUND WORK

Details in the technique of measuring the swelling coefficient of dry soils when wetted have been given further study and several minor improvements effected. The method is now ready for publication.

The set of pot cultures with wheat in black alkaline soil, previously reported as under way, has been completed. It seems to show the point of tolerance for wheat at something over .2 percent of sodium carbonate in the type of soil used and under the conditions of the experiment as described in the Thirtieth Annual Report. An interesting result of this experiment was that healthier looking plants were obtained in pots containing .1 to .15 percent of sodium carbonate than in those containing small amounts of alkali. The soils with lower percentage of sodium carbonate were prepared by blending leached black alkaline soil of the same texture as the other soils of the series with unleached soil. The grain yields, however, were highest in the .05 percent sodium carbonate soils. The heaviest grain yields were obtained in soils containing .2 percent of sodium carbonate with sufficient gypsum added to neutralize exactly the sodium carbonate. Larger amounts of gypsum did not increase the yield, but one-half and one-quarter enough gypsum to neutralize the sodium carbonate gave some increase over the untreated check. Other reagents were used to neutralize the sodium carbonate, but no definite results were obtained. It was apparent that the series throughout contained too few duplicates to give positive conclusions without several repetitions of the experiment. Consequently the facilities for culture work are now being increased to 240 pots.

THE TEMPE DRAINAGE DITCH

The monthly sample of water from the Tempe Drainage Ditch has been analyzed as usual and results are reported in Table IV. The number of samples is too few to require further discussion of the changes going on in the character of this water. The object of the project and results to date are given in the Thirtieth Annual Report.

TABLE IV.—MONTHLY VARIATION IN COMPOSITION OF WATER FROM TEMPE DRAINAGE DITCH. PARTS PER 100,000

Date	Total Solids	Chlorides as NaCl	Hardness (permanent) $CaSO_4$	Hardness (temporary) $Ca(HCO_3)_2$	Alkalinity Na_2CO_3	Qualitative		
						SO_4	Ca	Mg.
Jan.	218.0	140.0		52.4	11.9	Str.	Str.	Mod. Str.
Feb.	350.0	245.0		74.4	0.85	V. Str.	V. Str.	Str.
March	188.0	118.0		56.5	6.8	Mod. Str.	Str.	Mod. Str.
April								
May	291.6	99.0						
June	315.2	207.0	15.5	78.7		V. Str.	Str.	Str.

SILT CARRIED BY THE GILA RIVER

In cooperation with the Department of Irrigation Engineering, over 1100 samples of water from the Gila River were analyzed for silt content. The results are intended for use in studying the probable rate of silting of the proposed San Carlos dam. Incidental to the silt determinations, total soluble solids were determined in all samples and chlorides in one complete set. These data will be published later. Some additional assistance was required in making these analyses, the expense of which was borne by the Reclamation Service.

IRRIGATION WATERS IN SALT RIVER VALLEY

During the past year a large number of waters from the canals and from drainage wells in the Salt River Valley Project have been analyzed for the Salt River Valley Water Users' Association. At that time it was proposed to blend the pumped waters with the canal waters in such amounts that no harm could result to water users being served with the blended waters. This department was called upon to pass upon the quality of the blended waters, which was agreed to only under condition that certain rules would be adopted and administration of these rules delegated to an expert appointed by the Regents of the University and attached to the

Department of Agricultural Chemistry. Although this arrangement was never put into effect, due to a change in plans for the reclamation of water-logged areas in the Valley, the rules were formulated after very careful consideration of the problem from every known angle and may possibly have some future value. For that reason they are given here.

RULES FOR THE BLENDING OF PUMPED WATER WITH CANAL WATER UNDER THE SALT RIVER VALLEY PROJECT

I. The blended water delivered to irrigators may contain not more than 50 parts per 100,000 of chloride, estimated as sodium chloride, or not more than 100 parts per 100,000 of total dissolved salts, unless in the opinion of the University of Arizona Department of Agricultural Chemistry an unusually large part of the dissolved salts is temporary hardness or bicarbonate of lime.

II. Black alkaline waters may not be blended in proportions that will give the blended water a permanent black alkali content by the method of analysis used in the above named department.

III. Pumped water that shows by analysis at the time a lower content of chlorides and total dissolved salts than the unblended water of the canal into which it is pumped may be used in any quantity, provided the resulting water meets the standard of Rule II.

In formulating these rules the department rejects the erroneous popular opinion that pumped water is inferior to gravity water of similar composition. The limits set are much lower than those accepted by some other competent authorities. Waters containing more than double the amount of chlorides and solids permitted by the above rules have been used successfully for centuries in other arid countries. The department, however, has kept in mind the possibility of future damage to valuable lands rather than the immediate profitable use of waters of doubtful character. The waters permitted by the above rules are of better quality than the usable portion of the natural flow of Salt River before the floodwaters were impounded. The rules also insure water of considerably better quality than the flow of the Gila River at Kelvin from September, 1917, to July, 1918, with the exception of a few short periods of flood. This is representative of water that has been used successfully for a very long period at Florence. Black alkaline waters have been excluded on the ground that the natural flow of Salt River was rarely, if ever, black alkaline and that black alkali, even in otherwise tolerable amounts, has a more or less deleterious physical effect on the soil.

CHARACTER OF THE GROUNDWATERS IMMEDIATELY EAST OF THE AGUA FRIA RIVER

In April the department was asked to report on the quality of the groundwaters available by pumping immediately east of the Agua Fria. Certain portions of the report prepared at the time are of public interest, and consequently are made a part of this report.

With continued operation of the Salt River Project, unaccompanied by drainage, the groundwaters in the neighborhood of the Agua Fria and to the eastward have risen till in places they now stand quite near the surface. This has resulted in rise of alkali, which becomes very strong in some localities and would lead one to suspect strongly alkaline groundwaters. Analyses of waters taken in this district several years ago showed the presence of considerable alkali at that time. There has also existed a large body of rather alkaline water to the east and northeast of this district extending beneath and beyond the city of Phoenix. Surface wells along the Salt River Valley Canal in Range 2

East and the eastern part of Range 1 East show high percentage of dissolved salts and chlorides, averaging higher than we would recommend for irrigating purposes, as irrigation is usually practiced in this country, but nevertheless usable on well-drained lands if sufficient water were available for occasional leachings. Certain wells in this area, notably those in Section 12, Range 1 East, Township 1 North, are so salty that they should be excluded from the project if it becomes necessary to draw any water from this area. It is possible, however, that deeper wells may yield better water than the shallow surface wells, as may be indicated by the project well in Section 12, Range 2 East, Township 1 North, which, while not of very good quality, is much better than the shallow wells to the west. In all probability, the quality of the water pumped in this area will vary greatly from time to time as various alkaline pockets are drained, sometimes showing improvement, at others becoming worse.

The waters west of the Agua Fria, beneath Range 2 North, Township 1 West, are excellent in character almost without exception, so far as can be judged by the analyses available. They are purer than the waters impounded in Roosevelt Lake. These waters probably are the groundwaters of the Agua Fria River itself. To the north of the proposed project in Range 1 East, and Townships 3 and 4 North, are found some of the best irrigating waters of the State; in fact the waters of this area are ideal. They, too, are probably the groundwaters of the Agua Fria. A sample of the open flow of the river in Section 27, Range 2 North, Township 1 West, shows practically the same composition as the groundwaters to the west. The water coming to the surface in the slough, and suspected to be seepage from the area to the east, is identical in character with the open flow of the river. The groundwater of the Agua Fria shows its influence on the waters to some distance east of the river. The zone of blending between the groundwaters of the Phoenix area and those of the Agua Fria appears to be in this region. The rise of the groundwater in the Phoenix area has probably forced this zone westward and at the same time brought the purer Agua Fria waters closer to the surface. As would be expected, the two types of groundwater drive wedges into one another so that a serrated or ragged contact results. These wedges may be expected to shift considerably as will also the zone of blending, but the groundwaters of the Agua Fria will probably always modify in large degree the average composition of the waters of the western sections of Township 2 North, Range 1 East, in which it is proposed to install the major part of the pumps of the project. It is possible, also, that the shallow wells between the Salt River Project wells and the river may represent a thin, overlying sheet of the more alkaline water to the eastward rather than a wedge of this water forced into the Agua Fria underflow. In that case, deeper wells in Sections 6, 8, 17, and 19 will probably be of quality equal to the project wells in Sections 9, 17, and 20. In general, it must be noted that water developed in the northern half of the proposed project is of better quality than that developed in the southern half. The water taken from the canal in Section 1, Range 2 North, Township 1 West, resembles the water at Granite Reef rather than that at Joint Head. It may have come from the north through some of the cross-cut canals, or be due to recent floodwaters at Joint Head.

The influence of other developments in the Valley on the probable future composition of the available water should also be considered. The lowering of the water table in the Phoenix District is imperative and will gradually be accomplished by suitable means. This will check the westward movement of the salty groundwater of that area and promote the eastward movement of the Agua Fria groundwater. While the lift will be increased by such drainage, the quality of waters developed under the western half of Range 1 East, Township 2 North, will be improved. Heavy pumping in the Litchton area will lower the Agua Fria groundwater and tend to shift the zone of blending westward, thus neutralizing to some degree the benefits of drainage in the Phoenix area. If, however, the Agua Fria groundwater beneath Township 2 North, Range 1 East, originates from the flow of the river, this effect will be felt less strongly. Periods of flood in the Agua Fria will force the zone of blending eastward while long periods of drouth will probably be marked by the westward movement of the alkaline waters of the Phoenix area.

AGRONOMY

G. E. Thompson, R. S. Hawkins, S. P. Clark

The annual report of this department covering the work to June 30, 1919 (with subsequent items), reported practically all of the experiments with field crops for the growing season of 1919. Consequently this report, which closes definitely with June 30, 1920, covers only six months of time. During this period all the projects reported upon in the Thirtieth Annual Report have been continued. With the close of this crop season, the project dealing with the dynamiting of soils under dry-farming conditions will have been completed. One new project, namely, a study of Indian Agriculture, has been added to the work of the department. During the year a small amount of laboratory equipment has been purchased, the two most valuable items being a dynamometer, used in connection with our teaching work in farm machinery, and a very excellent camera for use in recording photographically the results of experimental work with field crops.

Considerable improvements have been added to the various experiment farms which materially aid in conducting the agronomic work carried on there. Likewise, valuable equipment and machinery as well as livestock have been added to these farms. Particularly in the case of the Salt River Valley Experiment Farm the work is made easier and more exact because of a better condition of the fields as a result of very careful leveling and improvement of ditches.

PROJECTS

I. CONTINUATION OF STUDIES AT PRESCOTT DRY-FARM

The work of this farm has been continued without change from the plans of the previous year. On March 1, Mr. Leslie Beaty, a graduate of the Oregon Agricultural College and later a county agent in New Mexico, succeeded Mr. T. F. Wilcox as foreman of the farm.

A cold wet spring forced us to plant a few weeks later than is the ordinary custom, but a considerable supply of moisture was stored in the ground; and, with the exception of beans, which were planted very late, excellent stands were secured. At the date when this report closes (June 30), the field crops are in good condition, although there has been practically no rain for the three

Fig. 1.—Corn and cowpeas. This method of growing corn and cowpeas is recommended for the valleys in the southern part of Arizona. (Salt River Valley Experiment Farm, 1920.)

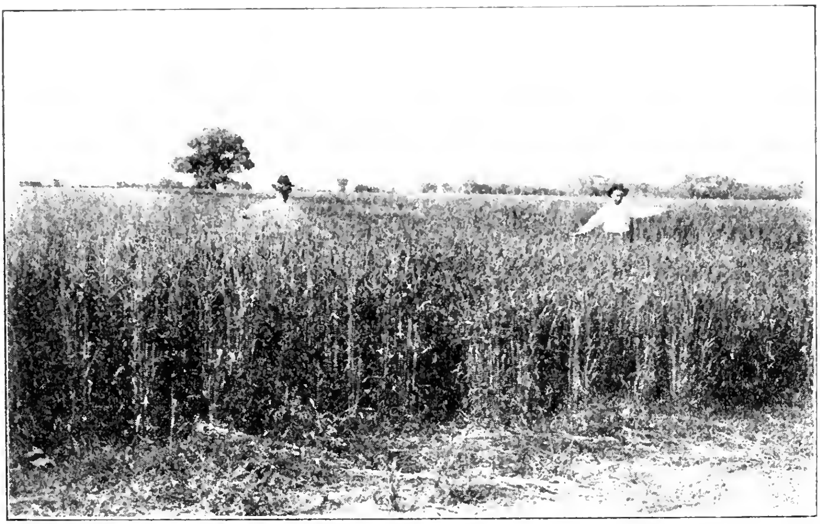


Fig. 2.—Wheat variety test. Early Baart wheat on right, Arizona No. 39 on left, and Kanred wheat in center, planted the same day and given the same conditions. Note the early maturity of Early Baart and Arizona No. 39 compared with Kanred. Early maturity is a desirable feature for southern Arizona.

months previous. The farm promises to produce sufficient silage to fill the silos on the farm and provide facilities for experimental feeding of beef or other cattle.

In furthering the work of this farm, plans are being prepared and work will soon begin on the construction of a general barn which will cost approximately $2500.

II. CONTINUATION OF STUDIES AT SULPHUR SPRING VALLEY DRY-FARM

Due to the very dry winter of 1919-1920, small grains planted in the fall of 1919 did not make profitable yields in the spring of 1920. From the farmers' standpoint, our experiments with Early Baart wheat, Macaroni wheat, Marquis wheat, common six-row barley, Abruzzi rye, and Red Texas oats would all be recorded as failures. Two plantings of each of these crops were made, good stands were secured, and the failure was due wholly to dry weather. In the spring of 1920 the regular plantings of field crops such as Mexican June corn, Hickory King corn, Papago Sweet corn, milo, hegari, Freed's sorghum, Red Amber sorghum, darso, and Tepary beans were made. On June 30 all of the crops of the Experiment Farm were in very poor condition, due to the extremely dry winter, spring, and early summer. Although Papago Sweet corn produced a perfect stand, and, early in the spring, grew well until it reached a height of approximately two feet, it practically ceased to grow at this point and on June 30 is beginning to head out at a height of two feet. From a practical standpoint this crop would not pay for harvesting.

Darso sorghum planted in March and given as good conditions as it was possible to give under dry-farming methods, has failed to germinate; following the first rain in the month of July, the field will be replanted to quicker maturing sorghums.

III. LEGUMES AND THEIR CULTURE FOR SOUTHWEST CONDITIONS

Under this project plantings were made on the five farms of the Experiment Station. The major part of these plantings, however, were made on the Salt River Valley Farm near Mesa. Several varieties of vetch were planted, the most profitable in this particular season being bitter vetch. One acre was planted in the fall of 1919 to garbanzas (chick peas). This crop made a reasonably good forage growth, reaching a height of approximately twenty inches. However, the yield of seed was comparatively light, being estimated at six or eight bushels per acre; because of the light seed yield, this crop was harvested for hay during the month of May.

During the spring of 1920, velvet beans were planted in corn and in kafir. Likewise, several plantings of cowpeas were made in fields of Mexican June corn. In these experiments a part of the legumes were planted without inoculation, while a part were planted with inoculation. Whether or not there will be any difference in the final yields remains to be determined later in the season. As another portion of this project, cotton has been planted by the ordinary method except that every third row has been planted to cowpeas instead of cotton. Part of these cowpeas were inoculated before planting and the rest were planted without inoculation. It is our intention to plow these cowpeas under about the time they reach the flowering stage. This is a repetition of an experiment carried last year. Last year there appeared to be no practical difference between the cotton produced where cowpeas were inoculated and where they were not inoculated. However, another acre of cotton planted in the same manner, but without the use of cowpeas, produced a little more cotton than either of the plantings indicated above.

On the Experiment Farms near Prescott, Cochise, and Yuma, comparative plantings are being made with different varieties of cowpeas and with a very few varieties of soy beans. However, June 30 is too early in the season to report definitely concerning the probable value of these crops.

IV. A STUDY OF THE VARIETIES AND METHODS OF CULTIVATION OF INDIAN CORN AND THE VARIOUS SORGHUMS

This project having been reported in full for the growing season of 1919, presents but little additional data by the close of June, 1920; consequently there are no definite results to report. Practically the same experiments have been outlined and started as were carried in 1919.

V. THE CULTIVATION AND FIELD MANAGEMENT OF EGYPTIAN COTTON

This project will be carried almost entirely on the Salt River Valley Experiment Farm near Mesa. However, observations intended to support or verify our experiments will be made throughout the sections of the State where Egyptian cotton is grown. Our experiments for the season of 1920 include date-of-planting tests, ranging from March 1 to May 15; rate-of-thinning tests, ranging from spacings of six inches apart in the row to spacings of eighteen inches apart in the row; methods of irrigation, varying from the ordinary flooding method to irrigation in furrows, and from the common method of watering early in the spring to the with-holding of irrigation water as late in the spring as is possible without severe stunting of the cotton plants. These experiments also include work in connection with the controlling of the black arm or angular leaf spot; experiments in topping cotton; and a very complete set of experiments dealing with cotton fertilizers. In this latter experiment barnyard manure applied at various rates is compared with cotton grown without fertilizers of any kind, with cotton fertilized with complete commercial fertilizer as ordinarily sold in the southern states, with cotton fertilized by the application of cottonseed meal, with cotton fertilized by the application of sodium nitrate, acid phosphate, and various combinations of the above fertilizers. This fertilizer experiment is an exact

Fig. 3.—Cooperative crop demonstration. Orange sorghum grown without irrigation—yield eight tons silage per acre. Navajo County.

duplication of the experiments carried in 1919, and, by the close of the season of 1920 will, we believe, supply some very definite information of value to the farmers of the Salt River Valley and other cotton growing sections of the State.

VI. CULTIVATION AND MANAGEMENT OF WINTER AND SPRING GRAINS, INCLUDING WHEAT, OATS, AND BARLEY

These experiments were for the most part an exact duplication of the experiments carried during the previous year. During the winter and early spring small grain crops appeared exceedingly promising. However, the moist conditions of early spring favored the development of the various rust diseases, and, by harvest time, the wheats, not only of our own Experiment Farm, but of the Salt River Valley in general, were more seriously affected by rust than during any of the past eight or ten seasons. In this connection it was very noticeable that the variety of hard red winter wheat named "Kanred" was decidedly more rust-resistant than any other variety on the farm. Early Baart was severely injured by rust, Sonora suffered considerably, Macaroni yields were reduced by not less than ten percent, and the ordinary hard red winter wheat of the Turkey variety, which matured very late, was so severely damaged that it was not harvested.

In these experiments Abruzzi rye made very excellent growth and produced approximately twenty-five bushels of reasonably good quality grain.

Almost perfect control of stinking smut of wheat and covered smut of barley was secured by means of treating seed with formalin before planting.

VII. EFFECT OF DYNAMITING SUBSOIL ON FIELD CROPS

This project has been handled entirely on the Sulphur Spring Valley Dry-Farm. During the seasons 1918-1919 no differences were noted on the yields of sorghums planted on the dynamited area compared to the same varieties planted on undynamited areas. During the season 1920 this experiment will be carried just as in previous years, but at the close of June, 1920, it promises to give the same results as in previous seasons.

VIII. VARIETAL AND CULTURAL TESTS OF GRAIN AND CULTURAL TESTS OF GRAIN AND FORAGE CROPS AND OF GRASSES AND MISCELLANEOUS CROPS

Under this project, experiments with Napier grass were carried a little farther than during the preceding year. Although an excellent growth was secured, it seems doubtful that this crop will be generally accepted by the farmers of this State. Our limited work of the early season makes it appear that the crop will be more difficult to handle and no more desirable than the varieties of sorghums already grown commercially in the State.

Rhodes grass has been planted on the University Farm near Tucson on extremely alkaline ground, and has made a satisfactory growth and produced abundant and valuable pasturage. Likewise the plantings of this grass made the previous year (on alkaline ground) have produced a more thrifty and vigorous growth this year than during the previous season. It seems likely that Rhodes grass is worthy of more exhaustive trial and probably worthy of general adoption by the farmers in need of pasturage on alkaline ground.

IX. COOPERATIVE CROP EXPERIMENTS

Under this project the Department of Agronomy supplies to certain picked farmers in all parts of the State limited quantities of seed of the varieties of crops that we have reason to believe will prove better than the crops already grown in their localities. The farmers in turn agree to test these crops under the same conditions as are given crops planted from local or home grown seed, and at some time during the growing season the experiments are visited by a representative of the Agronomy office and at the close of the season comparative yields are reported. In handling this work, cooperative tests have been carried with ninety farmers, and four hundred fifty lots of seed have been supplied to them. The work includes tests with wheat, oats, barley, cotton, cowpeas, soy-beans, fieldpeas, sweet clover, millet, corn, sorghums, velvet beans, sunflowers, vetch, kudzu, and Napier grass. This project is supplying very definite and valuable information concerning all parts of the State, and is invaluable to us in answering letters and handling general correspondence with farmers. It is our desire to increase this work considerably during the next few years.

X. A STUDY OF INDIAN AGRICULTURE

This is a new project and one that promises to be of considerable importance to the dry-farming regions of this and surrounding states. For a great many years, perhaps for centuries, the Indians of Arizona have been able—largely under dry-farming conditions—to grow the crops necessary to maintain themselves from year to year. In the same localities where these Indians have lived indefinitely, white settlers have repeatedly failed because of inability to grow crops. It appears that a detailed and comprehensive study of the crops grown by these Indians and the methods employed by them in growing these crops should be of material assistance to us in furthering the agriculture of our present day farmers.

XI. SEED CERTIFICATION WORK

There are certain areas in the State that, because of peculiar climatic and soil conditions, because of special market conditions, or because of local organizations, are particularly fitted to produce and market special varieties of field crops. At the present time the most notable instance of this character is the production and marketing of Hairy Peruvian alfalfa seed from the Yuma Valley.

In furthering this work the Department of Agronomy in cooperation with the Extension Service and the County Agent of Yuma County, and in cooperation with the Yuma Alfalfa Seed Growers' Association, has inspected all fields of the Yuma Valley and determined whether or not they were of commercially pure Hairy Peruvian alfalfa. Seed produced from such fields as have been found satisfactory has been handled under precautions which prevent the mixing of seed, either in threshing or in cleaning, and has been sold in sealed sacks bearing a certified tag showing that the seed was produced from fields growing commercially pure Hairy Peruvian alfalfa. This work has added many thousands of dollars to the sale price of alfalfa seed sold by Yuma Valley farmers and if its good results are not destroyed by commercial companies, it can and will be the basis of a thriving and permanent seed industry in that locality. We are now planning to handle similar work with other crops in other sections of the State.

COTTON IMPROVEMENT

In 1918 the cotton industry in the Yuma Valley was in an unsatisfactory condition, due to the haphazard introduction of cotton seed of different varieties by farmers and by seed houses. Through the crossing of these varieties over a term of years, the lint had deteriorated until it was very uneven in length and inferior in quality.

In the spring of 1919, in order to improve the quality of the lint and secure pure seed for general distribution, a small supply of excellent Mebane Triumph seed was imported from Lockhart, Texas. This seed was furnished to a few picked farmers of the valley who agreed to grow it under strict supervision of the Agronomy office. These fields were rogued during the summer and the crop ginned under special regulations in order to keep the seed free from mixture. In the spring of 1920 there was seed sufficient to plant 320 acres. Ten acres of this tract were rogued to maintain the purest seed possible and all of the cotton from this 320 acres will be ginned under strict supervision.

As a result of this work, we estimate that there will be available in the spring of 1921 enough good quality Triumph seed to supply all farmers in Yuma Valley who desire such seed.

Similar work is now being started in Cochise and Graham counties

EXTENSION WORK

Throughout the period covered by this report one-half of the time of S. P. Clark has been given to extension work along agronomy lines. He has made many farm tours with county agents, addressed a considerable number of public meetings, distributed bulletins and other publications dealing with farm crops, made personal visits to farms, written letters in answer to inquiries, etc. In carrying out this work, visits have been made to every county in the State, except one, and all county agents have been visited—most of them several times. Nearly a week was spent in cooperation with U. S. Government officials in roguing cotton which is used as the basis of the pure-seed supply of the Salt River Valley. Numerous timely articles dealing with farm crop subjects have been furnished the public press.

MISCELLANEOUS WORK

In addition to the regular teaching work the members of the department were called upon to handle extra classes for disabled soldiers sent here by the Federal Board for Vocational Education.

Upon urgent request Bulletin 90, "Growing Cotton in Arizona," was written and subsequently published.

Numerous samples of seeds were received for germination and purity tests.

By actual count, slightly in excess of 600 letters were received and answered during the six months covered by this report. Many 'phone inquiries were answered and numerous office consultations were held.

The department is now preparing for publication a bulletin dealing with small grains, and several other papers of definite, but less extensive, character.

ANIMAL HUSBANDRY

R. H. Williams, C. U. Pickrell, E. B. Stanley

Throughout the year just ended, feed has been unusually plentiful on Arizona ranges and the rainfall has been heavy and well distributed. Sheep have been profitable, for lambs and wool sold for highest prices in the history of this State. The lamb crop was larger than normal. Many of the early lambs sold for $10 in May and early June. Wool reached 90 cents a pound for the early clip, but fell to as low as 50 cents a pound by June 30.

The past year has been a very unsatisfactory one for cattlemen, although the animals wintered unusually well. In March the demand for range cattle weakened, and the situation gradually became weaker, until purchasers who contracted cattle for May and June delivery could not raise the money to move the stock.

Cotton raising has continued to be a prominent factor in the agriculture of irrigated districts. Many alfalfa fields have been plowed for this crop, and, as a result, less alfalfa has been available for livestock. Not as many cattle were fed in the irrigated districts the past year as formerly, owing to the high price of feeds and animals. Those who fed cattle lost money because of a decline in the market during March and April.

WORK OF THE YEAR

During the year a Hereford bull, Carlos Donald Second, and a Hereford cow were added to the herd. These animals were purchased from W. B. Mitchell, Marfa, Texas. More animals should be provided, because it is found next to impossible to teach certain courses without a representative selection of animals. The Poland China, Rambouillet, and Hereford breeds should be built up and improved. It is further recommended that registered draft horses be available for class purposes.

During a portion of the year a specialist in the department gave half his time to extension work in range livestock production. The results were favorable, and it is believed, that more time should be devoted to this work. Other work of an extension nature, such as the judging of livestock at fairs, addressing meetings, correspondence, and personal conferences with stockmen, has been done. A number of articles have been published in periodicals during the past year.

INVESTIGATION

The investigations in animal husbandry during the past year have been as follows:

1. Fattening range steers for market.
2. Fleshing thin cows.
3. Use of garbage for hogs.
4. Study of two methods for maintaining sows.
5. The toxic properties of rayless goldenrod. (In cooperation with the Botany Department. See report of Botany Department.)
6. Two methods of raising Hereford heifers.

FATTENING RANGE STEERS FOR MARKET

On the Salt River Valley Experiment Farm at Mesa, a feeding experiment with steers was conducted. The 36 steers were divided into six separate lots and fed six different rations over a period of 77 days. The experiment is reported in detail in Bulletin 91. The main points in this test are summarized as follows:

Alfalfa Hay Versus Alfalfa Hay and Silage: The addition of silage to a ration of alfalfa hay made the steers gain more rapidly at less cost and with greater profit. Alfalfa hay alone at the present high prices is neither a balanced ration nor a cheap feed for cattle, but silage makes a very good supplement to alfalfa hay.

Silage and Alfalfa Hay Compared with Silage and Cottonseed Meal; also Silage, Alfalfa Hay, and Cottonseed Meal: The results of this test indicated that the cheapest gains were made with silage and alfalfa hay, but the largest gains were made with silage, alfalfa hay, and cottonseed meal. Silage and cottonseed meal at the prices charged did not give good results, for the steers in this lot gained slowly and at a high cost. From a standpoint of rate of gains and cost of production, silage and cottonseed meal made a better ration than alfalfa hay alone.

Silage, Cottonseed Meal, and Alfafa Hay Versus Silage, Cottonseed Meal, and Ground Milo: Although the steers receiving silage, cottonseed meal, and ground milo maize finished earlier and were fatter and would dress out more as well as sell for more money, yet from a standpoint of uniformity of gains, staying on feed, total gains, and cost of gains, as well as profit making ability, the steers receiving alfalfa instead of ground milo maize did best.

Silage, Cottonseed Meal, and Milo Versus Silage, Cottonseed Meal, Milo, and Alfalfa Hay: Again it was noted that the addition of alfalfa hay to a ration seems to have a beneficial effect. The steers receiving an addition of alfalfa hay made larger, cheaper, and more economical gains, finishing more rapidly for market and sold for a higher price. One of the distinct differences in the animals in these two groups was in the uniformity of gains and the good appetities of the cattle receiving alfalfa, but those that did not receive alfalfa had two steers off feed and the gains of the lot were variable.

The animals in the above tests were given all the roughage, consisting of silage and alfalfa hay, that they would consume. Those receiving cottonseed meal were given an average of 2.56 pounds per day and those receiving ground milo maize averaged 5.77 pounds per day. It will be noted that the amount of concentrates was held at a minimum.

FLESHING THIN COWS

On the Cochise Dry-Farm twenty-one old, thin, and weak range cows were divided into three groups—one of them being fed silage and cottonseed meal; another silage, cottonseed meal, and alfalfa hay; and a third silage and cottonseed meal, with a dry pasture to run in. A maximum of three pounds of cottonseed meal was fed daily and the cows were given all the silage, alfalfa hay, and pasture they cared for.

Twelve weeks were required for the animals to take on sufficient flesh to suit the butchers. The cows in Lot II, receiving silage, cottonseed meal, and alfalfa hay, consumed an average of 60.42 pounds of silage, 2.83 pounds cottonseed meal, 2.64 pounds alfalfa hay daily over the twelve weeks and gained an average of 2.99 pounds per day. The next best lot was the cows receiving silage, cottonseed meal, and dry pasture. The animals, consuming only a small amount of dry pasture, received the same amount of cottonseed meal, and 63.18 pounds of silage daily. The cows in Lot 1 receiving an average of 66.86 pounds silage and 2.86 pounds of cottonseed meal, gained only 2.32 pounds daily. The results of this test indicate that there is a great difference between the different range cows, the fatter and larger the animals the better, on entering the feed lot.

USE OF GARBAGE FOR HOGS

On October 31, 1919, ten shoats averaging 100 pounds each were purchased at $16 per hundred. The pigs were fed on garbage at a cost of 40 cents a day over a period of 81 days. At the end of this time the pigs were sold at 15 cents a pound, there being only nine pigs, for one got sick, from some cause not considered associated with the feed, and for this reason was taken out of the experiment. The nine pigs weighed a total of 1770 pounds and brought $265.50. The gain over cost of pigs and garbage amounted to $73.10.

Beginning January 20, 1920, and ending May 4, 1920, a second test was conducted. Eighteen pigs weighing a total of 1615 pounds, or an average of 89.7 pounds, were selected. Six of the pigs died from cholera the first week, the remaining 12 pigs were sold May 4, and weighed a total of 2295 pounds. The pigs were on test 105 days and the cost of feed was estimated at $20 per month or $70 Table V gives the results of the two tests.

TABLE V. DETAILED STATEMENT OF FEEDING TESTS WITH GARBAGE

	Test No. I	Test No. II
Number of days fed	81	105
Number of pigs in test	9	12
Average initial weight per pig	100	89.7
Average final weight per pig	196.67	191.25
Average gain per pig, pounds	96.67	110.58
Average daily gain per pig	1.19	.97
Cost of pigs per hundred	$ 16.00	$ 15.00
Selling price per hundred	$ 15.00	$ 16.00
Cost of hundred pounds gain	$ 3.72	$ 5.74
Average cost of garbage per pig	$ 3.60	$ 5.83
Total cost of garbage	$ 32.40	$ 70.00
Total cost of garbage and animals	$192.40	$242.15
Total receipts from sale of pigs	$265.50	$367.20
Gain over cost of pigs and garbage	$ 73.10	$125.05
Gain per pig	$ 8.10	$ 10.42

According to Table V, gains were made at a cost of $3.72 per hundred in the first test and $5.83 in the second. These are extremely cheap gains in spite of the fact that one-third of the pigs in the second lot died. The pigs did well throughout the test and gave every indication of thrift and satisfactory gains from the feed given them. The supply of garbage at times was not sufficient to make rapid gains. It is believed that it is good policy to plan on giving hogs a small quantity of grain along with the garbage, except where garbage is produced in large amounts and can be secured at little cost.

TWO METHODS OF MAINTAINING SOWS

The five registred Duroc-Jersey gilts that were raised according to two different methods have been under inspection for another year. These gilts have been exchanged, with the exception of No. 2 which still remains at the University Farm. Thus gilts 1 and 3 are now on the Schumaker farm, and 4 and 5 retained at the University. At the time the exchange was made, careful measurements were taken of the pigs. It will make an interesting study to continue this test and note the effect of the different environment on the size, weight, and conformation of the animals, as well as their fecundity and their qualities for raising pigs. Shortly after the exchange, sow No. 3 farrowed a litter of thirteen pigs, saving seven of them the first week, but apparently the sow did not milk well and all the pigs died. This same sow was bred shortly afterward but she aborted about May 25. She was bred again shortly after this. Sow No. 1 has failed to get with pigs. Sow No. 2 aborted fourteen pigs. These were the large fat sows, and the results with them were not satisfactory from the standpoint of carrying their pigs through the gestation period, or raising a goodly portion of the litter.

In spite of the fact that sows Nos. 4 and 5 are small, thin, and very inferior in appearance, they raise a larger number and percentage of pigs than the large fat sows. Sow No. 4 farrowed a litter containing eleven pigs, and she raised four boars and three sows. On the ninth of June sow No. 5 farrowed nine pigs, raising five sows and three boars. Apparently sow No. 4 was the only one bred up till June 9. Further observations will be made during the coming years.

ALFALFA VERSUS MIXED RATIONS FOR RAISING BEEF HEIFERS

Alfalfa hay has been used extensively for feeding cattle in the Southwest. Dairy cows as well as beef bred animals have been raised on this feed with little or no other supplements and maintained on alfalfa hay throughout their entire life.

Reports have reached us that alfalfa hay is not a satisfactory ration for breeding stock. Some report that the animals fail to reach normal size, and that there is a tendency to sterility, or barrenness, and that in some way the ration has been unsatisfactory.

The department planned a feeding test and studied the effects of maintaining an animal on alfalfa hay. A registered Hereford heifer, Great Coronis No. 756193, calved September 29, 1918, was raised by allowing to nurse, and weaned at an early age, and placed in a dry lot, being fed on alfalfa hay alone. This heifer has been given nothing but alfalfa hay, which at times was poor in quality, containing weeds and other feeds. She was bred to Beau Carlos April 27, 1920.

Another heifer, Coronis Great 873919, was calved December 12, 1919. This heifer is a full sister of Great Coronis and was used as a comparison for making a study of alfalfa hay as a feed for raising and maintaining breeding stock. This heifer is to be fed in the ordinary way; she will be weaned at the same age as the other one; fed on mixed rations and bred as near as possible at the same age.

On June 30, 1920, both the heifers were looking well. Quite a number of stockmen are interested in the outcome of the test.

BOTANY

J. J. Thornber, J. G. Brown

The rainfall for the year ended June 30, 1920, at Tucson, Arizona, was 20.59 inches, or practically double the average annual rainfall for this station. This is the heaviest rainfall that has been recorded for Tucson for a similar twelve-month period during the past 39 years. Of this rainfall, 10.24 inches, or nearly 50 percent, fell during the summer rainy season, July to October inclusive; and 9.18 inches, or 44.7 percent, during the winter rainy season, November to April inclusive. October, December, April, May, and June were the months of lightest precipitation, while for each of the remaining months there was a minimum of one inch of rain, and usually much more than this. The rainfall for July was 26.9 percent of the total for the year.

Naturally, this rainfall resulted in a heavy growth of forage on the ranges during both the summer and fall of 1919 and the winter and spring of 1919-1920. There was an abundance of feed on almost all the ranges, except those badly overgrazed and trampled out, and at the same time a smaller number of stock to graze, since the herds had been much reduced during the two previous years on account of severe droughts. Scarcely more than 70 percent of the feed was eaten during the fall and winter and the plants matured a heavy crop of seed for future growth. Stock, generally, came through the winter in good shape, and the ranges were in better condition than they had been for some years.

The heavy winter rainfall just noted brought about two conditions. The feed on the ranges, which underwent natural curing with the dry weather in October, was badly leached out and weathered before spring. This was largely offset, however, by the excellent spring growth which was ready for grazing by the middle of March. The other condition was the heavy growth of poison plants on the ranges, induced by early and continuous winter rainfall.

LOSSES OF STOCK FROM POISON PLANTS

Losses of stock from poison plants were quite general and heavier than for some years past. On many ranges there was a heavy growth of loco and larkspur plants before the grasses and similar forage plants were tall enough to be grazed. Naturally, stock ate the succulent poison plant growth in preference to dry, weathered grass stems. During this spring season, no less than thirty complaints of stock being affected, or dying, from eating poison plants were received from southern Arizona, and a considerable number from central and northern Arizona. The following were the more important of these poison plants; spreading loco *(Aragallus nothoxus)*; Thurber's loco *(Astragalus Thurberi)*; hairy loco *(Astragalus Bigelowii)*; tall loco *(Astragalus diphysus* and *Astragalus diphysus MacDougali)*; purple loco *(Aragallus Lamberti)*; blue larkspur *(Delphinium scaposum)*; prairie larkspur *(Delphinium camporum)*; and death camas *(Zygadenus elegans)*.

At Patagonio, Elgin, and certain other localities, the loco poisoning was quite different from that ordinarily observed. Stock would become weak in the back, break down, and to a great extent lose the power of their hind legs. Stockmen call this "tottering loco." The plant causing this disease is believed to be a small loco weed which grows low and spreads out on the ground. It is known botanically as *Aragallus nothoxus*. Commonly it is abundant enough in places to form a nearly continuous growth, particularly in depressions on the prairies. This plant was more often reported by stockmen during the past spring as causing loco among stock than all the other varieties of loco in southern Arizona combined. Dr. C. D. Marsh, the Government poison plant specialist, visited Arizona during the latter part of March and April to study the situation.

STUDY OF ARIZONA GRASSES

The writer devoted the major part of his time in Experiment Station work for the year to a comprehensive study of the grasses of the State. This work is concerned with the identification, distribution, relative abundance, and economic value of our grasses and forage plants. As far as possible, all the grasses in the State growing wild, or without cultivation, are included in this study. The grass flora of Arizona is relatively large and diversified and includes a large number of Mexican and South American species. A small amount of work remains to be done on this study before the manuscript can be completed and submitted for publication.

WORK AT FLAGSTAFF

Beginning with the middle of July, the writer spent seven weeks at Flagstaff, Arizona. Most of this time was given to instruction work in the University Summer School at the Flagstaff

Normal. In addition to this, an economic study of the plants growing in the vicinity of Flagstaff was begun. One hundred species of grasses, including ten not heretofore recorded for the State, were listed and studied, and much valuable information concerning these plants was gathered. Trips were taken in nearly every direction for distances of thirty to forty miles and large plant collections were made. It is estimated that at least twenty-five species were added to the flora of the State in this brief study. In addition to this a study of the water plants in the lakes about Flagstaff, poison range plants, ornamental trees, shrubs, and vines of the city, and weeds was begun. It may be interesting to note that the Canada Thistle *(Cirsium arvense)* was observed for the first time growing in Arizona. This matter was referred to the County Agricultural Agent for disposal.

LOSSES OF STOCK FROM AN UNKNOWN CAUSE

(This work with rayless goldenrod was done in cooperation with Dr. R. H. Williams of the Animal Husbandry Department.)

For some years stockmen southwest of Tucson have complained of losses on the ranges during the winter season. In a specific case a rancher west of the Tucson Mountains lost 65 horses and about 30 head of cattle from an unknown cause. These animals, with others, were grazed in three pastures, each separated by several miles distance. Rayless goldenrod, or burro weed, was the only plant growing in any abundance in all these pastures, and, naturally, was believed to be the cause of the losses. In one pasture, cattle had been kept until all the forage had been grazed out, leaving only bushes of the rayless goldenrod. Stock had eaten some of the fresh shoots of this plant as well as some of the woody stems, both dry and green. In a second pasture, where some stock were dying, there was a considerable growth of dry, rather coarse grass, in addition to a small amount of annual growth and scattered plants of the rayless goldenrod. Stock were eating this fresh annual growth and the coarse grass just noted, but it was not observed that they had eaten any of the rayless goldenrod. In a third pasture, where the horses were kept, in addition to the usual growth on the desert ranges, including rayless goldenrod, a scattering of plants of the many-seeded saltbush *(Atriplex polycarpa)* was present. This saltbush is regarded as good winter feed and is invariably closely browsed when feed is short. No further losses of the stock in these pastures resulted after the animals were given a change of feed, a change of pasture, or turned out on the open range where feed was fairly good.

The first indication of this disease in animals is lack of thrift. They become gaunt, listless, separate from the herd, and lie down. The horses appear fagged as if overridden and exhausted. The disease seemed to exist in two forms. In the acute form the animals have some fever and die within a day or so, while in the slower form they linger three to five days, losing flesh and becoming weaker. A few hours before dying they tremble violently, often fall down with the legs spread out, drop the head and neck, and froth at the mouth. Some animals break down over the loins and fall down with their hind legs sprawled out. The disease attacks both sexes and all sizes, ages, and conditions of animals, and very few of the affected ones recover.

The rayless goldenrod or burro weed *(Bigelowia coronopifolia)* is abundant over large areas on the desert ranges and valley lands in southern Arizona. It is less abundant on the prairies. It belongs to the goldenrod group of the sunflower family and is a woody shrub one to three feet tall. The leaves are skeleton-like, and pinnately parted nearly to the mid-ribs. The flowers are golden yellow, and borne mostly in terminal clusters in the summer and fall. The whole plant is strongly resinous, with a pronounced bitter odor, and stock rarely eat it except when driven by stress of hunger. Sheep and goats, however, eat the blossoms and seed heads and appear to relish them.

A shrub nearly related to this goldenrod grows throughout the Gila Valley in Arizona and is known to stockmen as "jimmy weed." This plant is *Bigelowia heterophylla* and is believed to be the cause of the disease among stock known as "jimmies," losses from which, though rarely heavy, occur each year. *Bigelowia Wrightii* is still another plant belonging to this group of rayless goldenrods. This species grows in New Mexico and is known to cause losses among stock during the fall and winter months.

FEEDING EXPERIMENT WITH RAYLESS GOLDENROD

To determine whether rayless goldenrod was the cause of the losses of stock noted above, a quantity of the material, including the woody stems, leaves, and herbaceous growth, was gathered, dried carefully, and ground into a meal. This was fed to a mare kept in a stall so that she could get no feed other than what was given her. She was allowed all the water she would drink. To maintain her on a barely living ration, she was fed daily one pound of alfalfa hay, and one and two-thirds pounds each of rolled barley and bran. She was also fed daily one and two-thirds pounds of the rayless goldenrod meal, which was mixed with the bran and rolled barley and bran and one pound of rayless goldenrod meal, no change in the animal.

Following this, the proportion was changed to one pound of rolled barley and bran and one pound of rayless goldenrod meal of which she was fed five pounds daily, the alfalfa being continued as usual. The mare refused to eat this mixture at first, but picked out as best she could the rolled barley. Later she ate it, but some of it was usually left in the box. This was cleaned out each day and weighed back. There was still no noticeable change, but the mare appeared very hungry.

After three weeks with the above feed, the mare was given one pound of alfalfa hay twice daily and all the rayless goldenrod meal she would eat, with no other feed. Less of the rayless goldenrod meal was eaten with this ration than formerly and, later, a small amount of bran was added. With this the mare was eating daily about two pounds of rayless goldenrod meal, along with the two pounds of alfalfa hay and the small amount of bran. Though she disliked the goldenrod meal she ate it, but showed no symptoms of poisoning. The experiment closed June 30, the mare having eaten altogether about 150 pounds of the rayless goldenrod meal. At this time she had completely shed her coat, which originally was rough, and she looked sleek and glossy. She was also lively and to all appearances in good health. During the experiment she lost about five pounds in weight and her breath, urine, and faeces smelled strongly of the rayless goldenrod.

Since but one animal was used in the experiment, the results are not conclusive. There is no suggestion, however, that the large amount of rayless goldenrod consumed was injurious to the mare. It is possible that the alfalfa, bran, and barley helped her to throw off the effects of any poison present.

NOTES ON PLANT INTRODUCTION WORK

No planting of note was done in the introduction gardens during the year. This was due in part to a shortage of funds. A considerable number of the plants in the garden have made good growth and give promise to become valuable plant introductions In December, 1919, upon invitation from Mr. Walter T. Swingle of the Department of Agriculture, the writer made a trip to

Coachilla Valley, California, to study plant introduction work there.

The Evergreen Tamarisk *(Tamarix articulata)*. In the spring of 1909, this department introduced the evergreen tamarisk from Algiers. Along with cuttings of other tamarisks with which the writer was experimenting, Dr. Trabut included six small cuttings of the evergreen tamarisk. These were planted in the introduction garden on the University grounds and in four years' time made a growth of from 20 to 25 feet. During the cold winter of 1912-1913, with a minimum temperature of 6 degrees Fahrenheit, these trees were frozen nearly to the ground. They had been over-irrigated and the wood was in an immature, sappy condition. Other trees growing in the vicinity of the University with the wood well matured, were not injured in the least by this freeze.

On account of its symmetry and rapid growth, the evergreen tamarisk became almost immediately a favorite, and it has been impossible to supply the demand for cuttings. At this time it is being planted extensively in parts of southern California, southern Arizona, and Texas. It is regarded as one of the most rapid-growing trees in the Southwest. It grows readily from cuttings which, curiously enough,, may be made and planted at almost any season, though rooted trees, unless kept moist, do not transplant well. It is not uncommon for plants to make a growth of six feet from cuttings in one season. Small trees set in clumps on the University grounds have made growths of 12 to 18 feet in two years' time, and there are numerous examples of evergreen tamarisks in the Coachilla Valley, four and five years old, that are 40 feet or more in height. A brief description of this tree is found in Timely Hint 121 of this Station.

Arizona Cypress *(Cupressus glabra)*. This is a smooth-barked variety of the common Arizona cypress. It has made good growth in the introduction garden and is very resistant to our conditions. It grows quite erect, with ascending branches, and has light bluish green foliage and smooth brown, or olive-green bark, which falls off in flakes. Like other cypresses it grows readily from seeds.

Cupressus Goveniana is a native of California, and has rather slender branches which are more or less spreading and drooping. It appears well suited to southern Arizona conditions and grows 30 to 50 feet tall. Small plants have made a growth of seven to nine feet in two years and are very ornamental.

Aleppo Pine *(Pinus halepensis)* is a native of Syria and it is perhaps the only pine that can endure the heat and aridity of southern

Arizona. Young trees, three years from planting, are six to eight feet tall, while trees in the Salt River Valley six years old are 25 to 30 feet tall. This tree has a rather open, spreading habit of growth and bears cones when five to six years old.

Cork Oak *(Quercus suber)*. This is an important commercial tree in Spain and is an attractive live oak, picturesque in appearance, but of slow growth. The plants on the University grounds are sturdy and healthy and appear well suited to conditions in southern Arizona. They have made growths of four to five feet in three years' time.

Willow-leaf Pittosporum *(Pittosporum phillyraeoides)* is a graceful, weeping evergreen with brown, slender twigs and smooth, glossy, willow-like leaves. It is a native of Australia. It is slow to become established, but makes good growth afterwards. It is entirely hardy to our climatic conditions and thrives in both mesa and valley soils. During the ten years it has been under observation, it has not suffered injury from heat or frost.

Mastac Tree *(Pistacia lentiscus)* is a robust, spreading evergreen shrub from the Mediterranean region and grows four to ten feet high. The leaves are smooth and pinnately divided with six to ten leaflets. During the 18 years' time it has been growing on the campus it has never been injured with heat or frost. It thrives in a variety of soils and is tolerant to considerable alkali. The seeds are said to yield 20 percent by weight of oil.

Feijoa Sellowiana is a hardy evergreen shrub with spreading branches and oval or oblong leaves which are one inch or more long, green above and grayish-white beneath. It is a native of Brazil and is said to grow well wherever the olive succeeds. In five years' growth on the campus it has not been injured with heat or frost. It blossoms in the spring, but as yet has not borne fruit.

Yellow Jasmine *(Jasminum humile)*. This is a tall, loose-growing evergreen shrub with spreading branches and is a native of southern Asia. It grows rapidly and blossoms profusely in the spring. The flowers are borne in clusters and are yellow and very fragrant. The leaves are pinnately divided with five to seven leaflets.

Jasminum primulinum is a low-growing, evergreen shrub from China. The branches are spreading and recurved and often root at the tips. The leaves are 3-divided, and the flowers are produced early in the spring, and are yellow and fragrant. This plant endures our summer heat and zero degrees Fahrenheit temperature without injury, and thrives in both valley and mesa soils. It can be used to advantage as an undershrub in planting. It grows readily from cuttings or by layering and has been under observation for ten years.

Solanum jasminoides is a clean, evergreen climber from Brazil. It has smooth, glossy leaves and propagates readily by layering. The flowers are white, very attractive, and borne in clusters, and are produced in abundance from spring until late in the fall. It is tolerant to our hot summer weather and has not been injured with temperatures of 12 degrees Fahrenheit.

Common Rosemary *(Rosmarinus officinalis)* is an evergreen shrub with a pleasing aroma and spreading branches that grow three to five feet tall. The leaves are narrow and rather thick, with the edges recurved, and the flowers are light blue and appear during the winter and spring seasons. This is an excellent bee plant and can be propagated readily from cuttings. It is a native of the Mediterranean region, is drought resistant, and grows well under our conditions.

Golden bell *(Forsythia suspensa)* is an attractive shrub with smooth, yellowish-brown, recurved stems. The leaves are smooth and drop late in the fall. The plant is a native of China and produces a wealth of golden yellow flowers early in the spring before the leaves appear.

Algerita *(Berberis trifoliata)* is an evergreen shrub with thick, tough, bluish-green and more or less spiny leaves. The stems are reddish-brown and the flowers are yellow and borne in the spring. It is a native of western Texas and very resistant to southwestern conditions. The plant resembles generally our native Fremont's barberry, but is perhaps more ornamental. The fruits are edible.

Common Jujube *(Zizyphus sativa)* is a small, deciduous, spiny tree or large shrub from the Mediterranean region. It is of erect growth and very attractive during the growing season with its glossy foliage. The fruits are about the size and shape of an olive, blackish when ripe, and produced in enormous quantity. Plants have been under observation for 12 years and have endured without injury the usual summer temperatures and winter temperatures as low as six degrees Fahrenheit. On the University ground in lime soil the growth was very unsatisfactory, but at the University Farm with more or less alkali in the soil their growth has been all that could be desired. These plants are regarded as entirely hardy for growing under southern Arizona conditions and they should prove a valuable secondary fruit for the home.

Pistasch Tree *(Pistacia vera)* is a small, spreading, deciduous tree also native of the Mediterranean region, which succeeds well in southern Arizona valley soils. It bears the pistasch nuts of commerce. Plants have been grown on the University grounds and in the introduction garden at the University Farm for a period of 12 years, during which time they have not been injured with our usual summer temperature, nor with winter temperatures as low as six degrees Fahrenheit. In the lime soils on the University grounds the plants made poor growth, while in alkaline soil at the University Farm their growth has been excellent. There are trees of considerable size in the Government introduction garden at Sacaton which have begun to bear nuts.

Chinese Pistasch *(Pistacia chinensis)*. This is quite a rapid-growing tree, with deciduous leaves and stout twigs. It is a native of China, and grows to a height of 40 or 50 feet. The leaves are smooth, glossy, and pinnate with six to ten pairs of leaflets, and become deep red in autumn. This tree is very resistant to our heat and has not been injured with temperatures as low as zero degrees F. It grows best in valley soils and tolerates considerable alkali.

DAIRY HUSBANDRY

W. S. Cunningham, R. N. Davis

The Department of Dairy Husbandry has been strengthened by the addition of R. N. Davis, who joined the department January 1, 1920, with the title of Extension Dairy Specialist with the understanding that he give one-half of his time to the regular work of the department. Mr. J. F. Burrows was appointed as fellow assistant in the department July 1, 1919.

The Experiment Station activities of the department have been confined entirely to the University Farm at Tucson, on account of lack of facilities for dairy work at any of the outlying Station farms. A herd of Holstein-Friesian and Jersey cattle is maintained at the University Farm for classroom and investigational work. Daily records of milk are kept, and the milk is tested for two consecutive days in each month. The records of the cows for their last lactation are given in Table No. VI.

TABLE VI.—YIELDS OF DAIRY COWS AT UNIVERSITY FARM 1919-1920

Name of Cow	Breed	Days dry before calving	Days in milk	Yield in pounds milk	Yield in pounds butter-fat	Avg. % butter-fat
Princess of Chewanbeck....	Jersey	180	253	5609.6	240.6	4.29
Childeberte................	"	66	365	8442.2	510.8	6.05
Myrtle of Nogales..........	"	35	365	6380.4	277.1	4.34
Arizona Butter Girl........	"	53	365	6331.8	371.1	5.86
Average for Jerseys......			337	6691.0	349.9	5.23
Belle Liscomb De Kol 2nd...	Holstein-Friesian	22	306	9375.7	302.8	3.23
*Josephine Arizona Maid...	"	50	281	11338.4	309.2	2.73
Moensje Jesse Aspirante....	"	53	322	9977.4	295.1	2.96
Theresa Belle 3rd..........	"	43	365	9921.4	312.8	3.15
Josephine Arizona Maid 2nd	"	70	365	12679.6	359.7	2.84
*Madison Martha 2nd......	"	90	333	14481.7	405.4	2.79
*Miss Pell Peitertje........	"	120	285	11700.9	389.5	3.32
Johanna Madison Pauline...	"	100	365	13995.7	388.0	2.77
Theresa Belle DeVries.....	"	55	365	13063.3	404.9	3.09
Average for Holstein-Friesians.............			332	11837.9	351.9	2.97

*Milking period not complete.

EXPERIMENT WITH DAIRY COWS

The raising of cotton having crowded out so much alfalfa acreage, alfalfa hay has been scarce and high in price. It has been impossible at times to secure alfalfa hay at prices the average dairyman could afford to pay. Most farms have cane or corn fodder and stover which can be used as roughage if supplemented by protein concentrates.

An experiment was planned to determine whether chopped cane fodder supplemented by cottonseed meal can satisfactorily replace alfalfa hay in the ration. Two lots of cows were used, five cows in each lot. One lot was fed alfalfa hay, cottonseed meal, bran, and silage, while the other lot received cane fodder (chopped), wheat bran, cottonseed meal, and silage. The rations used were as follows:

RATION A		RATION B	
Alfalfa hay	15 pounds	Cane fodder (chopped)	15 pounds
Silage	25 pounds	Silage	25 pounds
Mixture:		Mixture:	
Wheat bran 5 parts		Cottonseed meal 4 parts	
Cottonseed meal 1 part		Wheat bran 2 parts	

The mixture of concentrates in each case was fed so that the Holstein cows received one pound of concentrates to each five pounds of milk produced daily, while the Jerseys received one pound for each four pounds of milk.

This test was run for two periods, and at the end of the first period the rations were reversed, so that the lot of cows receiving Ration A during the first period received Ration B during the second period, and vice versa.

This test was not continued for a long enough time to give any conclusive data, but the results indicate that while alfalfa hay as a roughage causes a larger milk production, cane fodder can be used satisfactorily, if accompanied by three to four pounds of cottonseed meal to provide sufficient protein. More work will be done along this line.

MILK SUBSTITUTES FOR FEEDING CALVES

On farms where the whole milk is sold and no separating is done, many dairymen sell the calves, both bulls and heifers, as soon after birth as a buyer can be found, and on some farms all grade bull calves are killed at birth. This practice makes it necessary for such farmers to replenish their milking herds from time to time by the purchase of cows, thereby exposing the herds to possible infection by disease germs, and preventing any intelligent improvement by breeding. Where there is a market for whole milk at a good price, one cannot afford to raise grade calves on it, as the value of the milk consumed up to five months of age is greater than the value of the calves. An experiment was planned and conducted to determine whether calves can be raised successfully on substitutes for milk at a cost which would justify their rearing. Four groups of calves were formed to test different methods of feeding and different rations.

Group 1 was known as the whole-milk group, and the calves in it were fed whole milk until they were two months of age, to give them a good start. The milk was then gradually decreased about one-half pound per day, and replaced by a home-mixed grain gruel. The mixture of feeds used in the gruel was as follows:

Rolled barley	3	parts by weight
Ground milo maize,	3	parts by weight
Wheat Bran,	3	parts by weight
Alfalfa meal,	3	parts by weight
Oil meal,	1	part by weight
Bone meal,	.2	part by weight

This feed mixture was run through a grinder to get it as fine as possible and was used in the gruel at the rate of one part to seven parts of warm water. Besides the gruel, they were given some of the dry-grain mixture and alfalfa hay.

The three calves in this group were kept on the test until they were five months of age, at which time they were in excellent condition and somewhat over-weight for their age. Considerable difficulty was experienced in getting them to eat the gruel. They were also troubled with scours.

Group 2 was known as the homemade grain milk-substitute group. These calves were fed whole milk for the first week or ten days; then a small amount of the homemade ration was added. This consisted of:

8	parts	corn meal
1½	"	alfalfa meal
1½	"	wheat bran
½	"	oil meal
½	"	blood meal
.2	"	ground bone meal

This was mixed in the proportion of one part of meal to seven parts of water and fed at a temperature of 90 to 100 degrees Fahrenheit. The milk was to be decreased and the grain gruel increased, until, at the age of five weeks, they were to receive a full ration of 18 to 20 ounces of the meal made into 10 to 11 pounds of gruel; but the calves were troubled with scours so much that they were kept on a partial milk ration and were given less than the allotted amount of gruel. This group did not thrive, as it seemed the feed was too coarse to be digested well by the young calves; one of them had to be taken off the test entirely. They were given what they would clean up of a dry mash of equal parts of ground milo, rolled barley, wheat bran with alfalfa hay.

Group 3 was fed on a commercial feed known as Red Horn Calf Meal. The calves in this group were given whole milk until ten days of age, at which time the calf meal was added gradually, so that at about five weeks of age each calf would be on calf meal exclusively. The directions of the manufacturers were followed as to amounts and methods of feeding the meal. The calves of this group were given the same dry grain mixture and alfalfa hay as were fed to Group 2. No difficulty was experienced with this group, and the results were satisfactory.

The calves in Group 4 were fed whole milk for about ten days; then started gradually on Red Horn Calf Meal. After about forty days, they were gradually shifted from the commercial calf meal to the homemade meal given under the discussion of Group 2.

This has seemed the most practicable method of using substitutes for milk, as the calves do better on the more finely ground commercial meal until several weeks of age. Then they can safely be shifted to the cheaper home-mixed ration. Unless one is able to grind the home-mixed ration fine, it seems best to use the commercial meal, as the young calf does not seem to be able to endure any considerable amount of coarsely ground feeds.

This test will be repeated during the next fiscal year to get a check on the data and to try out some changes in the rations.

ENTOMOLOGY

C. T. Vorhies

The research time of this department during the year 1919-1920 was cut in half by necessary teaching work, including the regular courses in General Entomology, and also a new course in Beekeeping for Federal Board students.

Work on the Adams Fund grazing range rodent project was pushed as much as possible throughout the year, but with some weather interference at the times free from class work. Trips have been made to the Range Reserve each month of the year with the exception of May, 1920. Unexpected difficulty developed in securing live jackrabbits for the enclosure, coyotes taking them from the traps before morning in some cases. Not until June, 1920, were the necessary rabbits secured and the success of their installation in the enclosure is still problematical. Kangaroo rats on two occasions were placed in the enclosure built for that purpose, but in both cases have shortly disappeared in some undetermined manner. Some excellent results on the life history of *Dipodomys spectabilis,* the large kangaroo rat, were secured and it is hoped to complete this phase of the work in the following year.

Some progress has been made in adding to the insect collections under the Hatch Fund, though assistance in arranging and classifying the material is badly needed to further this work. Of especial interest at this time is the collection of insects taken from the Arizona wild cotton, *Thurberia thespesioides.* A large number of insect species has been reported as occurring more or less regularly on this plant, some of which are of economic importance as potential pests of cultivated cotton. During the autumn of 1919 considerable scouting work was done on *Thurberia* in cooperation with a representative of the Federal Horticultural Board, and in the course of this work the collecting of *Thurberia* insects was carried on. It is planned to continue this collecting in connection with certain experimental work on a specific form which is planned for next year, the aim being to make this special collection complete as soon as possible.

In order to carry on the beekeeping work on a teaching basis it was necessary to add considerable equipment and to work primarily for extracted rather than for comb honey. The season of 1920 thus far has been very favorable in the Tucson region, and already sufficient honey nearly to pay for the additional equipment has been produced.

HORTICULTURE

F. J. Crider, A. F. Kinnison, D. W. Albert

This report covers a short but very active period in the work of the Department of Horticulture. While no final conclusions have been reached regarding the main projects under way, some very interesting and valuable data have been obtained and good progress made in the various lines of investigation. The work of the department has been strengthened through the appointment of D. W. Albert as Assistant Horticulturist.

CITRUS INVESTIGATIONS

During the past winter and spring, preparations were made for establishing an experimental citrus planting on the Yuma Mesa. This made necessary the installation of an individual pumping plant designed to lift water from the east main canal in the Yuma Valley and deliver through a pipe line on the Mesa, 85 feet elevation. An Allis-Chalmers direct-connected pumping unit, consisting of a 5-inch Type S, double suction pump and a 40-horsepower, 440 volt, 3-phase, 60-cycle, 6-pole motor, was installed; also a redwood pipe line 10 inches in diameter and 1050 feet long with an extension cement line 14 inches in diameter and 680 feet in length, which was sufficient to deliver water to the northeast corner of the 160-acre experimental tract. From this point the water is carried one-half mile through an open ditch to the citrus planting.

Other preparatory work consisted of the digging of a service well (fitted with a 6-inch casing and a Myers No. 95½ pump), building a corral, securing a team and other necessary equipment for orchard work.

Water was turned on the orchard land on May 27, and on June 2 the first planting of citrus was made. Five acres of Marsh Seedless grapefruit were planted, the trees being set 23 x 23 feet apart. One-year-old, bud-selected trees were used and the work of setting very carefully done. Shallow basins were left around the trees and water turned into them immediately after planting. To prevent evaporation and sunburn, paper collars were placed around the bodies of the trees, and the tops whitewashed.

Cooperative experiments with citrus growers to determine the effect of different cover-crops on the growth and production of citrus trees point favorably to vetch as a winter crop and cowpeas as a summer crop in the Yuma Mesa citrus district. Other citrus investigational work in progress and planned may be noted as follows:

(a) Determining the effect of winter cover-crops on the temperature of citrus orchards as related to Salt River Valley conditions.

(b) Studies in bud-selection as pertaining to the Washington Navel orange and Marsh Seedless grapefruit.

(c) Study of the adaptability of citrus stocks used in propagation.

(d) "June Drop" studies, as pertaining to the Washington Navel orange.

(e) Variety studies.

DATES

A serious outbreak of scale *(Parlatoria blanchardi)* in both the Tempe and Yuma date orchards made it necessary to defoliate the palms preparatory to "torching" for the control of the insect. The palms were cut back in May, the entire foliage being removed except a few leaves at the top which were shortened to about three feet in length. This treatment will prevent a crop of fruit this season; also it will cause the postponement of important investigational work in connection with the propagation of off-shoots.

It is worthy of record that the date has been a subject of study in Arizona since 1895, when the first notes were taken at the old Station Farm west of Phoenix. Cumulative evidence since that time proves that the date is a most valuable fruit crop for southern Arizona; that certain varieties are particularly resistant to unfavorable weather conditions during the ripening period; and that the plant will succeed and produce good crops on extremely alkaline soil.

OLIVES

In self-sterility tests conducted with twenty-four varieties of olives, interesting data were secured in that a majority of the varieties proved self-sterile. The work will be continued for confirmation of results and an effort made to determine the best pollenizers or planting combinations.

Three distinct methods of pruning being practiced at the Yuma Date Orchard and Horticultural Station are producing marked differences in tree growth. The trees should come into bearing next year, which will add to the interest of the work.

THE WALNUT AND PECAN

Nursery stock for propagating the walnut and pecan is being produced with a view to top-grafting cultivated varieties of these nuts on the Native Arizona walnut *(Juglans major)*, which is found in abundance in many parts of the State. The pecan is well adapted to the warmer portions of the State, and, if practical to top graft it onto the native walnut, will become a valuable commercial fruit crop for this section. The walnut, *Juglans regia*, has not proven well adapted to the warm, dry climate of the lower altitudes of Arizona although it does particularly well at elevations above three thousand feet.

PRUNING STUDIES

A project involving eight distinct methods of pruning has recently been started with a view toward determining the best pruning practices under Arizona conditions. A three-acre orchard is being used for this work at the Salt River Valley Experiment Farm. The trees were set during March, and consist of representative varieties of orange, grapefruit, peach, apricot, plum, and apple. They are being carefully trained during the present summer so as to develop a perfect formation of scaffold limbs. Definite pruning practices will be started during the coming winter at the normal period for dormant pruning.

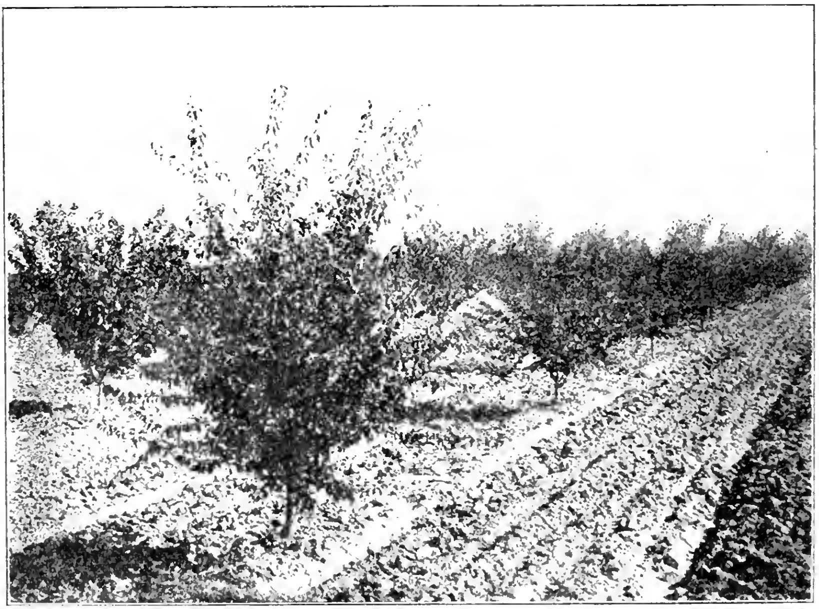
WATER REQUIREMENT STUDIES

In connection with investigations to determine the practicability of fruit-growing in parts of the State having an average rainfall of 16 to 20 inches, a four-acre fruit planting was set this spring on the Prescott Dry-Farm. The orchard is composed of some of the good commercial varieties of apple, peach, and cherry, with a separate planting of both European and American varieties of grapes. The trees have started into growth and, although severely taxed by a prolonged drouth, it is believed that only a small percentage will fail to grow. Distinct cultural practices and methods of pruning are being followed, tending toward moisture conservation.

In line with these investigations, an experiment to determine the actual water requirements of fruits has been planned and will be started during the next fiscal year. The effect of pruning on the moisture requirement of the trees will be a special feature of this project.

In the same connection, studies are being made of the environmental factors such as rainfall, humidity, elevation, topography,

4.—Four-year-o'd apple orchard near Sonoita, Arizona, being grown without irrigation.



5.—View in two-year-old variety orchard, Salt River Valley Experiment Station.

and soil conditions in sections of the State that appear to offer promise in the matter of "dry-farm" fruit growing. Striking evidence of the adaptability of certain un-irrigated localities to fruit was observed in Pima and Santa Cruz counties east of the Santa Rita Range at an elevation of approximately 4500 feet. In places where the soil is deep and fertile, the apple, peach, and grape do well, making a strong, steady growth and bearing good crops. A more detailed study will be made of this and other sections of the State where the rainfall is relatively high.

HORTICULTURAL PLANT INTRODUCTIONS

A rather large number of untried fruits, vegetables, and ornamental plants that show promise of being of economic value in Arizona are being tested. Some of these plants are being grown in regular orchard form, such as the white sapote, jujube, feijoa, and guava, while others are being held in the nursery row, mostly in the introduction garden at Yuma, to observe their behavior. The following is a list of plants under investigation: *Chayota edulis, Casimiroa edulis, Jubae chiensis, Morus alba, Jubae atlantica, Persea americana, Eriobotrya japonica, Psidium guajava, Achras zapota, Hovenia dulcis, Ziziphus jujuba, Musa sapientium, Feiojoa superba, Feijoa choiceana, Shepherdia argentea, Citrullus vulgaris, Helianthemum chamaecistus, Ananas sativus, Diospyros ebenaster, Annona muricata, Citrus sinensis, Achradelpha mammosa, Chrysophyllum cainito, Citrus nobilis, Diospyros kaki, Brassica pekinensis, Annona squamosa, Annona cherimolia, Mimusops zeyheri, Amygdalus davidiana, Asparagus acutifolius, Trichosanthes quinquangulata, Dolichos lablab, Tropaeolum tuberosum, Arachis hypogaea, Citrus Webberii, Cucumis melo, Garcinia mangostana, Prunus salicina, Cucurbita ficifolia, Alcurites Fordii.*

IRISH POTATOES

A striking instance of the unreliability of seed potatoes produced in warmer districts of the State and held in ordinary storage, developed in a test at the Yuma Date Orchard and Horticultural Station during the present season. In a planting consisting of six leading varieties, produced the previous spring, a complete failure resulted. The potatoes were kept for a period of six and one-half months from the date of harvest to planting, spread out thinly under an open shed. Although a good stand was secured, the plants were lacking in vigor, and tubers failed to develop properly.

In comparative tests at the University Farm at Tucson, the Peach Blow variety from seed produced in Coconino County gave the highest yield and proved most resistant to spring frost. The other varieties used were White Rose, Bliss Triumph, Early Ohio, Early Rose, and Irish Cobbler.

Fertilizer and spraying experiments in cooperation with potato growers in Coconino County were started this spring, but on account of a failure of the potato crop, due to drought, reliable data could not be obtained.

SWEET POTATOES

Storage tests with sweet potatoes are continuing satisfactorily. An adobe house designed and constructed so as to embody the principles of successful sweet potato storage is proving a cheap and efficient means of storage. It is believed that final data will be secured on the subject next year.

Interesting results are expected from a collection of forty varieties of sweet potatoes being tested this season at the Yuma Date Orchard and Horticultural Station.

MISCELLANEOUS

In a large collection of strawberry varieties tested at the Yuma Station the following showed distinctly superior qualities, considered from the standpoint of yield, quality, and resistance to heat: Early Ozark, Klondyke, Gandy, and Arizona Everbearing.

Nursery stocks of citrus, grapes, figs, and olives are being propagated with success at the Yuma Station.

The production of Bermuda onion seed has given evidence of promise at the Yuma Station and will be made a subject of further study.

Landscape gardening plans have been prepared for the Salt River Valley Experiment Farm, and some ornamental plantings were made during the past spring.

The orchard at the Cochise Dry-Farm has been considerably enlarged, leading varieties of apple, peach, cherry, grape, currant, gooseberry, and blackberry being added. The trees were set during March.

A new greenhouse designed by the Horticultural Department is being built on the University campus. It will be of material value in the handling of station and class work in horticulture.

Considerable time was required of the Horticulturist in the general supervision of work on the Yuma Mesa, at the Tempe Date Orchard, and at the Yuma Date Orchard and Horticultural Station. It was also necessary for the members of the horticultural staff to spend a considerable portion of their time in extension work in horticulture.

IRRIGATION INVESTIGATIONS

G. E. P. Smith, W. E. Code, H. C. Schwalen

The Irrigation Department has functioned, as in the past, with a wide range of duties, including research, investigation, and much extension service work. The personnel has remained unchanged

THE FUEL OIL SITUATION

Pump irrigation in Arizona, which has become of great importance, has been based in large measure on the availability of California petroleum oils of excellent character and at low cost. In February, 1920, the fuel oil situation became critical. The price of gas oil, or tops, the oil most used for individual farmers' pumping engines, advanced over a hundred percent at the refineries, and furthermore the supply seemed to have vanished, since it was most difficult to get any refinery to make contracts for the season's supply. While the price advanced, the quality depreciated. Shipments of gas oil to at least three pump irrigation districts, Higley, Casa Grande, and Tucson, were tested by this Department on request and found to be unsuitable for the ordinary type of farm engine. The oil could be burned in the engines only with the greatest difficulty and with rapid deterioration of the engines. Strenuous protests by the farmers, based on the reports of the tests, resulted in temporary improvement in the quality of shipments, but at intervals throughout the year unsuitable oil has been received in the Arizona pumping districts.

The Irrigation Department has been studying fuel oils for pumping engines for several years, and has accumulated much data on this subject. On account of the critical importance of the matter at this time, particularly in the case of pumping plants where the vertical lift exceeds fifty feet, a bulletin has been prepared and is in press. The subject of the bulletin is "The Supply, the Price, and the Quality of Fuel Oils for Pump Irrigation."

Fuel oils from the oil fields of north Texas have been tested with a view to promoting the production by the Texas refineries of an oil suitable for 4-cycle electric-ignition engines, and of minimum possible cost.

IRRIGATION BY FLOODING AND THE EFFICIENCY OF IRRIGATION

A monograph entitled "Irrigation by Flooding and the Efficiency of Irrigation," based on the experience of this Department during the past fifteen years, was prepared and read at a convention of the Associated Concrete Pipe Manufacturers of Southern California at Ocean Park, California, in September, 1920. The purpose of the monograph is to promote better judgment and economy in grading land for irrigation, and economy in the use of water, particularly limited and expensive irrigation water supplies. Reprints are available for distribution by the Agricultural Experiment Station.

SILT CONTENT STUDIES OF GILA RIVER WATER

In 1917, silt studies of the waters of the Gila River were initiated by the U. S. Indian Service, and over eleven hundred samples of river water were collected. The samples were so distributed as to show the silt content at six locations on the main stream from Duncan to Kelvin, and at Clifton on the San Francisco tributary. The period of sampling extended over nine months. After correspondence with Federal officials, this Department obtained possession of the samples in January, 1920. Since then the samples have been analyzed for silt content and for soluble solids, and the silt records at Winkleman have been combined with the stream flow records in such manner as to show the acre-feet of silt each day that would have been deposited in the San Carlos Reservoir if the reservoir had been in use. The total amount of silt carried by the river in the period was 196.5 acre-feet, which was 0.3 percent of the river discharge for the period.

A report on these studies has been prepared and a copy was presented to the U. S. Reclamation Service, which is now for the second time investigating the problems of storage, regulation, and use of the Gila River waters.

CASA GRANDE VALLEY

Groundwater development increased at a greater rate this year than during any previous year. The acreage under pump irrigation, or partial pump irrigation, this year was 9600, as against 5200 for 1919. The amount of water pumped is estimated as in direct proportion to the acreages, since there was little rain during the growing season and the increase was planted to cotton. This crop takes less water than alfalfa and on many ranches it replaced it. The volume of water pumped is estimated at about 12,500 acre-feet. This appears to be a high duty for the water, but it is made so by including about 3000 acres of lands along the Gila and under the Casa Grande Canal, which receive gravity water also.

Water level measurements were made on four dates, in March, in May, in August, and in October. In the pumping district near the Tweedy ranch there was a complete recovery from the preceding summer's pumping, and then followed a depression half a foot greater than the previous one. The pumping district has been extended south to the Lloyd Prouty ranch and with it also the area of depression has increased. Along the Gila for two miles back, the groundwater during May reached as high a level as has been yet observed and receded in October to the usual minimum—a fluctuation of about two feet.

The high price of gas oil (17 and 18 cents per gallon) and the difficulty of getting a good grade, have resulted in many of the semi-diesel and Brons type engines being purchased. These engines burn lower grade fuel oils known as 24 plus and 27 plus. The 27 plus is best adapted to the semi-diesel, but even this grade of oil is difficult to obtain. The Brons type engine burns the 24 plus oil readily, but no lower grade ought to be used because of the increase of solid matter contained. The greater cost of these engines offsets the lower price of the fuel oil.

Two plants using compressed air to raise the water have been installed, and unusual claims made for them regarding efficiency. At one of these plants the depth to water is 40 feet and at the other 95 feet. The efficiency of this method of lifting water has been shown in the past as being very low. The Department plans to make tests on these plants very soon.

The total rainfall and run-off have been normal. During the year 1920, 14,000 acre-feet passed Sasco. Of this flow 370 acre-feet reached the Southern Pacific tracks at Eloy, but none reached the tracks west of this point. At Lirim there was a local run-off of 1400 acre-feet. With the exception of the month of August it is known that there was no run-off at Maricopa. There were two winter floods from the Santa Rosa Wash.

SAN SIMON VALLEY

The Fourth Legislature of the State of Arizona, in Chapter 153, Session Laws, 1919, provided for special investigations of water supply and irrigation possibilities in the three great valleys of Cochise County. The largest item of the appropriation was for an experimental artesian well in the San Simon Valley, a smaller item was for a diversion dam in the Sulphur Spring Valley, and

$10,000 was specified for more general investigations in the three valleys of the county.

All water supplies, including the artesian waters, have their origin in the rainfall and run-off, and since no run-off measurements had been made in the San Simon Valley, the first effort was directed toward studying the run-off, both in the trough of the valley and at the mouths of the mountain canyons. Gaging stations were installed on the San Simon Creek at San Simon and above the Cienega, and at the mouths of Cave, East Turkey, and Wood canyons.

Four reservoir sites have been surveyed, three in the trough of the valley and one in Round Valley. The Round Valley site is situated between Cave and East Turkey creeks and at such an elevation that water from both creeks can be diverted into it.

The artesian area which extends nearly to Bowie on the west and for ten miles southeasterly from San Simon has been developed extensively already. It has been studied the past year to determine the possibilities of further development. The yields of wells and the artesian pressures have been measured and studied in their relation to the depths and types of construction. Cross-sections and piezometric lines have been drawn to determine the source and movement of the artesian waters. Influences of various factors, such as shutting off the flow in winter, are under investigation.

The possibilities of development of groundwater by pumping are being studied.

Owing to the great extent of arable land as compared with the water supply, a soil survey has been made of an extensive area reaching from Bowie to Portal. The survey was made cooperatively by this Department and the U. S. Bureau of Soils.

A site for the State experimental artesian well was selected, but owing to the high prices prevailing for well casing and well drilling, it has been impossible to contract the drilling of the well for a sum within the limit of the appropriation.

SAN PEDRO VALLEY

A cooperative agreement has been made with the U. S. Geological Survey for a joint study and publication of the geology and water resources of the San Pedro Valley. Dr. Kirk Bryan of the Geological Survey has been assigned to the Valley.

Gaging stations are being maintained at Hereford and Fairbank for the special purpose of determining the water supply available at the proposed Charleston reservoir site. Silt samples, also, are taken at intervals.

It is not considered feasible to continue the heading of the St. David canal in its present location, because of the rapidly increasing width of the river channel. The heading should be in the rock gorge about two miles north of Fairbank. Three alternative locations were selected in the rock gorge, and surveys and test borings have been made to determine the best site. Three test holes have been drilled to depths of 41, 79, and 52 feet without reaching bedrock. The best location is opposite the isolated rock island near the north end of the gorge. A diversion dam of the weir type is now being designed.

SULPHUR SPRING VALLEY

Gaging stations were installed August 1, 1919, at the mouths of Rucker, West Turkey, and Rock creeks, and in March, 1920, at the mouth of Post Creek. These stations and one on the Whitewater at Douglas are being maintained.

Seepage losses on the creeks were measured to determine the principal areas of recharge.

A project for a diversion dam on the Whitewater about 18 miles north of Douglas was surveyed and designed. This site is the present head of deep river cutting. The purpose of the dam is three-fold,—to permit the diversion of flood flows, to preserve the excellent grass pastures above the dam which will be underdrained if the headward erosion continues, and to forestall the necessity for many bridges on the main creek and its tributaries.

YUMA MESA EXPERIMENT STATION PUMPING PLANT

The pumping plant and pipe line, the design of which was noted in the last annual report, was installed in May, 1920. It has provided the water supply for the citrus groves throughout the summer. The plant is of the most reliable type possible for irrigation service. The rates for power, however, are high and the cost of the power for pumping for the irrigation season of 1920 has been almost $50 per acre.

THE CHIPPEWA PUMP

A Chippewa double-acting deep-well pump of small size was tested in the irrigation laboratory. The high efficiency that was expected was not found, but nevertheless the pump should be good for many situations, particularly stock-watering wells of small diameter.

PLANT BREEDING

W. E. Bryan, E. H. Pressley

The work of the Plant Breeding Department reported herein extends from January 1, 1920, to July 1, 1920. During this period the entire time of the department was taken up with the wheat project. Work with alfalfa and beans was taken up later in the calendar year.

In a milling and baking test which has been made with hybrid wheats originated at this Station, one sort has given particularly promising results. This wheat has been produced by crossing a hard Macaroni wheat with the soft Sonora and six years of careful selection. The following is the score of the breads produced from these wheats as rendered by the Milling Department of the Kansas State Agricultural College on the basis of 100 for perfect:

Soft parent	91.75
Hard Macaroni parent	91.50
Hybrid (1090)	*96.58*
Kansas patent	94.16

These wheats were grown under irrigation in the Salt River Valley under ordinary field conditions. The yield of this hybrid was 47 bushels per acre, which is about 5 bushels more per acre than that of the hard parent.

The third generation of the bread wheat hybrids made originally in the spring of 1917 was grown in the screen garden on the campus. Two lines of investigation have been carried out with this material, viz: inheritance of grain texture in a cross between hard and soft wheats, and the inheritance of earliness in a cross between early and late-maturing wheats. In making the cross, a late-maturing wheat with hard, glassy grains was crossed with an early maturing variety with soft grains. This combination made it possible for the two lines of work to be carried on with the same material. The economic end sought in this work is to produce a hard, early maturing wheat suitable for growth under Arizona conditions. In order to understand the significance of the present year's work, it will be necessary to make a study of all the material which has accumulated since the initial cross.

In the spring of 1917, thirty-three flowers of the hard-grained late variety (Turkey Red, 36-36) were pollinated with pollen from the soft-grained early variety (Sonora, 35). Two of these proved to be pure Turkey grains. All the thirty-one grains were as hard as the hard parent, no signs of xenia being apparent. The texture of the more than eight thousand seeds which grew on the 31F_1 plants was mostly of the diffuse type (soft), with a few grains almost as hard as the grains of the hard parent; but the diffuse grains of these first generation plants were distinctly harder than the diffuse grains of the soft parent. No selections were made in this generation on the basis of texture, the progeny of each F_1 plant being planted separately. The main object in making the cross was to study the segregation of these two types of texture in the second generation and to test them in the third and succeeding generations. However, selections have been made and planted for the purpose of testing the effect of the selection of hard and soft grains from the first generation plants.

For the second plant generation studies, 4581 plants were grown to maturity, and the classification of the grain of these plants according to texture was as follows:

983 plants having all hard grains;
2285 plants having hard and soft grains;
1313 plants having all soft grains.

A more desirable classification would have resulted if it had been possible definitely to separate the grains in the hard- and soft-grained plants into the two types used, but this was impossible on account of the almost insensible gradations in passing from one extreme to the other. This classification gives the ratio 0.859:1.995:1.146, which rather distantly approaches the 1:2:1 ratio. In testing this classification in the third generation, the following selections were grown:

Three hundred and six plants, grown from seeds of F_2 plants having all hard seeds, gave 301 plants having seeds all hard, and 5 plants having seeds all intermediate; 476 plants, grown from seeds of F_2 plants having all soft seeds, gave 476 plants all soft; 143 plants grown from hard seeds selected from F_2 plants having *both hard and soft seeds* gave:

131 plants having all hard seeds;
4 plants having all soft seeds;
3 plants having hard and intermediate seeds;
3 plants having hard and soft seeds;
1 plant having intermediate seeds;
1 plant having soft and intermediate seeds.

Eighty-two plants grown from soft seeds selected from F_2 plants having both hard and soft seeds gave:

47 plants having all soft seeds;
23 plants having soft and intermediate seeds;
4 plants having hard and intermediate seeds;
3 plants having hard and soft seeds;
1 plant having hard, soft, and intermediate seeds;
3 plants having all hard seeds.

The seeds of the third generation seem to confirm the second generation classification fairly well. The five plants with seeds all intermediate probably indicate either an error in the classification of the second generation or some environmental disturbance in the growth of the intermediate plants, such as receiving more water than the rest of the plants. The breaking up in the groups planted from seeds selected from plants having both hard and soft seeds is somewhat irregular, and the intermediates, as well as the intermediates occurring in the hard class, require further testing in at least another generation.

So far in this cross at least one thing is clear: the two types of texture have segregated sharply in the second generation and have maintained their identity. There is also a fair indication that there is a single factor difference beteen the two types of texture.

Along with the study of grain texture, considerable attention has been given to the question of inheritance of earliness in order to produce an early maturing variety. In the fall of 1919, selections were made from the second generation plants that headed during the heading period of the early parent.

Table VII shows the coefficient of heredity in the offspring of 34 of these early selections.

TABLE VII.—COEFFICIENT OF HEREDITY (r) IN THE OFFSPRING OF 34 EARLY SELECTIONS

Mean Date of First Head of Offspring

Heading Date of Parent		March 28	29	30	31	April 1	2	3	4	5	6	7	8	9	10	
March	28															
	29															
	30															
	31															
April	1															
	2	1														1
	3															
	4				3	1	7	3	4	5	3	3	2		2	33
		1			3	1	7	3	4	5	3	3	2		2	34

r = .4199 ± .0952

The offspring of 28 of the 34 selections had individual ranges of heading dates that were approximately the same as those of the parents. The standard deviations from the mean heading dates were of approximately the same size as those of the parents. These facts, together with the fairly high coefficient of heredity and the grain texture studies, indicate the possibility of producing early races of hard wheat which are suitable for the irrigated districts of Arizona.

POULTRY HUSBANDRY

Francis R. Kenney, N. L. Harris

During the fall, several cockerels of breeds and varieties prominent in Arizona were purchased for breeding purposes. These cockerels are of known pedigree from high-producing strains, and are to be used in founding high-laying strains from which males can be secured to improve the flocks of Arizona.

A number of vocational students enrolled for work in poultry, which greatly increased the incubation and brooding activities. Two large brooder houses were erected and equipped with oil-burning brooder stoves. These houses were designed to accommodate five hundred to one thousand chicks each, but it was soon found that they would handle these chicks for not to exceed four weeks.

An 1800-egg Mammoth incubator was also installed; but the results from it were not satisfactory, due to improper coal and unsuitable location for operation.

Owing to the very limited housing and rearing facilities for developing chicks, it was necessary to dispose of almost all the young stock.

Considerable data were secured as to the advisability of an intensive fattening period before marketing the early broilers and the practicability under many conditions of caponizing the later hatched cockerels.

The different climatic and environmental conditions in this part of the Southwest and the lack of information as to suitable buildings, feed, etc., make experimental work along these lines imperative. From the results of this season's work, the great importance of having a house that can be adjusted to care for the radical climatic changes, an abundnce of shade, and a plentiful supply of green feed the year around demand primary consideration

The correspondence course was inaugurated with an enrollment of over a hundred to meet, in part, the needs of those unable to leave their homes for such study.

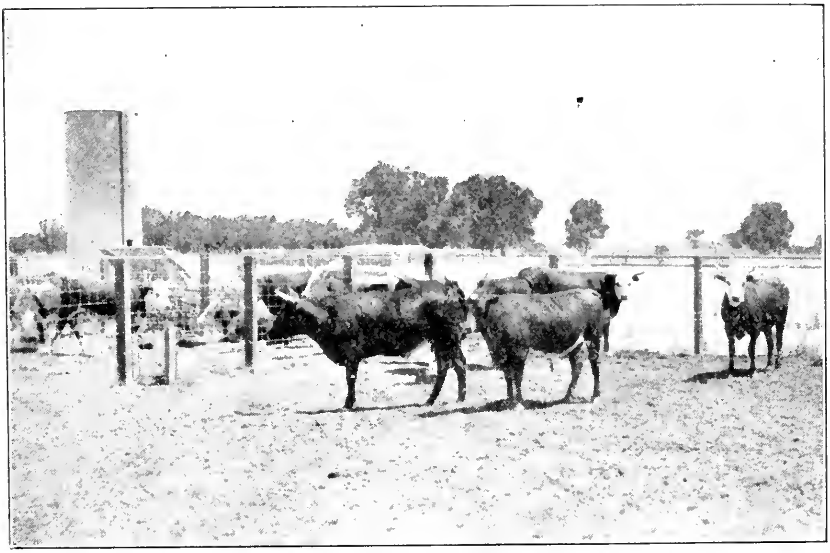
The department and people of this State suffered a severe loss by the resignation of N. L. Harris, the Extension Specialist.

In making a survey of the field at the end of the fiscal year, the legitimate demands on the Poultry Department are found to be rapidly increasing and it is hoped that in the near future the department may be enlarged, and a larger, better located, and better equipped plant secured so as more adequately to meet these needs.

The University of Arizona College of Agriculture

Agricultural Experiment Station

Bulletin No. 93



Steers in Lot IV—April 25, 1921.

FEEDING COTTON SEED AND COTTON SEED PRODUCTS TO RANGE STEERS

By E. B. Stanley

Tucson, Arizona, August, 1921

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J. W. WRIGHT, B.S. (Graham)	Safford

*On leave.

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Feeding Cotton Seed and Cotton Seed Products to Range Steers

By E. B. Stanley

INTRODUCTION

The rapid development of the farming industry in Arizona during the past ten years has been made possible by the outlet afforded for its products through feeding to livestock. A balanced agricultural policy demands a system of diversified farming in which livestock is an essential factor in maintaining soil fertility and the transformation of home grown feeds into a finished marketable product.

The advent of the cotton industry into Arizona and the consequent widening between the market prices of cotton seed and cottonseed meal, together with a lack of experimental information regarding the relative feeding values of these two feeds, prompted the Agricultural Experiment Station to conduct a steer feeding test at the Salt River Valley Experiment Farm during the winter and spring of 1921.

The purpose of the experiment herein reported was to ascertain the relative values of whole cotton seed and cottonseed meal when fed with a basal ration of alfalfa hay and corn silage for fattening steers. It was further planned to make a comparison of corn silage and cottonseed hulls when fed as the sole roughage supplemented with cottonseed meal in fattening rations and also to test the results of feeding cotton seed in a crushed form.

METHOD AND PLAN

The feeds which constituted the basal ration of the different lots were the two staple crops grown in our farming sections and widely recognized as leading roughage feeds, namely alfalfa hay and silage. Cottonseed meal, whole cotton seed, crushed cotton seed, and cottonseed hulls were the supplementary feeds used. All the feeds were of good quality with the exception of the cottonseed meal, which showed by direct analysis that it contained only 33.62 percent protein. The chemical composition of the feeds used was determined by the Department of Agricultural Chemistry as given in the following table:

PERCENTAGE COMPOSITION

Feed	Water	Ash	Protein	Carbohydrates: Crude Fiber	Carbohydrates: Nitrogen Free Extract	Fat
Cottonseed	6.50	4.06	18.50	23.26	31.98	15.70
Cottonseed meal	6.14	6.37	33.62	14.70	31.49	7.68
Cottonseed hulls	7.99	3.00	4.93	46.52	35.26	2.33
Corn silage	71.21	1.70	3.49	7.48	15.38	0.74
Alfalfa hay	3.7	8.02	15.73	29.75	40.59	1.67

The complete rations fed to the cattle were as follows: Lot I, corn silage, alfalfa hay, and cottonseed meal; Lot II, corn silage, alfalfa hay, and whole cotton seed; Lot III, corn silage, alfalfa, and crushed cotton seed; Lot IV, corn silage and cottonseed meal; Lot V, same as Lot I; Lot VI, cotton seed hulls and cottonseed meal.

The comparisons are:

1. Cottonseed meal with whole cotton seed, Lots I and V with II.
2. Corn silage with cottonseed hulls, Lots IV and VI.
3. Whole cotton seed with crushed cotton seed, Lots II and III.

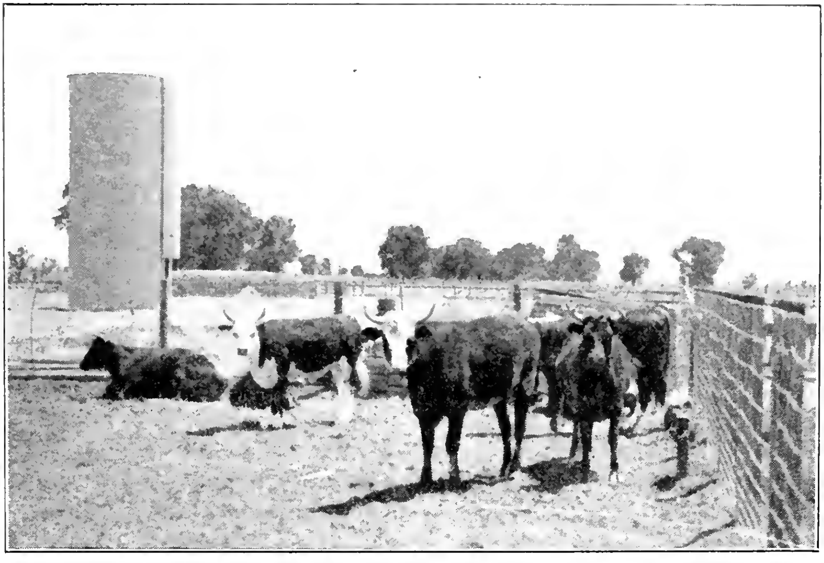
The cattle were divided into five lots of eight head each, care being taken to make each lot as nearly uniform as possible in quality, weight, and condition, and one lot of ten head in which were the smaller, more timid animals culled from the entire number. The feed lots in which the cattle were fed were alike in construction, each measuring 48x60 feet with a feed manger 3 feet wide and 36 feet long. No shed or covering was needed as there were no heavy rains, and the temperature during the test varied from 28° F. to 94° F.

The animals had free access to salt and water at all times.

Prior to the experiment proper, all the cattle were fed a liberal ration of alfalfa hay and silage for a period of ten days in order to get the animals to eating well before beginning the actual test.

The daily ration was given in two feeds, one at 8:00 a. m., and the other at 4:00 p. m. From the outset, the animals receiving hay, silage, and cottonseed hulls were given all of these feeds they would consume.

The first week, all the steers in Lot I received 1 pound cottonseed meal per head daily; those in Lots II and III, 4 pounds cotton seed; and Lots IV and VI, 2 pounds cottonseed meal. The cottonseed meal was increased to 2½ pounds per head daily the second week in Lot I; the cotton seed to 6 pounds in Lots II and III; and the



Steers in Lot I—April 25, 1921

cottonseed meal to 3½ pounds in Lots IV and VI. After the third week, the steers in Lot I were given 4 pounds of cottonseed meal and those in Lots IV and VI received 5 pounds cotton seed meal; while the steers in Lots II and III received 8 pounds cotton seed. Lot V received the same ration throughout the entire test as Lot I.

CHANGES IN FEEDS

From January 26 to February 16, the silage fed was from the Orange Cane sorghum. After this time the cattle were given corn silage but did not relish it as well as the sweeter sorghum silage previously used, but after a few days they were eating heartily of the corn silage.

The animals in Lot II did not consume the 8-pound allowance of whole cotton seed per head, and on March 16 it was reduced to 6 pounds. Beginning February 18, 6 pounds of crushed cotton seed was fed to each steer in Lot III in place of the whole cotton seed. After April 1 until the close of the test, the allowance of cottonseed meal was increased 1 pound in Lots I, IV, V, and VI.

ANIMALS USED

Fifty head of common bred two year old range steers were purchased from L. L. Bates at Prescott, Arizona, and shipped to the Salt River Valley Experiment Farm January 15, 1921. In consequence of the poor condition of the ranges during the past season, the animals arrived at the farm in poor condition. They were a hardy, uniform lot showing a predominance of Hereford breeding, and immediately took to their liberal ration of alfalfa hay and silage.

COSTS

The animals cost $6.80 per hundred, which included shipping expense and cost of feed during the preliminary feeding period.

The prices charged for the feeds used in the experiment were as follows: cottonseed meal $30 per ton; whole cotton seed $10 per ton; alfalfa hay and corn silage at $24 and $8 per ton respectively; cotton seed (crushed) at $12 per ton, and cottonseed hulls at $12 per ton. In handling such a small number of steers as 50 head no charge was made for labor nor any credit given for the manure, it being considered that this by-product will pay for the labor of feeding.

The cattle in Lot I receiving a ration of alfalfa hay, silage and cottonseed meal made an average daily gain of 2.71 pounds per head, while it will be observed that Lot V receiving the same ration gained 3.35 pounds per head daily. The steers in Lot I were larger and in better condition than the animals in all the other lots, which accounts for the wide variation in the comparative results of Lots I and V. Two steers in Lot V which were under size, made the average initial weight per head of the animals in this lot less than the other lots, but the condition of the animals in this lot was more nearly representative of the entire number than was that of Lot I.

The cattle in Lot II made an average daily gain of 2.58 pounds, or .77 pound less than the animals fed cottonseed meal in Lot V, and .13 pound less than those fed cottonseed meal in Lot I. The better condition of the steers in Lot I accounts for the small difference in gains compared with Lot II, because the cotton seed fed steers naturally took on a greater fill, due to their poorer condition.

Further comparisons of Lots II and V, receiving the cotton seed and cottonseed meal, respectively, indicate that less feed was required per 100 pounds in Lot V and at a cost difference of seven cents.

The steers receiving cottonseed meal in Lots I and V produced a better finish and made a better gain and a higher dressing percentage, averaging 56.85 per cent, as compared with Lot II with 53.6 per cent.

Lot II receiving alfalfa hay, silage and whole cotton seed made an average daily gain of 2.58 pounds per head. Lot III, receiving the same ration, except that the seed was crushed, gained 2.41 pounds per head daily. The cost and amount of feed required per 100 pounds were practically equal in both lots.

The steers in Lot IV, fed silage and cottonseed meal, made an average daily gain per head of 3.02 pounds as compared with Lot VI, receiving cottonseed hulls and cottonseed meal, which made a daily gain of 2.41 pounds per head. The silage fed steers gained .61 pound more per head daily at a feed cost of only sixty-three cents more per 100 pounds gain, and gave a much smoother finish with only a small difference in dressing percentage. The steers in Lot VI required 823.5 pounds cottonseed hulls to produce 100 pounds gain, which is one-half the weight of silage consumed per 100 pounds gain in Lot IV. This amount of silage and hulls cost $6.70 and $4.94 respectively at current prices. The hull fed steers consumed 192 pounds of cottonseed meal per 100 pounds gain, or 36 pounds more than the silage fed steers required per 100 pounds gain. Since the allowance of cottonseed meal was the same in Lots IV and VI, the difference in favor of Lot IV must be attributed to the silage. During the last ten days of the feeding period the hull fed steers became unthrifty and their normal rate of gain decreased.

SUMMARY OF STEER FEEDING EXPERIMENT COMPARING COTTONSEED MEAL AND WHOLE AND CRUSHED COTTON SEED BASED ON ONE AVERAGE STEER JANUARY 26, 1921, TO APRIL 26, 1921

Lot number	1	2	3	4	5	6
No. steers in lot	8	8	8	8	10	8
Fattening ration fed	Hay Silage Cotton seed meal	Hay Silage Whole seed	Hay Silage Crushed seed	Silage Cotton seed meal	Hay Silage Cotton seed meal	Cotton seed hulls Cotton seed meal
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Av. initial weight	718.8	705.0	636.8	697.5	553.0	643.8
Av. final weight	963.0	937.5	854.0	969.5	854.8	860.8
Av. total gain	244.2	232.5	217.2	272.0	301.8	217.0
Av. daily gain	2.71	2.58	2.41	3.02	3.35	2.41
Average Daily Ration:						
Alfalfa hay	2.41	2.28	2.28		2.31	0.24
Silage	47.77	32.99	30.93	50.63	39.83	2.82
Cotton seed whole		6.24				
Cotton seed crushed			5.54			
Cotton seed meal	3.85			4.72	3.90	4.64
Cotton seed hulls						19.86
Feed required for 100 pounds gain:						
Alfalfa hay	88.6	88.8	95.0		68.9	10.1
Silage	1760.6	1277.2	1280.8	1675.4	1187.6	117.0
Cotton seed whole		241.6	51.0			
Cotton seed crushed			178.5			
Cotton seed meal	141.3			156.2	116.2	192.0
Cotton seed hulls						823.5
Cost 100 pounds gain	$10.23	$ 7.39	$ 7.57	$ 9.04	$ 7.32	$ 8.41
Initial cost per head at $6.80 cwt.	$48.88	$47.94	$43.30	$47.43	$37.60	$43.78
Feed cost per head	24.99	17.16	16.62	24.60	22.09	18.27
Interest at 8%	.80	.80	.80	.80	.80	.80
Marketing expense	.60	.60	.60	.60	.60	.60
Total cost per head	75.27	66.50	61.32	73.43	61.09	63.45
Selling price per cwt	$ 7.00	$ 7.00	$ 7.00	$ 7.00	$ 7.00	$ 7.00
Returns per steer	62.02	60.38	55.00	62.44	55.05	55.44
Loss per steer	13.25	6.12	6.32	10.99	6.04	8.01
Necessary selling price	8.50	7.71	7.80	8.23	7.77	8.01
Necessary margin	1.70	.91	1.00	1.43	.97	1.21
Dressing percentage	56.9	53.6	55.6	56.4	56.8	55.5

SUMMARY

Cottonseed meal compared with cotton seed gave uniformly better results as evidenced by the greater gain of the animals, their smoother finish, and their higher dressing percentage.

When fed with a basal ration of alfalfa and silage to two-year-old steers, 100 pounds of cottonseed meal are equal to 170 pounds of whole cotton seed. Cotton seed at $17 per ton is equal to cottonseed meal at $30 per ton. (The cottonseed meal was low grade, containing only 33.62 percent protein, although it was purchased as choice meal.)

It was found that the use of cotton seed in a crushed form was not warranted.

Corn silage when fed with cottonseed meal gave larger and more uniform daily gains than did the ration of cottonseed hulls and cottonseed meal. Cattle fed a ration of cottonseed meal and cottonseed hulls made good daily gains for the first 60 to 80 days, after which time the gains began to diminish rapidly. If the roughage is silage instead of hulls the meal may be fed for a longer period of time without ill effects.

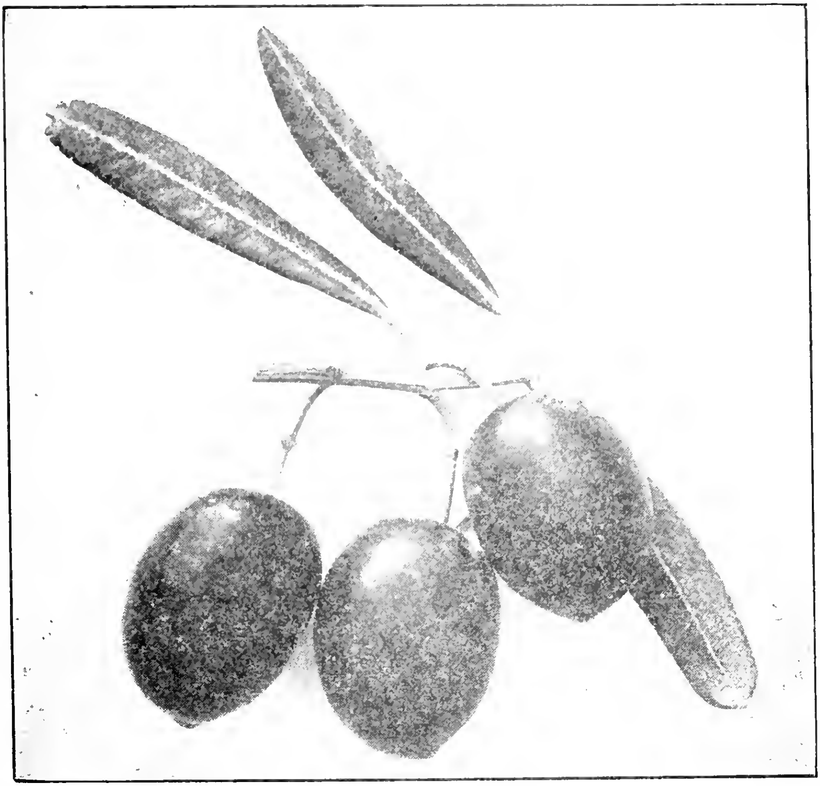
The lack of finish of the steers receiving cottonseed meal indicated that it would have required a feeding period of 120 days to put them in good marketable condition, and 150 days for those receiving cotton seed, had they continued to make the same rate of gain.

The University of Arizona

COLLEGE OF AGRICULTURE

Agricultural Experiment Station

Bulletin No. 94



The Mission Olive.

THE OLIVE IN ARIZONA

By F. J. Crider

Tucson, Arizona, January, 1922

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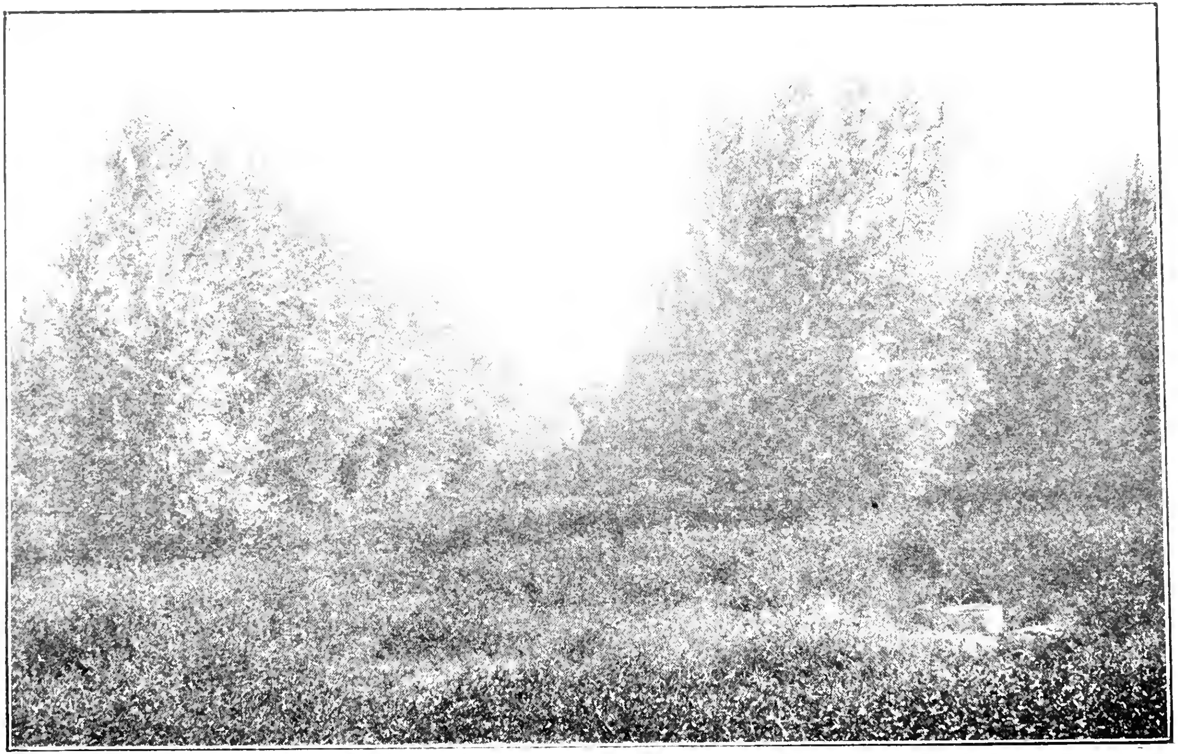


Fig. 1. View in eight-year-old olive orchard. Alfalfa cover crop

THE OLIVE IN ARIZONA

By F. J. Crider

INTRODUCTION

Olive growing promises to become a very important industry in Arizona. Vigorous commercial orchards in the Salt River Valley and lesser plantings in other localities bear witness that the olive is perfectly at home in this State. The size and quality of the fruit compare most favorably with the finest olives of the Mediterranean region, its native habitat.

The purpose of this publication is to emphasize the best practices in successful olive culture, based on investigations made by the Arizona Experiment Station during the past twenty-six years. In addition to the material contributed by the Station plantings in the preparation of this bulletin, valuable data have been obtained from commercial orchards in the Salt River Valley owned by the following: Gregg Olive Company; Munson Brothers; Walter Wilson; B. F. Carper; T. E. Bradshaw; H. Leppla; F. H. Redewill; W. S. Perry; and E. L. Graver.

CHARACTERISTICS OF THE OLIVE

The olive is an evergreen tree, attaining a height of thirty to thirty-five feet when fully developed. Its symmetrical growth and beautiful foliage make it very ornamental and worthy of a place in the home grounds as well as in the commercial orchard. The better varieties blossom rather late in the season compared with most deciduous fruits, which is an advantage in minimizing danger from frost. Only one of the seventeen varieties at Tucson was in bloom during the cold spell of April 5, 1921, which caused great damage to fruit throughout the country. The blooming season at Yuma begins about March 25 to 30, and in the Casa Grande and Salt River valleys about one week later. Most olive varieties have the habit of bearing a heavy crop one year and very little the next, but this can be largely overcome by good culture, proper attention to plant food requirements, and regular pruning. The fruit of some varieties hangs on the trees all winter if not gathered. The fruit of others falls easily and is likely to be shaken off in picking.

The olive is adapted to extremely arid conditions, through special leaf structure and a much ramified root system. Trees are known to maintain themselves under extremely hot, dry conditions with a mean

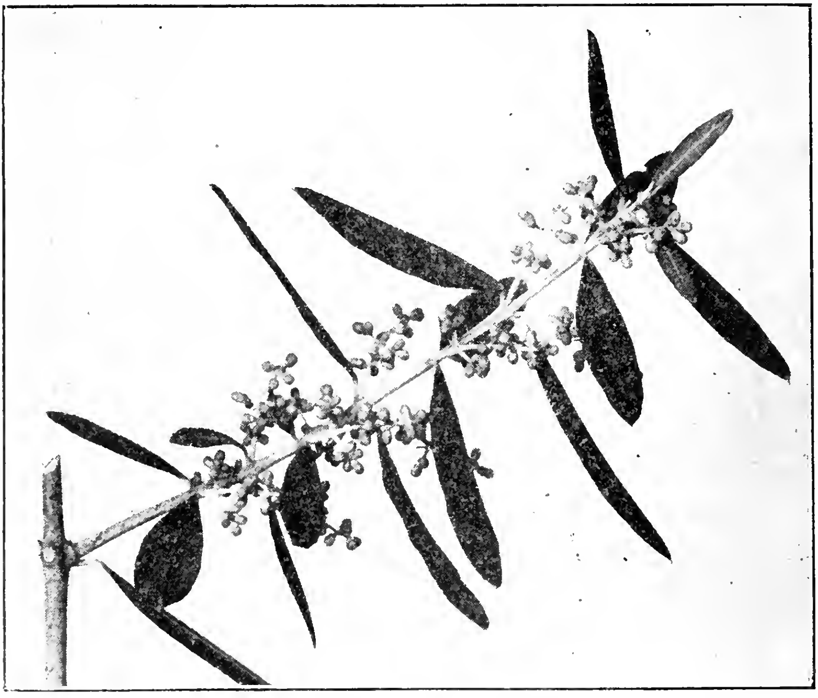


Fig. 2. Showing fruiting habit of the olive. Flowers borne on wood of previous season's growth.

annual rainfall of not more than four inches. In the Casa Grande and Salt River valleys isolated trees are growing and producing small crops without irrigation.

A peculiar growth is found on old trees in the form of enlarged swellings or burls on the trunk, extending about a foot above the surface of the ground, from which the roots radiate (Note the base of the old tree in foreground, Fig. 3). Another habit of the olive is that of forming suckers around the base. If allowed to grow without pruning, it develops several trunks and persists in throwing out protecting sprouts.

The olive is generally considered a slow-growing tree; but under favorable conditions its growth is quite rapid, as shown by five-year-

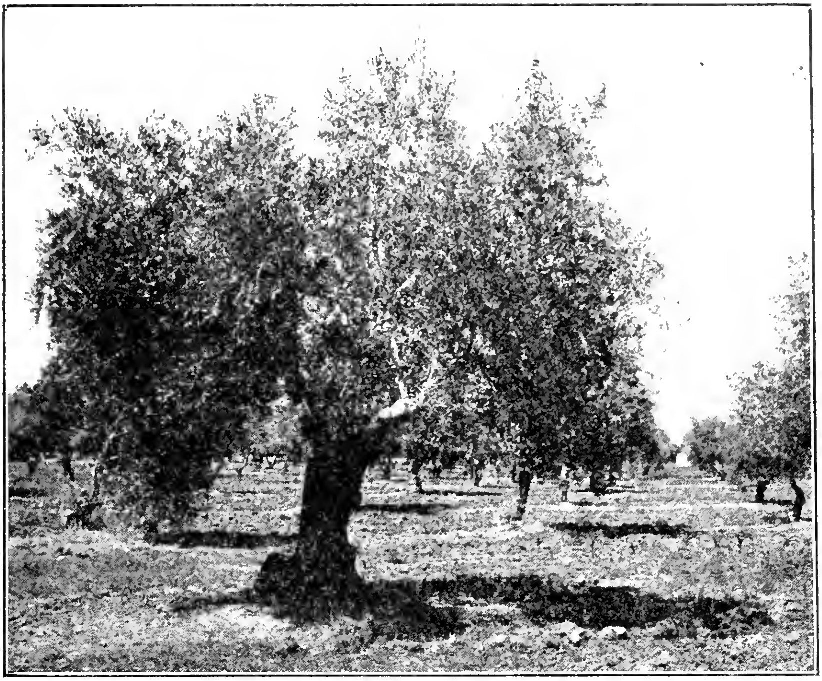


Fig. 3. Old olive orchard top-grafted to more desirable varieties.

old trees at the Yuma Date Orchard and Horticultural Station which have reached a height of fifteen feet and a spread of twelve feet. Figure 4 shows the growth of a Mission tree two years from planting (Salt River Valley Farm). Olive trees attain great age, as is evidenced by the old monarchs of the plant world growing in parts of Europe and Asia.

NATURAL REQUIREMENTS

The olive is easily grown under favorable conditions, but it is more exacting in its natural requirements than most fruits.

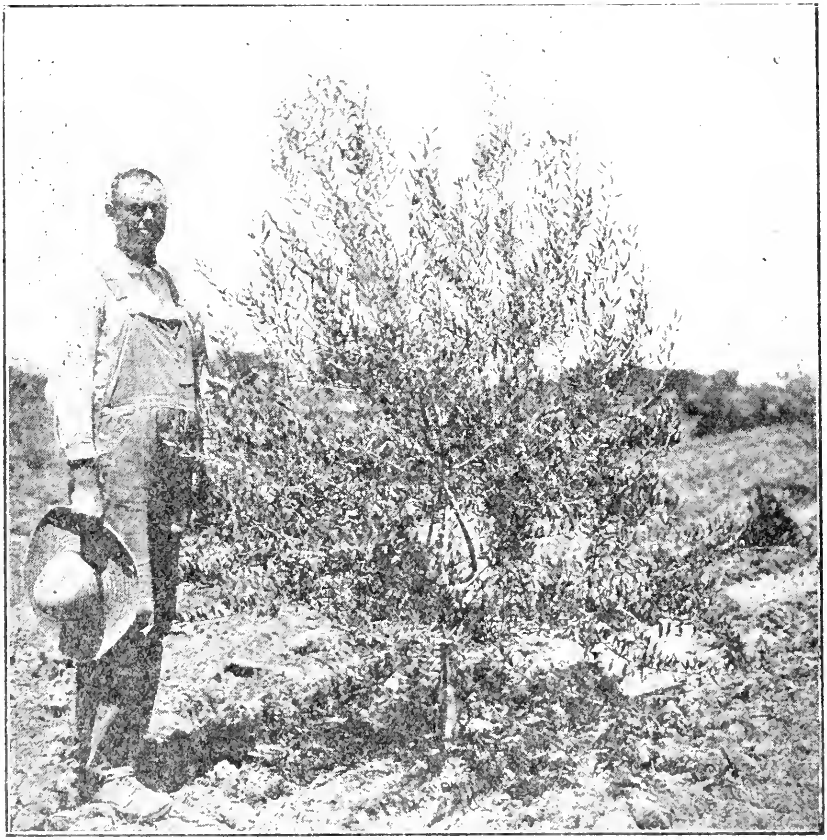


Fig. 4. Tree of the Mission variety at the end of the second growing season.

HEAT

The olive reaches greatest perfection in our warm southern valleys. Its dense foliage protects the fruit against direct sunshine, and summer temperatures of a hundred degrees or more are conducive to good growth and proper development of the fruit.

COLD

Well established olive trees withstand comparatively low temperatures. Bearing trees at Tucson survived a temperature of 6 degrees F. in 1913; but the outer foliage, buds, and young twigs were injured and bore no fruit the next year. At the same time young trees were frozen to the ground. It is inadvisable to attempt commercial plantings where the temperature falls below 15 degrees F. The fruit is injured with temperatures of 24 to 26 degrees F., but the crop is usually harvested before temperatures as low as these begin. Light frosts during blossoming do not injure the crop, but heavy frosts are disastrous. Temperature is perhaps the most important factor in Arizona in successful olive culture.

HUMIDITY

Arizona is especially suited to olive growing on account of its dry climate. The olive has never been able to accustom itself to high atmospheric humidity. In humid climates it is often seriously affected by insects and diseases, and the fruit is late in maturing. Rain at the time of blossoming or ripening of the fruit is a disadvantage, but rains seldom occur during these periods in Arizona.

TOPOGRAPHY

Olives succeed at various elevations in the State below 2500 feet. However, the suitability of localities between 2000 and 2500 feet elevation is largely dependent upon local topography. Often a high mesa may be comparatively free from severe freezes, while nearby valleys, on account of poor air drainage, are too cold for olives. The writer has observed a locality having an elevation of 2400 feet where olives are never injured by cold; whereas a short distance away in a narrow river valley all attempts to establish orchards have met with failure, because the trees were frosted. On high mesas and foothill slopes the trees bear earlier than in rich valleys; although in the latter they grow more rapidly and attain larger size.

SOIL

The olive is a comparatively shallow-rooted tree, and draws heavily upon the plant food of the surface soil. This does not permit the inference, however, that it will succeed on shallow, barren soils.

The tree is very tenacious of life and will live under such conditions, but the growth is slow and the yield of fruit limited. Soil of good fertility and physical character is required to produce high yields of fine-quality fruit. The trees do particularly well on calcareous soils. If hardpan is present it must be broken by dynamite or a subsoil plow to allow the roots to penetrate the better soil below.

OLIVE DISTRICTS

The natural requirements of the olive indicate that a large portion of southern Arizona is well suited to this tree. The sections of the State that stand out most prominently in this particular are the Salt River Valley; the Gila Valley, from Florence southwestward to Yuma; and the Colorado Valley, from Parker southward to Mexico. This includes not only the river valleys proper but extensive areas of adjacent mesa land, wherever water is available for irrigation. In addition to these districts, there are smaller ones in the southern part of the State where the olive will succeed.

PROPAGATION

Arizona has very wisely quarantined against olive stock from all outside sources in order to prevent the introduction of serious insects and diseases. This makes the propagation of the olive a subject of extreme interest and suggests a study of the leading methods of propagation.

HARDWOOD CUTTINGS

Large, mature branches one to two inches in diameter are used for making hardwood cuttings, and the work is done during January and February while the trees are dormant. The cuttings are made twelve to fifteen inches in length, tied in bundles of fifty or one hundred each, and buried horizontally to a depth of six to ten inches in moist sand, preferably on the north side of a building, where they are allowed to remain until spring (See Fig. 5). They are then planted in nursery rows three and one-half feet apart and fifteen inches distant in the rows. The soil should be packed well at the base of the cuttings and only the tips left exposed. As an extra precaution the tips may be coated with a film of melted grafting wax or covered lightly with loose soil. Under favorable conditions the cuttings may be set in the nursery as soon as made. This method of propagation is suited to the grower who wishes to produce his own stock from old trees of known qualities.

During the first summer a number of sprouts form at the top of

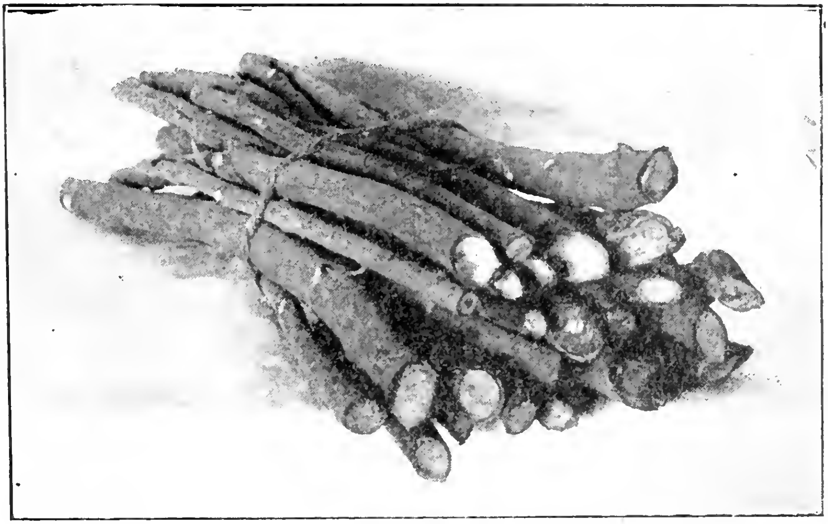


Fig. 5. Bundle of olive cuttings made from mature, large wood.

the cuttings. These are allowed to grow to strengthen the root system of the young plants. Just before growth begins the following spring, however, all sprouts except the strongest one, which is trained into the permanent tree, are removed. Such trees should be large enough to transplant to the orchard by the end of the second growing season.

SMALL CUTTINGS

Small cuttings are made from young shoots, and the tips and lower portions of the twigs are used. The cuttings are made four to six inches long, and all the leaves removed except a few at the top (See Fig. 6). They are set closely in boxes of clean sand with only the leaves and tips exposed (See Fig. 7) and rooted under a lath shelter. Roots form in four to six weeks, and in a few months the young plants may be set in good soil in nursery rows, twelve inches apart in the row and three and one-half feet between the rows. Such plants may

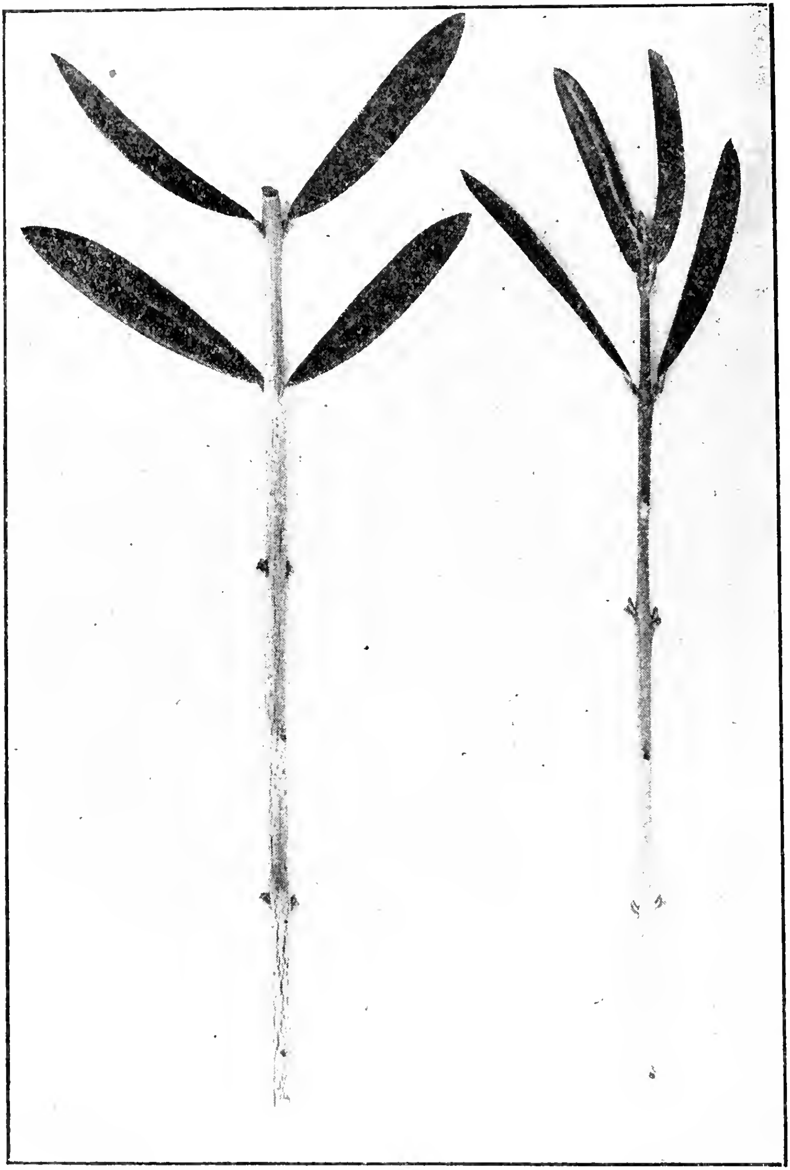


Fig. 6. Types of small olive cuttings, natural size.

be carried through the first season in good soil in pots or widely spaced in boxes. With good care these plants should be ready for the orchard in two years.

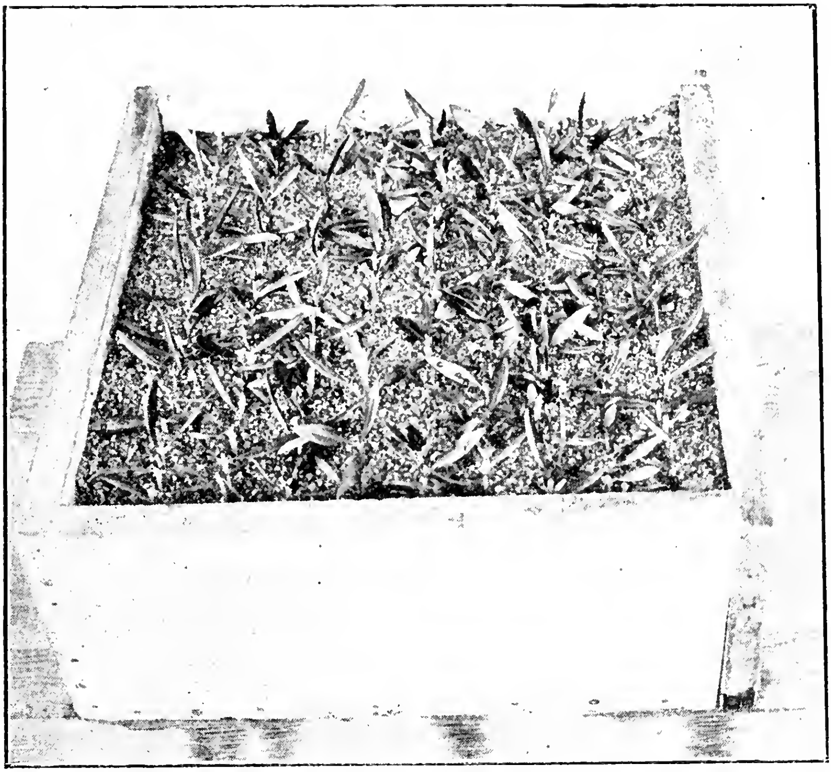


Fig. 7. Small olive cuttings in propagation box.

It is very important to take the small cuttings when the wood is in proper condition (neither too hard nor too soft), otherwise, the rooting will not be satisfactory. This is the most widely used method of propagating the olive. A larger number of cuttings can be made from a tree, and in addition, the plants have more symmetrical root systems than those grown from hardwood cuttings.

GRAFTING YOUNG STOCK

Grafting young seedling stock is practiced by some nurserymen, but this method of propagation does not carry advantages that recommend its use by the general grower. The ordinary bark graft (subsequently described under top-grafting) is largely used, the operation being performed on seedling stock, about three or four inches above the ground.

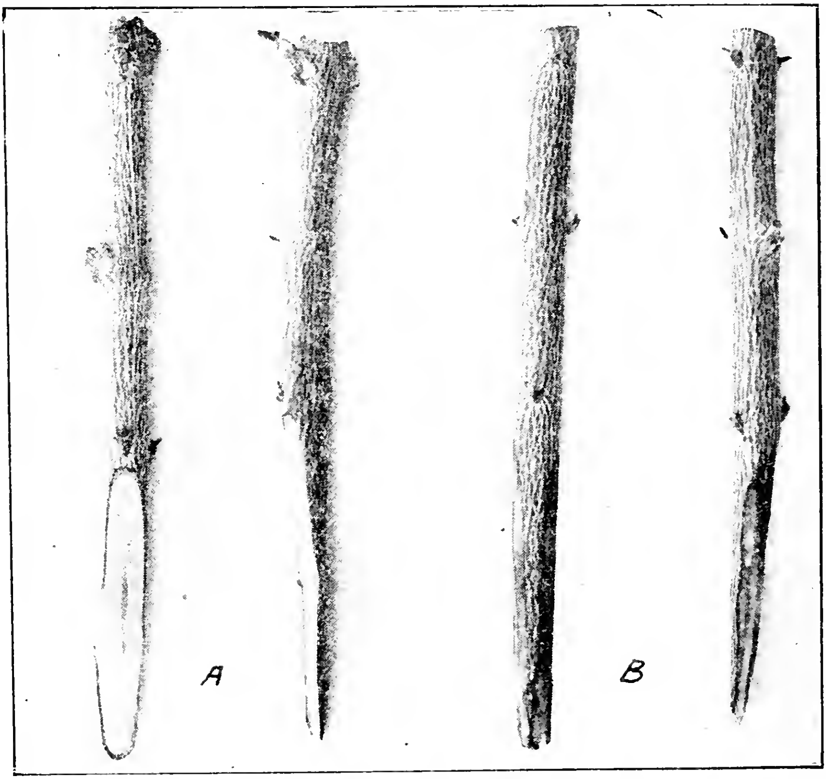


Fig. 8. Method of preparing scions for bark graft; (a) ordinary scion, (b) scion trimmed on back, exposing chlorophyll layer.

A discouraging feature experienced formerly in the growing of seedling stock for grafting was the length of time required for olive seeds to germinate, since they often remained dormant a year or more. However, this difficulty is overcome by clipping the ends of the seeds to allow the penetration of moisture. (See Bulletin 268 Calif. Exp. Station).

TOP-GRAFTING

Sometimes it becomes necessary to top-graft old trees with more desirable varieties, which is not difficult since the olive is quite amenable

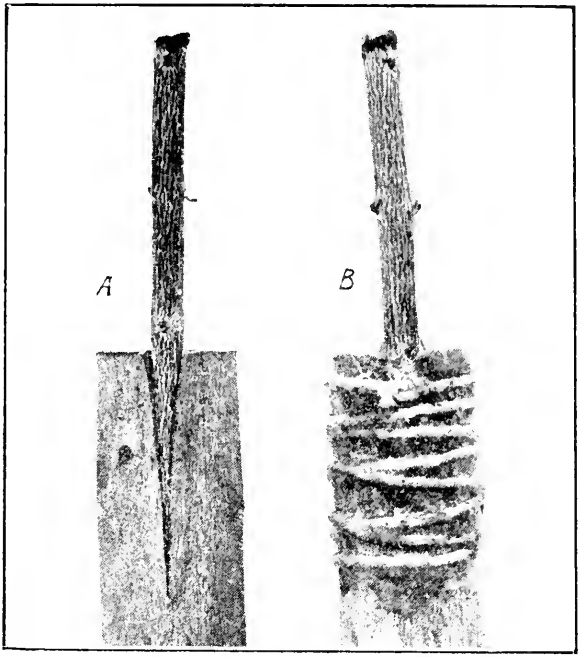


Fig. 9. Showing stock with scion inserted, and the completed graft.

to such treatment. Top-grafting can be done most successfully in spring by using the bark graft. Preparatory to grafting, the trees are cut back to stubs four and one-half to five feet from the ground. The bark is then split downward from the top about one and one-half inches and the scion, cut with a long single bevel, is inserted (See Fig. 9, A). The method of preparing scions for the bark graft is shown in Figure 8, one to four being used, depending on the size of the stock. A greater percentage of grafts will set if the scions are prepared as indicated in Fig. 8, B (the Biederman method) in which a portion of the outer bark on the back is removed. In thus exposing a larger surface of the green chlorophyll layer a better union is secured. The grafts are bound firmly in place with strong cotton twine and all exposed surfaces, including the top of stock and the tips of scions, are covered with melted grafting wax to prevent evaporation (See Fig. 9, B). Scions are made from mature, two to three-year-old wood about one-fourth to three-eighths inch in diameter. The wood should be cut late in winter and kept in a dormant condition until used. This may be done by tying it into bundles which are buried in cool, slightly moist sand on the north side of a building, or placed in cold storage at a temperature of about 45 degrees F.

Experience has shown that ordinary grafting wax will melt and run in southern Arizona during hot days. In a series of tests to find a wax that would resist the heat of summer without melting or becoming brittle, paraffin having a melting point of 65 degrees C. was found most satisfactory. This grade of paraffin is not common on the market, and parowax is suggested as a substitute. It is necessary to boil down the parowax until it will remain firm at a temperature of 115 degrees F.

PLANTING

Good results have been obtained by this Station from plantings made in the winter and spring. However, better growth was obtained by planting from the middle of February to the latter part of March, just preceding the growing season. The temperature of the soil and air is moderate at this season and well suited to the growth of newly planted olive trees.

DISTANCE APART FOR PLANTING

The fact that the olive is long-lived, makes the distance apart for planting a question of great importance. For the best development of the tree and the finest quality fruit, there must be space enough between the rows so that the branches will not touch, thus permitting sunlight to reach the tree from all sides. A distance of thirty-five to forty feet apart is good spacing for commercial planting. Figure 10 illustrates an orchard with the trees well spaced. The distance may be varied slightly in different soils, because the lighter soils do not produce as strong growth as the heavier soils. Differences in the growth of varieties influence the distance of planting; for example, the Manzanillo variety is much less vigorous than the Mission, and consequently may be planted closer together.

PLANTING THE TREE

A wide, deep hole is necessary to insure sufficient loose soil for strong, rapid root development. If hardpan exists it should be blasted. The trees should be set two to three inches deeper than they grew in

Fig. 10. Eight-year-old olive orchard, showing good spacing.

the nursery. After the soil is thoroughly settled, the tree will be at the proper level. When the tree is set the roots are spread out horizontally, with the tips pointing slightly downward, and soil is packed around them by hand. Irrigation should follow immediately, which will settle the soil about the roots in a way that is impossible to accomplish by packing. If not convenient to irrigate soon after planting, one or two bucketfuls of water should be poured around the roots of each tree during planting. The orchard should be cultivated in order to form a loose soil mulch around the trees, as soon after planting as the condition of the ground will permit.

TRIMMING THE ROOTS AND TOP

It is particularly important that the roots and top of an olive tree be cut back at the time of transplanting. The larger roots are trimmed smoothly and shortened to a length of six to ten inches, and the smaller root masses thinned. After the tree is set, the central leader or main

Fig. 11. Young tree properly cut back at time of planting.

trunk is cut back to three feet from the ground and the branches shortened to mere stubs. On account of their larger size and longer life, olive trees are headed higher than ordinary fruit trees (See Fig. 11).

CULTURE

Because the olive can endure a great deal of neglect, one must not infer that it will thrive and bear successful crops under improper or careless methods of culture. A study of the olive orchards of the State shows conclusively that the growth and yield of the trees and the quality of the fruit are directly proportional to the character of the cultural conditions.

TILLAGE

Tillage is important in maintaining the proper physical condition of the soil, preserving moisture, and rendering plant food available. At least once each year, preferably during winter when the trees are less active, the orchard should be thoroughly plowed. If the soil remains long unbroken, masses of feeding roots accumulate near the surface, which will be injured when the plowing is done, thus disturbing the growth of the trees more than if the work is done regularly. The depth of plowing should be varied from year to year to avoid the formation of a hard, impervious plow sole.

The orchard should be kept cleanly cultivated when the land is not occupied by a cover crop. The principal direct benefits of cultivation are conservation of soil moisture, eradication of weeds, and aeration of the soil. The soil should be stirred to a depth of four or five inches every two or three weeks during summer.

COVER CROPPING

Cover crops which supply plant food and humus have an important place in the olive orchard. Although some of our valley soils are quite fertile, the yields of most olive orchards could be increased and the quality of the fruit improved by growing cover crops between the rows. The method followed and the kinds of crops used depend a great deal on the condition of the orchard. In some cases the growing of winter legumes, such as common or hairy vetch, alfalfa, or sour clover is satisfactory; in others, summer cover crops, such as cowpeas, tepary or soy beans are best; and in still others (if water is expensive) the use of winter and summer cover crops is the best practice.

Alfalfa is sometimes grown for hay in the olive orchard. This may be done while the trees are young, if the soil is fertile and a cleanly cultivated strip is maintained along the tree rows; but the practice is not desirable in bearing orchards, as the trees need all the available plant food. Generally, alfalfa should not be grown in the orchard for more than two or three years or until the roots have penetrated to a sufficient depth in the subsoil to make possible better aeration for the trees.

FERTILIZING

Olive orchards must be well supplied with plant food, otherwise they will not produce maximum crops of large fruit. According to analyses made by the Experiment Station chemists, most Arizona soils contain an abundance of the essential elements of plant food, except nitrogen, which can be supplied through the use of leguminous cover crops and stable manure. Usually, if cover crops are grown and the orchard is cultivated, first-class olives can be produced without using artificial fertilizers.

IRRIGATION

The olive will remain alive with a very meagre supply of water, but it will not bear fruit. Measured by the standard of common fruits it requires approximately the same amount of water as the deciduous fruits, and about one-half as much as the citrus fruits. Unless careful attention is paid to the amount and time of irrigation, the orchard will not respond with regular crops of first-class fruit. There are three special periods when bearing orchards should be irrigated, based on the yearly life cycle of the tree. The first irrigation should be in early spring before the trees come into blossom. The application of water during blossoming often causes the flowers and young fruit to drop. The second irrigation should be in the middle of summer, while the fruit is in the growing stage, and the third one in September, as the fruit is nearing maturity. The last irrigation materially increases the size of the fruits and is an important matter where the crop is grown for pickles. In the absence of winter rains one or more irrigations are necessary during this season.

PRUNING

Unless young trees are properly trained, they will not form strong, well-placed branches; nor will bearing trees produce regular crops of large, good-quality fruit if not carefully pruned.

The main objects for pruning olive trees are as follows:

(a) To develop a strong, well-shaped tree;

(b) To encourage regular growth of strong, productive wood;

(c) To eliminate weak, non-productive wood; and,

(d) To secure regular crops of large, uniform fruit.

PRUNING THE YOUNG TREE

The first three or four years an olive tree must be pruned so as to develop a perfect framework of limbs. Numerous sprouts usually appear on the tree the first summer; when they are eight to ten inches long they should be thinned to six or seven in number, distributed along the trunk twelve to fifteen inches from the top (See Fig. 12). This is a larger number than necessary for permanency, but if too little growth is left, the tree will be slow in becoming established. On the other hand, if all the sprouts are allowed to remain until the end of summer, none will have developed into strong branches.

Winter pruning consists in reducing the branches to three or four in number, three being preferable if properly distributed. The remaining branches will form a part of the permanent framework of the tree, and should be well selected. They should be located so as to form a well-balanced top, and spaced not closer than four to six inches (See Fig. 13). If the branches have made proper growth, they should be cut back fifteen to eighteen inches from the trunk.

During the following summer the trees should be gone over at least two or three times. Frequently vertical shoots form on the body of the tree or on the scaffold limbs, near the base. These should be removed early because their further development would be at the expense of useful branches.

The second winter after transplanting, the shoots on the scaffold branches should be thinned to allow two laterals on each limb as a continuation of the main framework of the tree. Whether or not these leaders are shortened at this time depends on their size. If stocky and of an ascending habit, they should not be cut back; but if long and slender, tending to droop or assume a vertical position, they should be shortened.

The next summer the trees should be gone over two or three times to remove water-sprouts and to prevent irregular growth. In some cases the latter may be accomplished by removing a branch or sprout; in others by pinching out the top. More can be done towards properly training a tree by frequent attention during the summer than by heavy winter pruning.

Fig. 12. Thinning of young tree during first growing season.

By the third winter the tree should have a framework of strong, well-spaced branches, requiring very little subsequent pruning except light thinning. However, if any of the branches are very tall they should be shortened to properly located side branches; and if they grow in the wrong direction, they should be removed. The aim should be to develop a tree of round, wide-spreading form. Tall, upright-growing trees allow less exposure of the fruit-bearing surface than open, wide-spreading trees, and the fruit of the former is more difficult to harvest.

The pruning of young olive trees may be briefly summarized as follows:

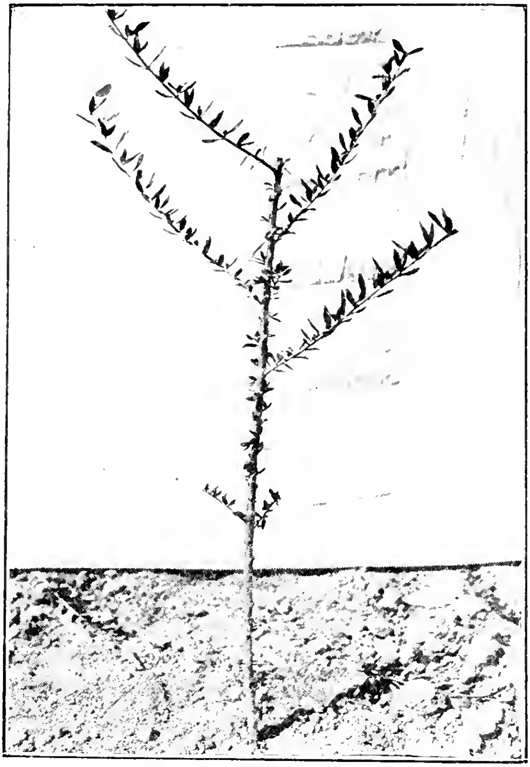


Fig. 13. Final selection of framework branches. (Note distribution).

(a) First Summer: Thin to six or seven well-selected shoots.

(b) First Winter: Remove all except three or four well-placed branches and shorten to approximately fifteen or eighteen inches.

(c) Second Summer: Keep upright shoots removed and pinch back shoots appearing on trunk.

(d) Second Winter: Thin side shoots on main branches, allowing two strong laterals on each as a continuation of the framework.

(e) Third Summer: Keep off water-sprouts; remove or pinch back branches where necessary.

(f) Third Winter: Thin out top and shorten the over-vigorous leaders.

PRUNING BEARING TREES

Bearing olive trees must be pruned carefully and regularly if annual crops are to be secured and fruit of the proper size and quality for the best grade of ripe olives produced. It is difficult to prescribe definite methods of pruning trees of this age on account of the individual differences in growth. Certain principles, however, are generally applicable. In most cases the trees send out strong vertical branches, which if allowed to remain will bear very little fruit except at the top. Ordinarily these branches are removed, but if the tree is much exposed they may be cut back to side branches. The shortening of top branches should be done with caution, as there is danger of the tree-tops becoming too crowded. Sunlight and air are required for the proper development of wood and fruit; consequently, the top of the tree must be kept open. This does not mean that large openings should be made at any point, but that the treatment should permit the even distribution of dispersed sunlight throughout the tree. Failure in this will lessen the size and quality of the crop and cause the fruit to be borne largely on the outer and upper parts of the tree, whereas it should form on the inside as well.

A careful watch should be maintained for weak, diseased, and injured parts, which must be removed in order that the space may be occupied by vigorous, useful wood. Not infrequently such treatment, together with thinning out crowded parts of the top, will be all the pruning required.

It is not good practice to shear back the branches of olive trees to mere stubs. This causes a thick, abnormal growth of side shoots, excludes sunlight and weakens useful parts of the tree. In shortening a branch, the cut should be made just above a side shoot.

TIME TO PRUNE

Olives should be pruned at least three times during the year, once late in winter just preceding active growth and twice during the summer. Under no circumstances should a young orchard go through the summer without being pruned, as the trees will assume improper shapes; and later efforts to correct them will retard development and fruit bearing. It is also important that older orchards be pruned during the summer, sometimes to the extent of removing fruiting branches. When trees are heavily loaded it is better to thin out the weaker fruit-laden branches than to have small, inferior fruit or run the risk of the trees expending so much energy in developing the crop that they will not bear the following year.

INTERPLANTING

The spaces between olive rows should be utilized in the growing of other crops. It is possible to secure paying inter-crops without injury to the trees until they are eight or ten years old, at which time the orchard itself should yield profitable returns. Truck crops, early bearing fruits such as the grape and peach, or field crops may be used for this purpose. Although the growing of other crops in an olive orchard is highly desirable, the trees must not be neglected for the sake of the secondary crop. It is easily possible for an inter-crop to rob the trees of moisture and plant food; however, the orchard can be handled so that good returns may be secured from the inter-crop without injuring the trees. Whatever crop is used, a cleanly cultivated strip should be maintained along the tree rows, its width depending upon the size of the trees.

The grape has proved a most satisfactory fruit for interplanting with olives, because it comes into bearing early and the vines do not hinder the full spread of the trees. Mr. B. F. Carper of the Salt River Valley has used this combination very satisfactorily, having secured from his five-year-old orchard a yield of one and one-third tons of olives and one ton of grapes per acre. The peach and the apricot have also been used very successfully as fillers where the trees were pruned to prevent crowding the olives.

Fig. 14. Five-year-old olive orchard interplanted with Thompson seedless grapes. Owned by B. F. Carper, Salt River Valley.

HARVESTING

The proper time to harvest olives for ripe pickles is when the oil has completely formed in the fruit. Unless the fruit has reached this stage of maturity when pickled, it will be largely devoid of the rich nourishment and fine flavor which make the ripe pickled olive so highly desirable. On the other hand, if the fruit remains on the tree any length of time after reaching its full oil content, the quality is seriously impaired.

In consideration of the market demand, color also plays an important part in deciding when olives may be harvested. The trade prefers an olive that is black. Although the fruit of most varieties is ripe when the skin becomes diffused with red, it must remain on the tree longer to attain the desired color. Since the fruit ripens unevenly, several pickings may be necessary. Ripeness may be further indicated by the "feel" of the fruit, which is slightly soft to the touch when fully mature. It is a common practice to test the ripeness by pressing out the juice of the fruit and allowing it to stand for some minutes. If minute globules of oil rise to the surface, the fruit is ready to be gathered either for ripe pickles or oil.

The most important point to be observed in gathering olives for pickling is to prevent their being bruised. If the fruit is even slightly bruised its quality is seriously impaired, and the way is open for bacterial growth and decay.

The best receptacles to use in picking olives are canvas bags, such as are used for gathering oranges. When buckets are used, they should be lined with cloth or burlap. The lug boxes used in carrying the fruit from the orchard should not be filled more than one-half to two-thirds full. If the fruit is to be kept for some time before processing, it should be placed in a brine made by dissolving one pound of common salt in five gallons of water. Handled in this way, olives may be shipped great distances by truck or rail, as they will keep perfectly for several weeks.

It is not necessary to exercise the same care in harvesting olives for oil as for pickles. The olives may be pulled off the trees and allowed to drop onto canvas. A wooden comb with teeth wide apart is sometimes used for stripping the fruit from the trees. It is practicable to ship oil olives in sacks, but if the distance is great the fruit should be dried somewhat before shipment.

GRADING

Olives used for pickles must be carefully graded according to size. This is necessary because uniformity in size adds to the attractiveness of the fruit, making it more salable than if the sizes are mixed, and lessens the difficulties of processing. It is practically impossible to process all grades of olives together and obtain a uniform product. Several types of machinery are used for grading olives, all based on the variation in the shortest diameter of the fruit and having a sixteenth of an inch as the unit of measurement. At least four grades should be made, designated as follows:

Extra Fancy: All fruit failing to pass through a 15/16-inch mesh;
Fancy: All fruit passing through a 15/16-inch mesh but failing to pass a 13/16-inch mesh;
Large: All fruit passing through a 13/16-inch mesh but failing to pass an 11/16-inch mesh.
Small: All fruit passing through an 11/16-inch mesh, but failing to pass a 9/16-inch mesh.

AGE OF BEARING AND YIELD

A small crop may be expected the fourth year from planting; and a yield of approximately one to one and one-half tons per acre the fifth year. After that the yields should increase from year to year until the trees are in full bearing, when the average production per acre should be not less than five to six tons. A yield of four and one-half tons per acre was secured some years ago at the Station Farm west of Phoenix; this was from ten-year-old trees of the Columella variety set forty feet apart. The percentage of oil in the fruit as well as the yield increases as the trees become older.

VARIETIES

Varieties of olives differ in size, color, quality, and other characteristics. A large number of varieties are suitable for oil, a less number for green pickles, and still fewer for ripe pickles. A good ripe-pickle variety must be well colored, firm, and of good size.

A number of varieties have been tested by the Arizona Agricultural Experiment Station. Some of these have meritorious qualities, but none equals the Mission. Therefore, until a variety of large size possessing the high qualities of the Mission is found, this old standard sort must remain the leading commercial variety for ripe pickles. In the meantime, the olive grower should use the best cultural practices with the Mission variety, even resorting to thinning, in order to produce fruit of large size.

Following is a list of the varieties growing on the University Campus: Nevadillo, Regalis, Altro Violacea, Mission, Pendulina, Uvaria, Oblonga, Precox, Morinello, Rubra, Cayon, Manzanillo, Frautoia, Razza, Grossia, Correggiola, and Columella. The trees were planted April 1, 1895, making them about twenty-six years old. The first winter after planting they were killed back to the ground but came out again the following year. The trees have succeeded remarkably well considering the rather unfavorable soil conditions, and have seldom failed to set good crops. Typical fruits of these varieties are illustrated in Plates I, II, III, IV, and V.

A detailed description of the varieties tested by the Arizona Experiment Station at Tucson is given below. The measurement of the fruit was obtained by securing the average of a large number of typical specimens.

MISSION

Fruit of medium size, 12 x 16-sixteenths of an inch, broadly oval, tending slightly to conical, oblique, borne singly or in clusters, and of excellent quality; flesh very firm and withstanding comparatively rough handling; season of ripening from the latter part of October to December, the fruit not dropping readily. Tree large, very vigorous, hardy, blossoming from April 10 to 25, partly self-sterile. Self-sterility is overcome by interplanting with other varieties, particularly the Manzanillo which is often used for this purpose in Arizona. The Mission is the leading variety for ripe pickles and oil.

RAZZA

Fruit of large size, 14 x 20-sixteenths inches, ovate, tending to oblong, of inferior quality and dropping badly after maturity; season of ripening from early October to the middle of November. Tree hardy, large, vigorous, blossoming from April 5 to 20, self-sterile. This variety does not make satisfactory ripe pickled olives, but may be used for green pickled ones.

MANZANILLO

Fruit above medium size, slightly larger than that of the Mission, 14 x 18-sixteenths inches, from almost round to slightly oval, ripening and coloring uniformly, and with very good flavor; flesh less firm than in the instance of Mission olives, and hence the fruit requires more careful handling; season of ripening from the middle of October to the middle of November. The fruit drops badly if the picking is long delayed after maturity. Tree of medium size, less vigorous and less hardy than the Mission; heavy annual bearer, and blossoming about the same time as the Mission, April 10 to 25; self-fertile. This is an excellent olive for ripe or green pickles, ranking next to the Mission, and is the kind so extensively used for pimento olives.

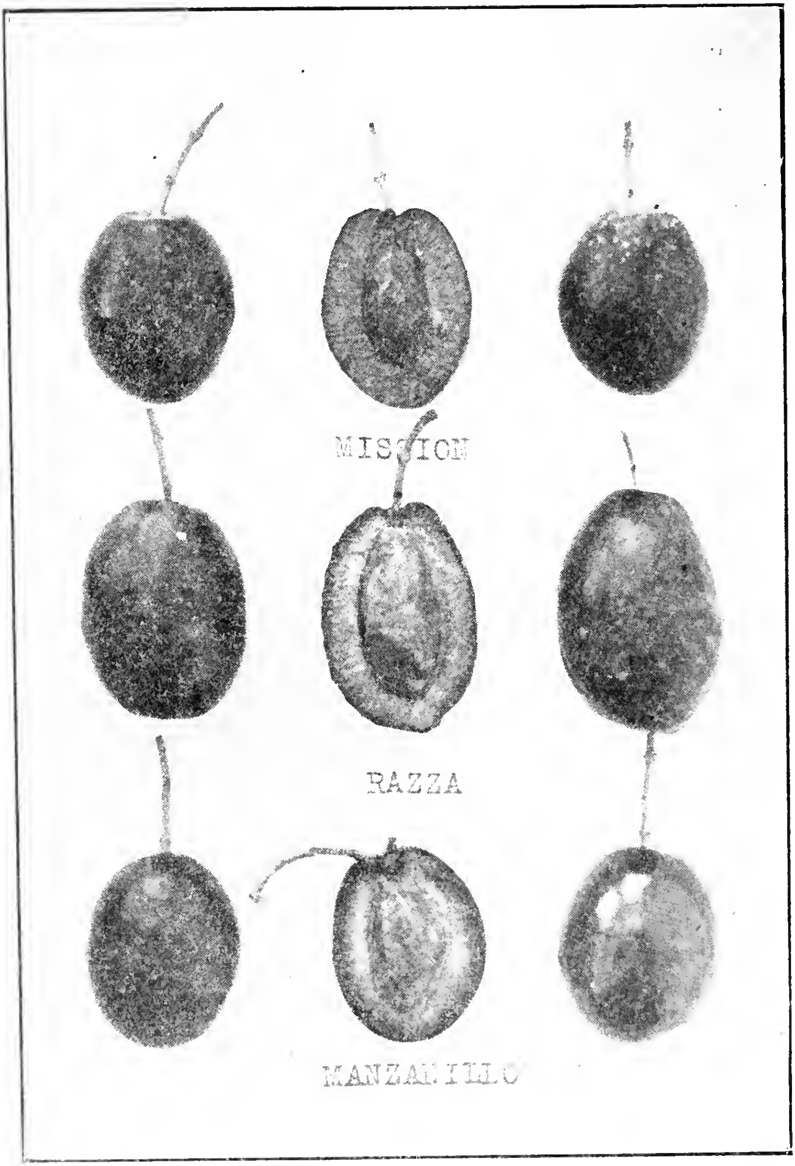


Plate I. The Mission, Razza, and Manzanillo olives (slightly less than natural size).

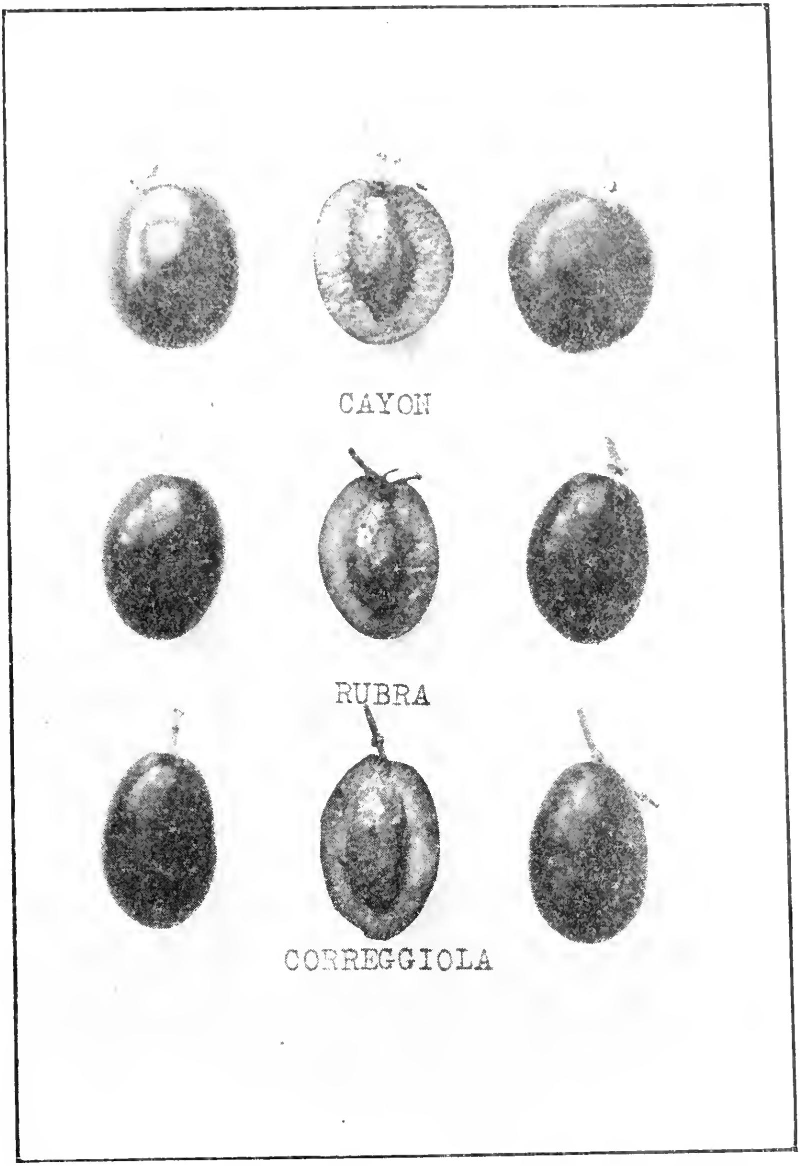


Plate II. The Cayon, Rubra, and Corregiola olives (slightly less than natural size).

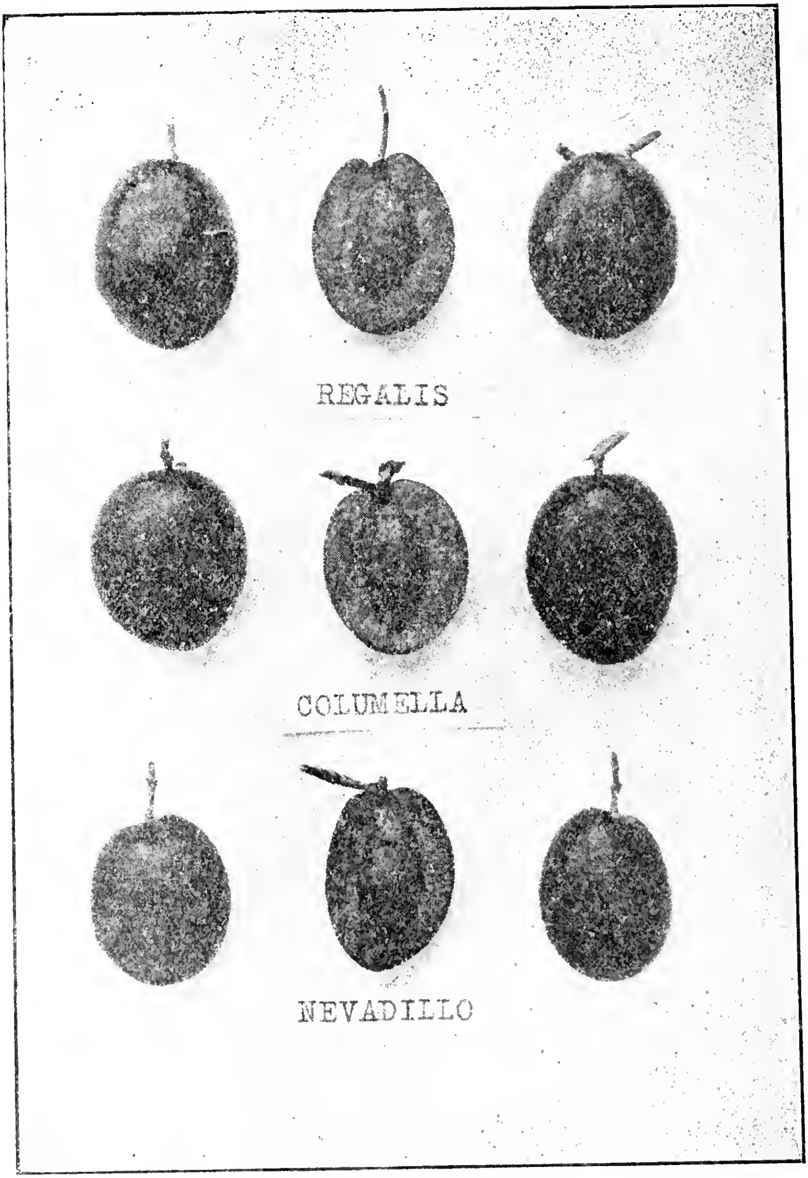


Plate III. The Regalis, Columella, and Nevadillo olives (silghtly less than natural size).

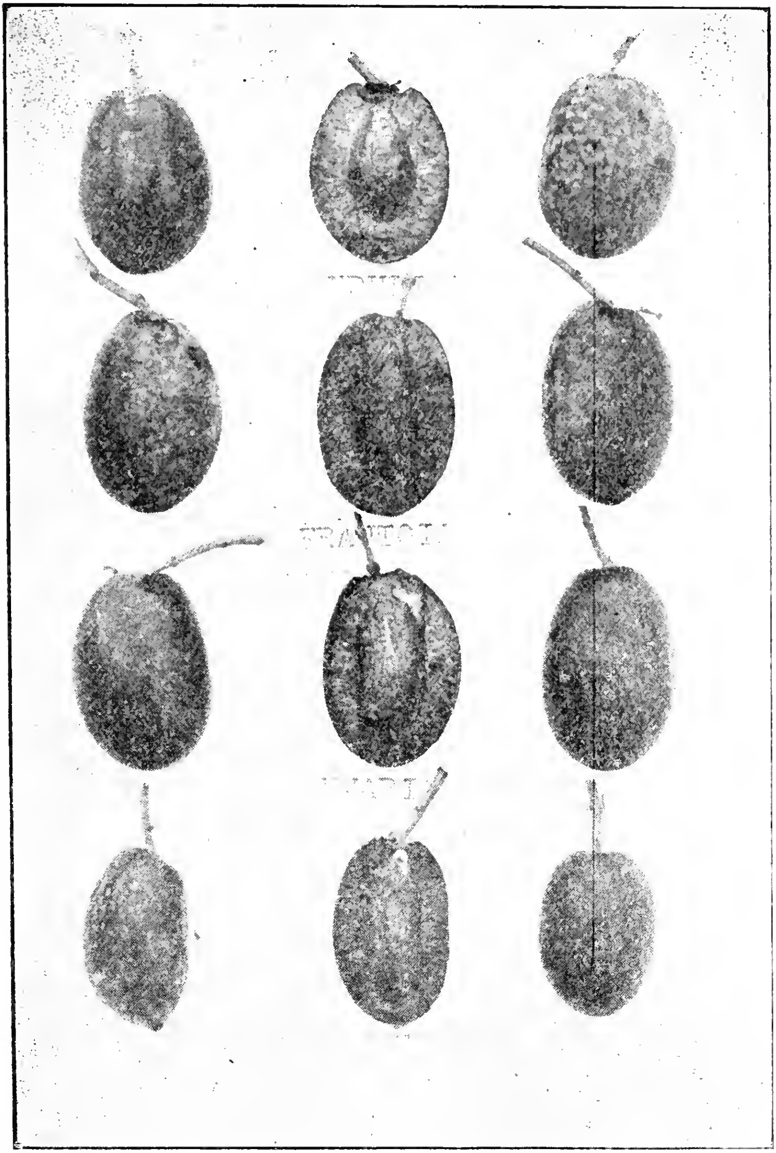


Plate IV. The Pendulina, Frantoia, Uvaria, and Atro Violacea olives (slightly less than natural size).

REGALIS

Fruit of medium size, 12 x 16-sixteenths of an inch, broadly ovate; ripening unevenly, the quality being rather inferior; season middle of November to the middle of December. Tree of medium size, tender to frost, blossoming from April 20 to May 10. Makes fairly satisfactory ripe olive pickles but is said to be of little value for oil.

COLUMELLA

Fruit of small to medium size, 12 x 15-sixteenths of an inch, roundish-ovate, tapering to a roundish point at the apex, with very rich flavor and little bitterness; season of ripening very late, from December to January, the fruit hanging on the tree until spring. Tree vigorous, hardy, prolific, blossoming from April 5 to 25. The season of this olive is too late to warrant commercial plantings in Arizona.

NEVADILLO

Fruit of small to medium size, 11 x 15-sixteenths of an inch, elongated-ovate, slightly pointed and somewhat resembling the Mission olive; usually borne in clusters of three to five; season of ripening from the middle of October to December. Tree large, vigorous, a regular bearer, rather tender to frost, blossoming from April 10 to 25. This variety does not make high quality pickled olives, but is said to be very satisfactory for oil.

CAYON

Fruit of small to medium size, 12 x 14-sixteenths of an inch, ovate, rounded at both ends; season of ripening from the middle of November to the middle of December. Tree of medium size, with thick growth of top, blossoming from April 10 to 25, self-fertile. This variety has proved a shy bearer in Arizona.

RUBRA

Fruit of small size, 10 x 14-sixteenths of an inch, similar in shape to that of the Mission; flesh very soft when the fruit is ripe; season of ripening from November 1 to the middle of December. Tree of medium size, hardy, slow growing, and only fairly productive, blossoming from April 10 to 25. This variety cannot be recommended as a ripe pickle olive.

CORREGGIOLA

Fruit of small size, 10 x 16-sixteenths of an inch, oblong, tapering slightly towards the stem end, ripening unevenly from December to

May, and hanging on the tree without shriveling. Tree very vigorous, hardy, prolific, tending to overbear in alternate years. The unevenness of ripening and the exceedingly bitter quality of the fruit make it undesirable as a pickle olive. This variety is considered well suited for oil.

PENDULINA

Fruit of medium size, 11 x 15-sixteenths of an inch, variable and often remaining small and undeveloped, oval, rounded at both ends, and borne in clusters of two to five; season of ripening from the middle of October to the middle of November. Tree vigorous, hardy, prolific, blossoming from April 5 to 25, self-fertile. This fruit makes fairly satisfactory ripe pickled olives but is considered better suited for oil.

FRAUTOIA

Fruit of medium to large size, 12 x 17-sixteenths inches, distinctly ovate, regular, very slightly pointed at the apex; season of ripening late, from the middle of November to the middle of December. Tree large, vigorous, fairly prolific, slightly tender to frost, blossoming from April 5 to 20.

UVARIA

Fruit of medium to large size, 12 x 17-sixteenths inches, ovate, regularly rounded at both ends, and borne in clusters of three to seven; season November, the fruit ripening uniformly; flesh quite soft, and the pit large. Tree medium size, heavy bearer, rather tender to frost, blossoming from April 15 to May 1, self-fertile. Desirable for green pickled olives but too soft for satisfactory ripe pickled ones.

ATRO VIOLACEA

Fruit of small to medium size, 9 x 16-sixteenths of an inch, oblong, slightly oblique and pointed at the apex, with the flesh soft and slightly colored; season of ripening from the middle of October to December. Tree vigorous (more so than the Mission), hardy, and a somewhat irregular bearer, blossoming from April 10 to May 1, self-sterile. The fruit is too soft for satisfactory ripe pickled olives, and is valuable chiefly for oil.

MORINELLO

Fruit of small to medium size, 12 x 14-sixteenths of an inch, quite regularly roundish-ovate; flesh rather heavy; season of ripening very late, from November to April, the fruit ripening unevenly. Tree vigorous (about the same as the Mission), slightly tender to frost; a

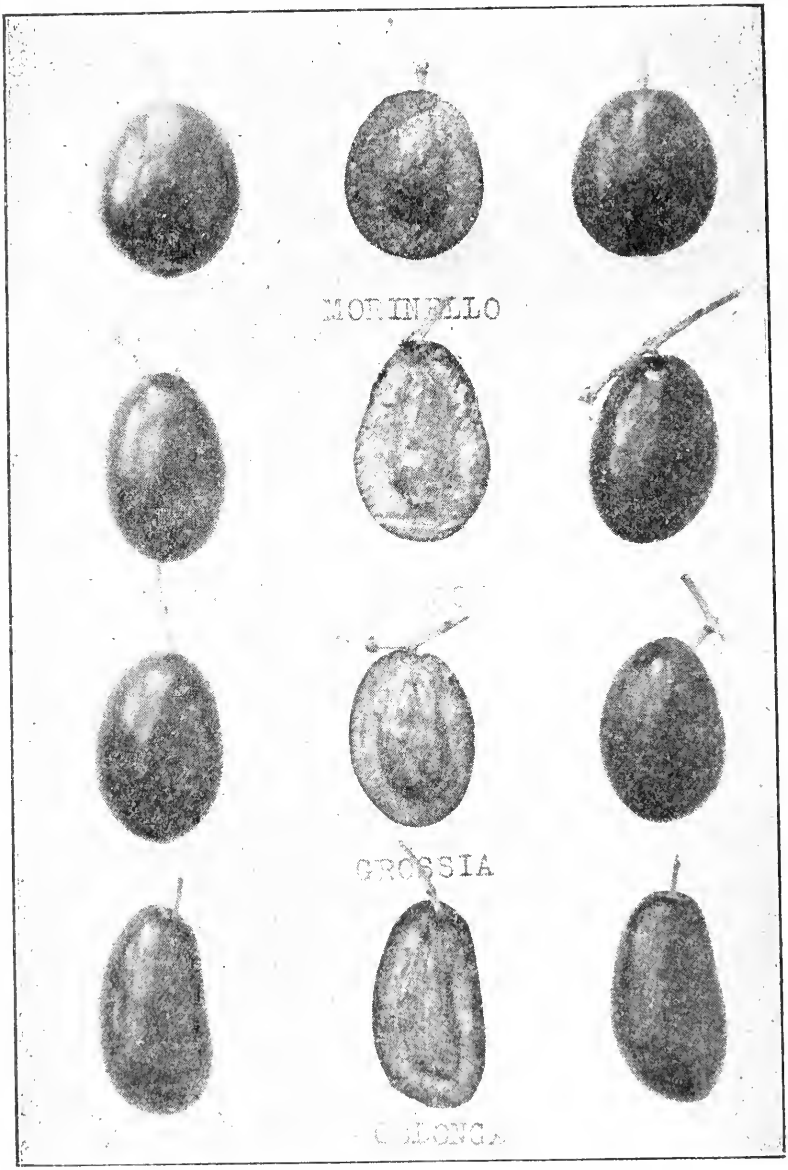


Plate V. The Morinello, Precox, Grossia, and Oblonga olives (slightly less than natural size).

heavy bearer in alternate years and blossoming from April 5 to 20. On account of its unevenness in ripening this variety is not suitable for either ripe or green pickled olives.

PRECOX

Fruit of small to medium size, 10 x 15-sixteenths of an inch, ovate, tapering toward the stem end, ripening unevenly; pit very large; season of ripening from October 15 to December 1. Tree of medium size, slow growing, hardy, a shy bearer, and blossoming from April 10 to 30. This variety has not proved satisfactory in Arizona.

GROSSIA

Fruit of medium size, 11 x 15-sixteenths of an inch, ovate, rounded at both ends, ripening unevenly; pit large; season of ripening from November 10 to December 20. Tree vigorous, hardy, prolific, blossoming from April 10 to 25. Not satisfactory for ripe or green pickled olives; distinctly an oil olive.

OBLONGA

Fruit of medium size, 10 x 18-sixteenths inches, oblong, larger at the apex and narrow at the stem end, strongly oblique, ripening unevenly; season of ripening from the middle of October to the middle of November. Tree upright, large, fairly heavy bearer, blossoming late, from April 15 to May 5, self-fertile. The fruit makes very satisfactory ripe or green pickled olives and is said to be very desirable for oil.

PICKLING RIPE OLIVES

The main objects to be obtained in pickling olives are the removal of the bitterness, the preservation of flavor, and the retention of firmness. The bitter property of olives varies according to the variety, stage of maturity, and character of the orchard soil. Consequently, not any one method of procedure is applicable to all kinds of olives. Successful processing is very largely a matter of experience, careful observation, and good judgment, backed by proper cultural practices. An orchard must be so handled as to produce fruit of good size, color, and quality if a first-class product is to be secured. Although no set rule can be laid down for making ripe pickled olives, certain principles pertaining to the different methods employed are generally applicable. They are given with the understanding that they must be modified according to the condition of the fruit.

LYE PROCESS

The olives are placed in the processing vat and covered with a lye solution, varying in strength from one to four ounces to the gallon of water, according to the condition of the fruit. Two ounces of lye to the gallon of water is most acceptable when the olives are in prime condition for pickling. The olives are allowed to remain in the solution, with frequent stirring, until the lye has penetrated almost to the pit, which usually takes from eight to forty-eight hours, depending on the condition of the fruit and the strength of the lye solution. Recent tests in processing the Mission variety gave fifteen hours for two-ounce, ten hours for three-ounce, and eight hours for four-ounce lye solutions. The point of penetration is marked by a slight discoloration of the flesh. The fruit should be examined frequently to prevent too long or too short treatment. If the first treatment does not remove all the bitterness, the operation should be repeated.

The lye is removed by rinsing and soaking the olives in fresh, pure water, which is changed twice daily. The washing is continued until no trace of lye is present, this being determined by the taste or by the use of red litmus paper. Sometimes the olives have a tendency to soften, in which case it is necessary to soak the fruit in brine (four ounces of salt to the gallon of water) before washing, until it has regained its firmness. In extreme cases of softness, salt may be used with the lye solution.

Immediately after soaking in the lye solution, the olives are given a series of brine treatments. The strength of the brine is gradually increased to prevent shriveling and wrinkling, and each treatment is continued until the solution has penetrated to the pits. The first brine is made of four ounces of salt to the gallon of water and allowed to stand on the olives two to four days. It is then replaced by a brine containing six ounces of salt to the gallon of water, which is left six to eight days. This solution is in turn drawn off and the olives are allowed to stand ten days to two weeks in a ten-ounce brine. Finally, a fourteen-ounce brine is used in which the olives remain until canned.

The brine commonly used in canning is made of four ounces of salt to the gallon of water. Where the olives are insufficiently colored, the brine may be drawn off and the fruit exposed to the air until properly darkened, which often requires only a few hours.

SPECIAL CONSIDERATIONS OF THE LYE PROCESS

1. Use a good grade of lye of known strength.
2. Use pure water for soaking the olives and for making the lye and brine solutions.
3. Avoid the use of metal containers and prevent the olives from coming in contact with anything that would impair their flavor, which means that all vessels used in handling the fruit must be kept absolutely clean.
4. Processing vats should be provided with the following: (a) removable false bottoms and spigots to permit thorough drainage of the fruit after each treatment; (b) close-fitting, floating covers to exclude air, which spots the fruit; and (c) tight-fitting super-covers to keep out dust and light.
5. Olives in the processing vats should not be more than two feet deep.
6. The different treatments vary in length according to the variety, maturity of the fruit, and locality, and must be determined by experimentation.

PURE-WATER PROCESS

The pure-water process consists simply in soaking the fruit in water until the bitterness is extracted. The essentials in the use of this method are chiefly changing the water frequently (twice daily), using pure water, and keeping the soaking vats clean. The process requires from thirty-five to sixty days, depending on the condition of the fruit, and for this reason is not adaptable to commercial usage.

GREEN PICKLES

The essentials for making ordinary green pickled olives are the same as those for making ripe pickled olives, including the lye and brine treatments. The fruit is picked shortly after attaining full size, and before it begins to color. In order to obtain a product similar in flavor and appearance to the imported green olive, it is necessary to carry the fruit through a fermentation process lasting several months. Briefly, the process consists in placing the olives (after the bitterness has been removed) in barrels with loosely fitting bungs, and keeping them covered with a ten-ounce brine until fermentation ceases, when they are ready for the trade.

THE FUTURE OUTLOOK

The ideal climatic and soil conditions for olive culture found in this State strongly indicate that Arizona will become one of the great olive-producing centers of the world. This assertion is further supported by the fact that this State does not have the serious insects and diseases that hinder certain phases of olive production in other countries. In the olive-growing districts of the Old World it is not possible to make satisfactory ripe pickles on account of the destructive olive fly; and in California, particularly within range of ocean influences, the black scale is a serious menace to olive orchards. With our present system of quarantine, it is unlikely that these pests will become established here.

The rather lengthy harvest period of the olive and the delightful weather that prevails in southern Arizona at this season, together with the fact that the fruit is not difficult to gather, makes it possible for the grower (if he desires) to do much of the work of picking; also, the crop is often sold on the trees. This materially reduces the cash outlay incident to handling an olive orchard and adds to the attractiveness of olive growing as a business.

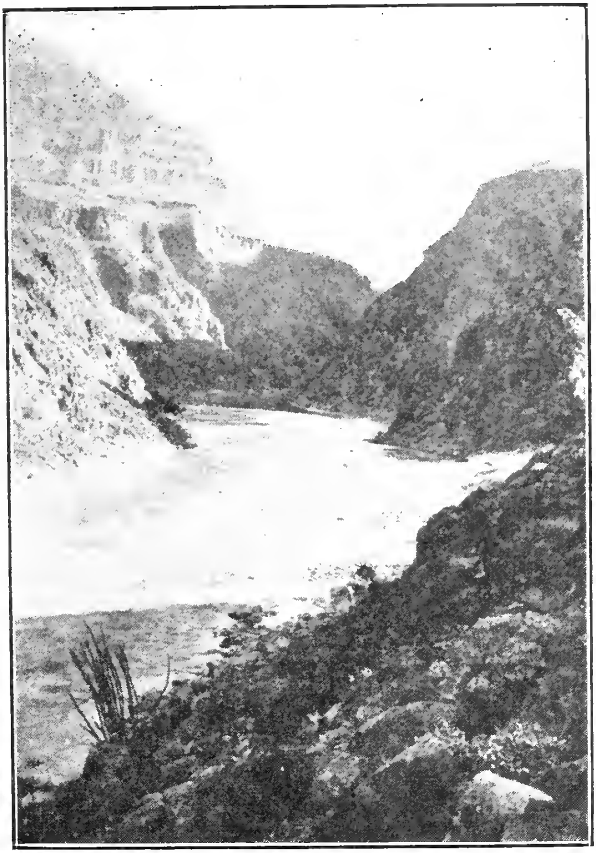
Arizona olives are unexcelled in quality, size, and attractiveness. Moreover, the American people are beginning to appreciate the food value of and to acquire a taste for pickled ripe olives, as is evidenced by the demand for them on the local and eastern markets. Apparently the greatest possibilities in this industry lie in the production of ripe olives with oil as a major by-product. Our growers have an excellent opportunity to build up a large, substantial industry in the field of olive culture. A forward step in this direction would consist in the formation of efficient co-operative growers' organizations which would insure the output of a first-class, thoroughly standardized product. Conservative advertising and the employment of an experienced sales manager would complete the general machinery for the profitable handling of a much increased acreage.

The University of Arizona

COLLEGE OF AGRICULTURE

Agricultural Experiment Station

Bulletin No. 95



View of Diamond Creek dam site, looking upstream.

THE COLORADO RIVER AND ARIZONA'S INTEREST IN ITS DEVELOPMENT

By G. E. P. Smith

Tucson, Arizona, February 25, 1922

ORGANIZATION

The Colorado River and Arizona's Interest in Its Development*

By G. E. P. Smith

It is nearly four hundred years since Spanish explorers discovered the canyons of the Colorado River. During these centuries mankind has coped with many problems and has surmounted great obstacles. But the six hundred mile stretch of canyon of the Colorado of the West is still under nature's control. No stone has been turned to impede the flow of water; no revolving wheel converts the power of the flood to useful purposes.

The development of the great river is a stupendous problem. Not alone is the layman staggered by the difficulties involved and by the immensity of the stakes, but the engineer is challenged and is struggling to conceive of the gigantic works that are required,—dams of twice the height of the highest dam yet attempted, reservoirs twelve to twenty times as large as the largest artificial reservoir in the world, and power generation on a prodigious scale.

GEOGRAPHY AND IRRIGABLE LANDS

Before presenting the problems of the Colorado River it may be helpful to review the geography of the region and to present a digest of the character and extent of the water supply.

The drainage basin of the Colorado is shown in Fig. 1. It includes parts of seven states,—the southwestern part of Wyoming, the western half of Colorado, the eastern half of Utah, a strip along the west side of New Mexico, all of Arizona except the southeast corner, the southeast part of Nevada, and the southeast edge of California,—in all, 251,000 square miles. The watershed on the east side of the basin is the Continental Divide, from the Mexican boundary line almost to Yellowstone Park. All of the northern half of the basin, and part of the southern half, consists of high, mountainous country, on which there is a heavy annual precipitation.

Until a year ago that part of the stream system draining western Colorado was called the Grand River. In the southeastern part of

*An address delivered at the Annual Farm and Home Week at Tucson, January 18, 1922. It was voted by the audience that the address should be published, and in response to the widespread demand for authentic information on the subject, the paper is included in the bulletin series. —Publication Committee.

Utah that stream unites with the Green River, the head waters of which are in Wyoming. Below the junction of the Grand and the Green the stream was called the Colorado. A year ago, by Congressional action, the name of the Grand was changed to Colorado; presumably geography and, ultimately, public usage will adopt the new name for the upper river. The principal tributaries below the junction of the Green and the Grand are the San Juan, flowing westerly from the northwest corner of New Mexico; the Little Colorado, which drains the north side of the Mogollon Rim in Arizona; and the Gila, which drains the central and southern parts of Arizona.

In the upper basin, that is, the basin above the Grand Canyon, there is a large area of land under cultivation, about 1,500,000 acres, mostly on the headwaters and tributaries where diversions from the streams are easily accomplished. The irrigation of the land, however, requires comparatively little water, on account of the high altitude, cold climate and short growing season, and part of the water applied returns underground to the streams. An even greater area, now idle, is susceptible of irrigation, part of it, however, at such high cost as to make the projects of doubtful feasibility. Studies made by the United States Reclamation Service indicate that the irrigated area in the upper basin will be increased to 3,000,000 acres.

In the lower basin, below the Grand Canyon, the areas irrigated in 1920 included 39,000 acres between Needles and Yuma, mostly on the California side; 54,000 acres in the Yuma project; 415,000 acres in the Imperial Valley; and 190,000 acres south of the international boundary line,—a total of 698,000 acres. This total is almost exactly double the acreage irrigated in 1913, showing the rapid rate of increase in the use of water in the lower basin. The possible extension of irrigation in the lower basin has not been determined fully, but conservative estimates indicate that the following additional areas can be brought under irrigation:—260,000 acres between Needles and Yuma, 150,000 acres of which is on the Arizona side; 76,000 acres in the Yuma project; 400,000 acres in the Imperial and Coachella valleys; and 630,000 acres in Mexico.

WATER SUPPLY

Engineers have methods, of comparative accuracy, for measuring the quantity of water flowing in rivers. The record of the flow, day

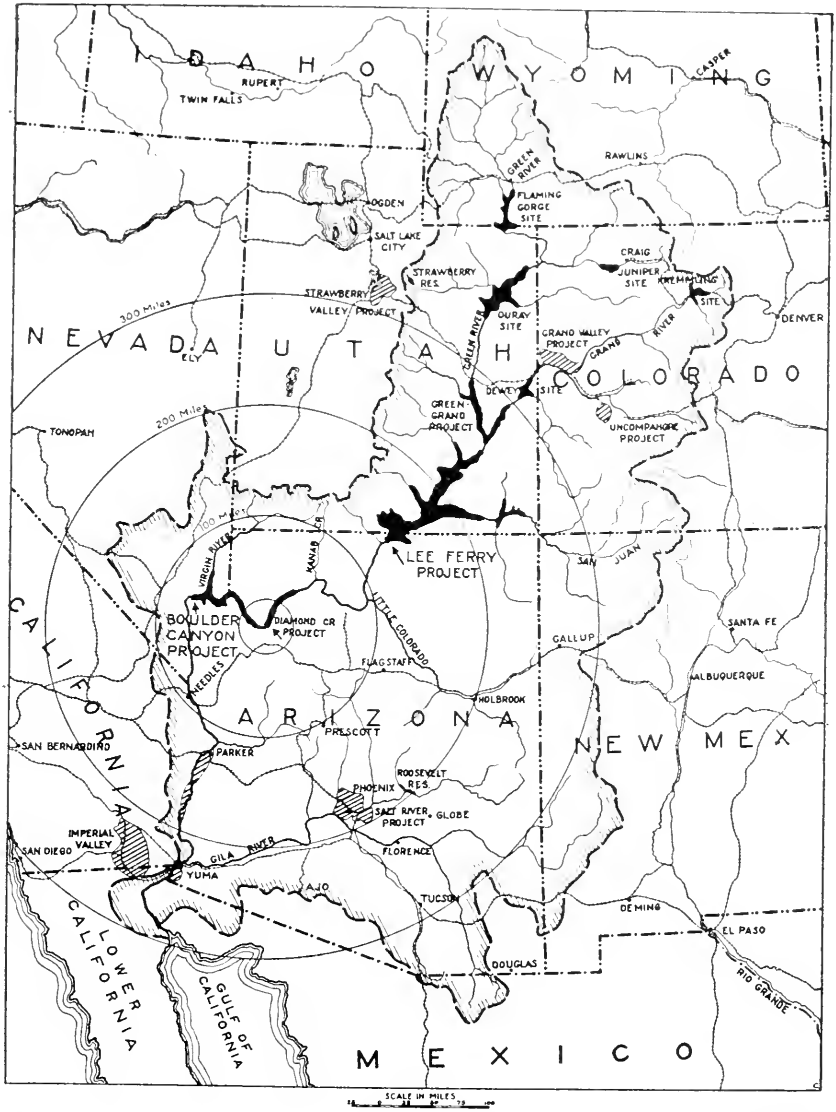


Fig. 1. Map of drainage basin and river system of the Colorado River. The drainage basin is shown by the shaded line.

by day, month by month, shows the extent of the water supply and its fluctuations, and furnishes a basis for the design of engineering works. On the Colorado River and its tributaries, many gaging stations, at carefully chosen locations, have been kept for varying periods of time, some of the records extending over twenty-five years.

The records of stream flow at Yuma have been kept since January, 1902. The gaging station is below the mouth of the Gila River and below the Yuma diversion dam, but above the head gates of the Imperial Canal. The average annual flow at the gaging station for the period 1902-1920 was 17,300,000 acre-feet. Had the present irrigated area been under irrigation throughout the period of the record, the average annual flow would have been about 16,000,000 acre-feet. The average flow at Boulder Canyon is practically the same amount, since diversions and losses between Boulder Canyon and Yuma are balanced by the inflow of tributaries.

Most of the water comes from the upper basin. At the junction of the Grand and the Green, the average annual discharge of the Grand is 6,900,000 acre-feet, and of the Green 5,500,000 acre-feet. The Green and Grand and San Juan rivers together, though draining less than two-fifths of the area of the Colorado basin, furnish 86 percent of the total water supply.

By far the greater part of the precipitation in Colorado and Wyoming is in the form of snow. During the winter the snow accumulates to great depths. The melting of the snow during the spring months produces a long period of high water, the annual flood, which lasts from two to three months and reaches its highest point at Yuma usually in June. During the June flood of 1909, the flow at Yuma reached 150,000 cubic feet per second. On June 27, 1921, all previous June records were broken by a flow of 186,000 cubic feet per second. The low water season begins in August and lasts from three to seven months. The minimum flow at Yuma has been below 4000 cubic feet per second during several low-water seasons.

The Gila River drains an area of 57,000 square miles. While the average annual discharge of the river is not great, it is very variable. In 1916 the discharge of the river at its mouth was 4,500,000 acre-feet; in some other years the total has been less than 100,-

000 acre-feet. Short-lived, "flashy" floods, greater than the highest peak floods in the Colorado, occur at times. The flow on January 16, 1916, reached 220,000 cubic feet per second. It is fortunate that the Gila floods do not come at the same time as the Colorado floods, in May or June. Should they coincide, the menace to the Yuma and Imperial valleys would be intensified; the levees would be overwhelmed.

RESERVOIR SITES

There are scores, hundreds, of storage sites in the middle and upper parts of the Colorado basin. Many of them have been surveyed, and at several of the sites the depth to bedrock has been ascertained by diamond drilling. The Strawberry Valley site in Utah and the Roosevelt site in Arizona and some small sites have been occupied already. For the complete regulation and utilization of the river, there are adequate natural opportunities; the real problem is as to which is the best. A few of the largest and most promising sites, those which are of greatest public interest, will be discussed.

The Dewey reservoir site is situated on the Grand River just west of the Utah-Colorado line. Although one of the last to be discovered, it is one of the best. It is the only site for a large reservoir on the Grand River except the Kremmling, and that site is occupied by a railroad. The bedrock at the Dewey site is only 44 feet below the river bed, and the capacity with a dam only 215 feet high from river bed to spillway is 2,300,000 acre-feet.

The Flaming Gorge site is on the Green River in Utah just south of the Wyoming line. The greatest depth to bedrock is 73 feet, and a 215-foot dam will impound 3,120,000 acre-feet. The width of the canyon is 200 feet. The Flaming Gorge and the Dewey sites control the most important headwaters of the Colorado. Both are excellent projects and should be under construction today.

Another excellent site is on the Yampa tributary, near Juniper Mountain. The drainage area is small, but the stream flow approximates 1,000,000 acre-feet of water per year. A 200-foot dam would provide a capacity of 1,500,000 acre-feet. The depth to bedrock is 24 feet.

The Ouray reservoir site is on the Green River a hundred miles below the Flaming Gorge site. This site is remarkable in that a dam only 210 feet high would impound 16,000,000 acre-feet of water. The greatest depth to bedrock, a factor of great influence on the cost of a dam, is 121 feet, and the canyon is not narrow. This site should be held available by the Federal Government until it is absolutely certain that the site is not needed in the general scheme for development of the river. If the site is restored to entry, it will be seized at once by the Denver and Salt Lake Railroad. The railway can be built around the reservoir site.

A reservoir at the junction of the Green and the Grand has been under consideration for many years. It would regulate partially both streams. A dam 250 feet high would impound 7,450,000 acre-feet. Borings were made to 120 feet without encountering bedrock. It is unfortunate that the borings were not carried somewhat deeper.

An apparently excellent reservoir site exists on the San Juan near Bluff, Utah, but its feasibility has not been established by test holes to find bedrock. A dam 264 feet high would create a reservoir of 2,600,000 acre-feet capacity. The accumulation of silt in this reservoir would be very rapid.

The Glen Canyon, or Lee's Ferry, site outclasses all other proposed sites in its gigantic possibilities. The maximum development contemplates a dam 700 feet high, 450 feet long at the level of the river, and 1400 feet long on top. The proposed slopes are one to six downstream and one to four upstream, making the length of base up and down stream over a mile. The capacity of the reservoir would be over 50,000,000 acre-feet, and 86 percent of the entire water supply of the Colorado basin would be regulated completely. Over a million continuous horsepower could be developed without sacrifice of irrigation interests. Complete surveys of the reservoir site have been made during the last few months. No test borings have been made, and it is stated that the depth to bedrock is not a crucial matter on account of the radical character of the dam contemplated. Test borings should be made at once.

Excellent dam sites exist in Cataract Canyon and Marble Canyon. The project for Marble Canyon provides for a power development of 1,300,000 horsepower, but the storage possibilities are small. This will be the last of the major projects because of its magnitude and high cost.

On the Little Colorado River, there is a dam site at Tolchaco, where the entire flood flow of that stream can be controlled by a dam 50 feet high.

The site at the mouth of Diamond Creek is of particular interest to Arizona, on account of its favorable location and because it is controlled by Arizona people. The site is only 16 miles from Peach Springs, a station on the Santa Fe Railroad. It is a power project only, there being practically no storage. Present plans, subject to modification, call for a dam 284 feet high, 324 feet above bedrock, to the spillway crest, and the top of the structure would be 25 feet higher. About 110,000 horsepower could be developed with the unregulated flow of the river, but in case the flow is equalized by a project with storage farther up the river, the ultimate power development may reach 600,000 horsepower. The canyon at this site is only 220 feet wide at the water level, and the length of the dam at the top will be 600 feet, about the same as the Roosevelt dam. The walls and foundation are of granite. The main electric transmission line would extend through, or near, Prescott, Phoenix, Mesa, Florence, and Tucson to Douglas, with important laterals to Jerome, Ray, Globe, Clifton, Ajo, and Yuma.

The Boulder Canyon site is in a similar narrow canyon in granite rock. The canyon walls are 300 feet apart. Here it is proposed to build a solid concrete masonry dam 600 feet high, 735 feet above bedrock, to elevation 1300 feet above sea level. The capacity of the reservoir is 31,600,000 acre-feet, and the estimated cost of the dam alone is $55,000,000. The great depth to bedrock is the main disadvantage of this site. While the problems of carrying the foundation to so great a depth and of passing the annual and occasional floods of the river during the construction period strike terror to the heart of the engineer, the task can be accomplished if adequate funds are provided. The power development will be 700,000 continuous horsepower as long as the irrigated area in the lower basin does not exceed 1,500,000 acres, and will decrease to 600,000 horsepower as the acreage increases to 2,000,000 acres.

The last annual report of the United States Reclamation Service states that an inspection of the lower river was made by boat by Homer Hamlin, a noted engineer, in April, 1920, and that he reports that there is no good dam site for a storage reservoir between Boulder Canyon and Yuma.

THE THREE GREAT PROBLEMS

Three objects are sought in the development of the Colorado River. They are:—

1. Storage for flood protection;
2. Storage to provide more water for the latter half of the irrigation season and for dry years; and,
3. Hydro-electric power.

The flood protection is the main incentive which is spurring many agencies to action. The people of the Imperial Valley, for 16 years, have been fighting a defensive battle against the Colorado, sometimes gaining, sometimes losing, but in the main losing. They cannot hold out for many more years. At least once every year, in June, and sometimes at other seasons, the river threatens to change its course from the Gulf of California to the Imperial Valley, as it did in 1905. The only protection at present is the system of levees, called respectively the first, second, and third lines of defense. Frequently the floods break through the first and second lines and reach the third line. Each year the river, through silt deposition, builds up that part of the alluvial fan in front of the levees, in some years as much as four feet, and each year the levees must be raised an equal amount. Over one-quarter of a million dollars is expended each year by the farmers of the Imperial Valley in this work. The limit will be reached soon. Levees forty or fifty feet high cannot be maintained.

The Yuma Valley, also, is protected by levees, but the danger there does not increase. Arizona hopes to develop another great irrigated valley farther upstream at Parker, but much of the Parker Valley is now subject to overflow and must be protected by an expensive system of levees unless adequate regulation of the floodwaters is provided by storage reservoirs. Regulation of the Green and the Grand will solve the problem in large measure, but tributaries below the junction must be given consideration. On one occasion a flood of 150,000 second-feet measured at Bluff, Utah, was contributed by the San Juan, and the Gila River floods likewise are a menace with which to reckon.

As for storage to equalize the supply for irrigation, the situation is more critical than is commonly known. Despite the great excess of water which is wasted to the ocean each year, there is an actual shortage during the latter part of the irrigation season in dry years. In 1915 the entire flow of the river was diverted into the Imperial Canal at the end of August, and yet there was not enough water to meet the demand. Since that time the acreage irrigated from the river has increased 300,000 acres. If the natural flow next September is as low as it was in 1915, there will be 300,000 acres of crops without any water to bring them to maturity, and the financial loss and human suffering will be appalling. Again, it is the Imperial Valley that is in danger, for other projects have the advantage of location upstream. No further expansion of irrigation use should be allowed until storage is provided; it should be admitted that the natural flow is entirely appropriated. It does not seem practicable, however, to prevent continued appropriation and use of water in Utah and Colorado.

But how can storage be financed? The Imperial Valley is burdened already with a heavy bonded indebtedness and is facing the further problem of the All-American Canal, which is expected to cost $30,000,000. The farmers cannot finance the river regulation which they require and must have.

Now enters the third element of the great project—power. The power possibilities are so great, and power is so valuable, that it is estimated the sale of power will pay for the entire project. A few months ago the proposal was to charge five percent of the cost of the storage dam to irrigation, ten percent to flood protection, and eighty-five percent to power. Now it is proposed to charge the entire cost to the power privileges. About 4,000,000 horsepower can be developed in Arizona at the four sites mentioned above.

Is there a market for so much power? Arizona can take about 100,000 horsepower to replace present steam plants. Cheap power will permit of increased pump irrigation, the mining of lower grade ores, and the electrification of our railways. We shall have factories where our own raw materials can be fabricated,—cotton mills, copper and brass foundries; and the electrolytic refining of Arizona copper can be done in our own State. All city and house lighting will be done with hydroelectric power, and any excess can be used for making nitrate fertilizers.

But other states, especially California, will compete for the power. A great amount can be marketed in southern California now. It is estimated that in fifteen years all possible hydro-electric development in that State will have been accomplished, and California interests are looking much farther ahead than that.

Nearly all of the power requirements of the mining industry in Arizona are now supplied from petroleum fuel oil. The best opinions regarding the future supply of fuel oil point to a diminution of the supply and rapidly rising prices. It is essential that hydro-electric power be developed to replace the failing oil supply.

PROPOSAL OF THE UNITED STATES RECLAMATION SERVICE

Engineers of the United States Reclamation Service have been studying the problem of the Colorado for eight years, and have decided quite definitely on what they believe should be the first project. The Service has recommended to Congress that it should be a project of the Federal Government, and the Secretary of the Interior stated publicly at the Riverside and San Diego conventions in December, 1921, that, because of the international and interstate character of the river, the Federal Government is the only competent agency to construct the great dam that must be built, and to control and operate its gates. He is right, and Arizona should back to the limit federal ownership and operation of the main river control project.

The Reclamation Service recommends that the dam be located in Boulder Canyon on the boundary line between Arizona and Nevada. On account of the peculiar situation, the west end of the dam would rest on the Arizona side. A transmission line from that point to Phoenix would be about 250 miles long, and a line to Los Angeles 277 miles in length. The proposed 600-foot dam provides for storage for irrigation and for storage of silt for sixty years, and for 5,000,000 acre-feet capacity at the top to be used only for detention of high flood crests, such as those of 1907, 1909, 1914, and 1920.

Last July, when Congress was committed to retrenchment, and it seemed impossible to interest the East in this most necessary undertaking, plans were made to contract the power privileges in advance to municipalities and states or to other purchasers, and the purchasers were to obtain the necessary funds through sale of bond issues. The city of Los Angeles was ready to take all or as much of the power as would be allowed to that city. Now, it is believed that there is a good fighting chance to obtain the money through federal appropriation, with ultimate return of the cost to the government by the sale of power.

ALTERNATIVE PROPOSALS

Although crystallization of sentiment in favor of Boulder Canyon project has made considerable headway, still some widely divergent views are being expressed, and it may not be impertinent to discuss alternative proposals. It is contended that for many reasons the river development should begin farther upstream. That the Boulder Canyon site is the one nearest to the best market for power is a sound argument. Of the other arguments advanced for that site, some are not valid, and the others may be met by the statement that extensive storage in the upper basin can be followed advantageously, and will be, by projects providing additional storage on the lower river. If the flood hazard is removed or is greatly reduced by means of extensive storage in Utah, the Boulder Canyon dam can be built at much less cost and in fewer years. Further, if the river regulation is effected in the upper basin, the power sites from Glen Canyon to Boulder Canyon inclusive become much more valuable, since the water supply is equalized, and because less reserve space is required for detention purposes. The upper locations will be developed eventually; why not now?

From that standpoint, the Dewey site on the Grand River and the Flaming Gorge site on the Green offer the best solution. Both dams could be built at once, and the total cost would be only about $25,000,000. The Juniper Mountain reservoir would cost $4,000,000. These sites are above the great silt-gathering area of the drainage basin. The Flaming Gorge and Dewey reservoirs would provide ample late-summer water supply for the lower basin for many years to come. The Flaming Gorge reservoir would serve to reduce the spring floods on the Green River one-third, and the Dewey reservoir would take the peak off from the spring floods of the Grand. The Dewey reservoir would be operated so as to be entirely empty at the beginning of the flood period. Both dams could be completed in five years. It is premised, however, that the construction of these dams would be followed by that of one or more others farther downstream,—possibly one on the San Juan or at Lee's Ferry, and either the Diamond Creek dam or Boulder Canyon dam or both. The dams on the headwaters should be built under the same theory of government as were the thirty-three dams on the Ohio River, that is, to secure river regulation and control, to make the stream manageable and utilizable. Navigation is no more vital to the economic and social welfare of the group of six states bordering the Ohio than is the taming and harnessing of the Colorado to the welfare of the seven states along its course. In due time, the Government might be reimbursed for the investment, for, after the construction of large storage reservoirs in Arizona, the Utah reservoirs would be of great value for power production.

The Diamond Creek project is capable of comparatively rapid construction, and is quite likely to go ahead of the Boulder dam in point of time. It would be a strictly Arizona enterprise, and free from the entangling jurisdictions that are inevitable in the larger projects. It does not in any way lessen the necessity for the Boulder dam or some other dam which can provide storage and flood control.

Another proposal is to make the Lee's Ferry reservoir the first major undertaking. On account of the type of dam planned, the extent of flooding in the river during construction would be immaterial. This reservoir as planned would store 30 percent more water than the Boulder Canyon reservoir, the production of power would be much greater, and the cost would be less. However, on account of the radical design and proposed methods of construction, the project should be submitted to the best engineering talent in the world before it can be right or wise to adopt it.

WATER RIGHTS

The Supreme Court of the United States has decided that in the case of interstate streams in the arid region, neither the riparian theory of water rights nor the priority of appropriation theory can obtain, but that each State is entitled to benefits from the river,—to substantial benefits. Presumably, the distribution of benefits must be made by the federal court. But in the case of the Colorado River, where there is water enough for all, there seems to be no necessity for any litigation.

The states of the upper basin seem to fear that the construction of large reservoirs will serve automatically to appropriate the waters of the river for use in the lower basin, and that additional development of irrigation in the upper states will be prevented. Oft-repeated assertions of the United States Geological Survey and the United States

Reclamation Service that the water supply is ample and adequate for all of the irrigable lands of both upper and lower basins have not served to allay the fear. Another cause of alarm in Colorado is the doubt as to whether that State will be allowed to divert 310,000 acre-feet of water per year from the Colorado basin, through tunnels at narrow places in the watershed, for use on the plains north and east of Denver, as is desired.

The upper states therefore are demanding a guarantee of unrestricted irrigation development in the upper basin, before they will lend their support, or consent, to a federal project in the canyon region. The lower basin states are asking for an allotment of the water supply among the seven states.

The wisdom of a perpetual guarantee or of an allotment of the waters of the river is questionable. On no other river basin has either been attempted. It is not possible to forsee conditions a hundred years ahead, or even thirty years ahead. All irrigators who are putting the water to beneficial use should be protected, but in principle it may be exceedingly dangerous to reserve a valuable water supply for a project which may prove to be of doubtful feasibility. If an allotment of the water is attempted, most of the seven states will advance extravagant claims to water. Some of the states most involved have no adequate conception of the feasibility of their projects, and no just allotment can be made without thorough surveys of all proposed irrigation lands. It is unlikely that any allotment can be proposed which will not be held up in some legislature for many years, and meanwhile the ruin of the Imperial Valley may be accomplished.

There is no necessity for a distribution of the unused water rights at this time. If the act to appropriate money for a Colorado River project shall state as follows, "Provided, that nothing in this Act shall be so construed as to affect in any way the rights to the use of the waters of the Colorado Basin of any state or any part of a state," then the upper states cannot be affected adversely by the project.

The average annual discharge of the river into the Gulf of California is 13,000,000 acre-feet. The projects of the upper basin are such that probably no more than 3,000,000 acre-feet of water additional can be consumed in those projects, and the balance of 10,000,000 acre-feet is more than twice as much as the states of the lower basin can use,— at least until a different economic order shall prevail.

Congress, through the Mondell act, has provided for a Colorado River Commission, consisting of one representative from each of the seven states, and one from the Federal Government. The Commission is now organized with Herbert Hoover as its chairman, representing the Federal Government. The purpose expressed in the Mondell Act is the negotiation of a compact or agreement, providing for an equitable division or apportionment of the water supply among the seven states.

NAVIGABILITY

The existing treaty with Mexico declares the Colorado River to be a navigable stream, and a federal court prohibited any action which might interfere with its navigability. The diversion of water for irrigation, therefore, is contrary to the treaty. As soon as diplomatic relations with Mexico are re-established, steps should be taken to amend the treaty in so far as it affects the Colorado. The river should be declared to be an unnavigable stream.

ARIZONA'S PROGRAM

Arizona owns the Colorado River bed, or half of it, for 580 miles. We do not own the water. We do not have unlimited millions of wealth to invest in the Colorado enterprises, nor many votes in Congress. We should endeavor to cooperate with our neighbor states. When the seven states agree upon a plan of action, the extreme urgency of the case will secure the appropriation needed.

With regard to some features of the project, Arizonans will express their opinions, but should not insist upon them. The immediate construction of the storage dam and the height of dam and the type of dam are far more vital to California than to us. Nothing can prevent our obtaining all the power the State can use, both now, and for fifty years to come. Our preferential rights to power are recognized. Also, it is proposed to grant Arizona and Nevada each a free block of power at Boulder site. Our concern must be to insure that there shall be no monopoly of power by a single corporation, and that every nook and corner of the State shall be able to receive power at equitable rates.

We should pledge the State's honor to the states of the upper basin that any construction of dams for the benefit of the lower basin shall not prejudice in any way their equitable rights.

But, the irrigation of our lands we must insist on; the development of the Parker project of 110,000 acres and of the Mohave Valley of 27,000 acres, and of the Cibola Valley of 15,000 acres, and that the right to double the acreage under irrigation at Yuma, as is contemplated, shall not be denied. It will require at least two new diversion dams similar to the Laguna dam, and they must be started in time to be finished when the storage dam is finished. The great river control dam and the power will be secured largely because California is fighting with us. But for the irrigation of Arizona lands we must fight alone. It does not follow necessarily that our lands will be irrigated if the Boulder dam or Lee's Ferry dam is built. Provision for the Parker diversion dam should, if possible, be put into the act which shall provide for the larger project. Be it said also, that the Parker and Mohave projects do not have the usual influential citizens and real estate boosters to present their claims. They are still under the care of the United States Indian Service. Congress passed an act for their opening to entry several years ago, and the matter is now sleeping. There are only a few Indians, and they have received allotments. It is the finest opportunity in the whole United States to provide lands for former service men, not less than 3500 of them. The State of Arizona has got to speak loudly for those projects.

Lastly, the high-line irrigation project — what of it? It has been claimed that if the high dam is located in Boulder Canyon, water can be turned into a canal on a high level, and led through the mountain passes of Mohave County, across Bill Williams River, through the Bouse Valley to Harrisburg Valley, and down the Centennial Wash to the Gila River. The writer has studied all the available data, and is of the opinion that the project is not feasible. Regardless of how desirable it would be to bring under irrigation from the Colorado River an extensive area of elevated desert land, yet it is better for the people of Arizona to dream no vague dreams, and to concentrate all efforts to obtain those developments which are practicable.

In the first place, the high-line project would require a dam 500 or 600 feet high to raise the water to the level of the canal. A great reservoir of dead storage water would be created, for the water level could never again be allowed to fall below the elevation of the canal.

Storage to regulate and equalize the water supply must be provided by building the dam considerably higher than the canal level or by means of another reservoir, preferably at Lee's Ferry. Probably there would be two great dams required instead of one.

The high-line canal would be built along the rough mountain sides of Mohave County, but no water could be taken through the Sacramento Valley Pass or through any other pass to lands behind the mountain range that borders the river, in that county.

Assuming an elevation of 1200 feet above sea level for the canal at its head, the elevation in the vicinity of Bouse would be about 1050 feet, 120 feet lower than the proposed canal that is designed to irrigate the Bouse Valley from the Williams River. About 90,000 acres in the Bouse Valley could be irrigated by pumping from the canal. By boosting the water 350 feet by means of pumps, the water could be led to Vicksburg, and then another boost of 500 feet would deliver it into the Harrisburg Valley, or, perhaps it would be cheaper to avoid the last-named lift by tunneling through the Little Harquahala Mountains. It would be more feasible to leave the Little Harquahalas and Coyote Mountain to the east of the canal, but even so, the pumping lift would be impractical. The maximum area that could be brought under such a high line system would be less than a million acres, mostly in Yuma County.

As an alternative proposal, the water for the high-line canal might be dropped at the high dam, generating power, and this power could be used to lift the water from the river near Parker into a high-line canal starting at that point. The electrical transmission losses would be no larger in percentage than the seepage and evaporation losses of water from the 260 miles of canal; and the investment would be less. About one kilowatt would be required per acre irrigated for the main lift to elevation 1060 at Parker, requiring an investment of about $100 per acre for power equipment, while the cost of the canal from the high dam to Parker would be more than twice as much. The value of the power used on this one lift, per irrigated acre, at one-half cent per kilowatt-hour, would be about $30 per year. Neither proposition is feasible, at least not during the present generation. An investment of over $300 per acre would be required. The best raw valley land in Arizona cannot stand a construction charge for irrigation over $150 per acre.

There is one possibility for which plans and estimates should perhaps be prepared. This is the possibility of pumping from the river at or near Cocopah Point, near the head of Laguna Lake, on a lift of about 350 feet, to a canal which would then run easterly on the north side of the Lower Gila Valley, crossing the river near Sentinel, and running thence on grade toward the southwest, covering about 250,000 acres of land. Power could be generated at Cocopah Point by means of a low rock-fill dam, after river regulation has been secured farther upstream. This project may be practicable twenty years hence.

THE GILA RIVER SYSTEM

It seems to have been forgotten that the Gila tributary is a vital element of the Colorado River, and that the study of Colorado River problems must take cognizance of the necessity for river regulation on the Gila. Be it remembered that it was the Gila River floods, five of them, in the winter and spring of 1905, which were responsible for the great disaster of that year, when in August the whole of the river was diverted into Imperial Valley. Had it not been for the continuous high water and repeated floods in the Gila, the narrow cut from the temporary heading of the Imperial Canal could have been closed easily. The Gila flood of January 22, 1916, was greater than the highest recorded flood of the Colorado itself. River regulation of the Gila River is absolutely necessary for the security of Yuma and Imperial valleys.

About seven years ago when the Federal Government began a comprehensive study of Colorado River problems, the Gila River was included in the studies. The plans prepared by the United States Reclamation Service at that time provided for regulation of the Gila by means of a dam 225 feet high near Sentinel, Arizona. The reservoir was to be operated for stream regulation only, and would have been of little service in reclaiming desert lands between Sentinel and Yuma. In 1918 borings were made at the dam site by the Reclamation Service, and it was ascertained that suitable foundations for a storage dam do not exist; hence the Sentinel project was abandoned.

In 1920, the Reclamation Service made an extensive study of the Gila River from source to mouth, examining all possible storage sites. It was concluded that the best solution of water problems of the Gila River is the construction of the San Carlos dam. The report of the

Engineer, Mr. C. C. Fisher, favors a dam 250 feet high above bedrock, about 20 feet lower than the Roosevelt dam. Mr. Fisher finds that the irrigation project should have an area of 148,000 acres. In February, 1921, a board of engineers of the United States Reclamation Service reviewed the Fisher report. The board recommends that the dam to be first constructed be 200 feet in height, and that in the next generation, thirty years hence, the height be raised to 250 feet. The board states that such a project is entirely feasible, provided satisfactory arrangements can be made with the Arizona Eastern Railroad, the line of which passes through the reservoir site.

The San Carlos dam must be constructed. Furthermore, storage must be provided on the Verde River. Additional storage is needed on the Salt River, and with this additional storage will come 24,000 additional hydro-electric horsepower at the Horse Mesa dam. It is hoped, too, that a feasible storage project on the Agua Fria can be accomplished, and perhaps the Walnut Grove dam will be rebuilt at some time. Each one of these projects will reduce materially the flood crests of the lower Gila River.

FINAL

Arizona's program, therefore, should be:—

1. To encourage all development projects, both public and private, on the Colorado River. In the case of publicly owned projects, the State must receive a block of free power in lieu of taxes.

2. To demand that as much power be allotted to this State as can be used by this State.

3. To demand that the federal project include a diversion dam at Bull's Head Rock at the head of Mohave Valley and one at Gatehead Rock at the head of the Parker Valley.

4. To demand that provision for river regulation on the Gila River be included in the federal program.

In the above exposition of the Colorado River problems and proposals, I have presented the case from the Arizona viewpoint. Arizona's future is to a high degree wrapped up in the development of the Colorado. The highest statesmanship is demanded at this time that the latent wealth of this great natural resource may be wisely and speedily secured and that this Commonwealth may share in its benefits in the largest practicable measure.

The University of Arizona
College of Agriculture

Thirty-Second Annual Report

of the

Agricultural Experiment Station

For the Year Ended June 30, 1921

This Report constitutes Part III of the Annual Report of the Board of Regents of the University of Arizona, made in conformity to Article 4483, Title 42, Revised Statutes of Arizona, 1913.

Tucson, Arizona, December 31, 1921

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Richard H. Williams, Ph.D........Animal Husbandman
Walter S. Cunningham, B.S........Dairy Husbandman
Charles T. Vorhies, Ph.D........Entomologist
Walker E. Bryan, M.S........Plant Breeder
George E. Thompson, B.S.A........Agronomist
Franklin J. Crider, M.S........Horticulturist
James G. Brown, M.S........Plant Pathologist
†Francis R. Kenney, B.S.A........Poultry Husbandman
Royal B. Thompson, B.S.A........Poultry Husbandman
†Heber H. Gibson, A.M........Professor of Agricultural Education
Clifford N. Catlin, A.M........Associate Agricultural Chemist
William E. Code, B.S.C.E........Assistant Irrigation Engineer
Allen F. Kinnison, B.S.A........Assistant Horticulturist
Ralph S. Hawkins, B.S.A........Assistant Agronomist
Harold C. Schwalen, B.S........Assistant Irrigation Engineer
Elias H. Pressley, B.S........Assistant Plant Breeder
Stanley P. Clark, B.S........Assistant Agronomist
Richard N. Davis, B.S........Assistant Dairy Husbandman
David W. Albert, B.S........Assistant Horticulturist
Ernest B. Stanley, B.S........Assistant Animal Husbandman
†Stuart W. Griffin, M.S........Assistant Agricultural Chemist
†William E. Schneider, B.S........Instructor in Animal Husbandry
Ethel N. Ikenberry, B.S........Secretary College of Agriculture
†F. H. Simmons..Foreman, Yuma Date Orchard and Horticultural Station
C. J. Wood........Foreman, Salt River Valley Experiment Farm
T. L. Stapley........Foreman, Tempe Date Orchard
Carl Clark, B.S........Foreman, Prescott Dry-Farm
M. H. Woody........Foreman, Sulphur Spring Valley Dry Farm
Leslie Beaty B.S........Foreman, Yuma Date Orchard and Horticultural Station
J. R. Reed........Foreman, University Farm

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* On leave.
† Resigned.

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Thirty-Second Annual Report

ADMINISTRATION

D. W. WORKING

The University year which ended June 30, 1921, represents an important period in the life of the College of Agriculture. In its teaching work the College has had the best year in its history. More students of college grade were registered and taught than in any previous year. The teaching has been inspiring and effective. Students of agriculture have worked diligently and have ranked high in scholarship in comparison with their fellow-students of the other Colleges of the University. There is good reason for believing that the people of the State have greater faith than ever before in agricultural education as a preparation for the business of agriculture.

A summary of the registration of students in the College of Agriculture for the ten-year period which ended with the University year, June 30, 1921, shows in a general way the growth of the educational work of the College on the University campus. The first column below gives the year; the second, the total number of students enrolled. It is to be noted that in 1919-20 the University admitted a considerable number of students who were unable to comply with the ordinary requirements. This was done to enable former service men to secure vocational training. The result was that the College of Agriculture enrolled 31 students of the subcollegiate grade during that year. As it was found undesirable to continue the practice, during the year 1920-21 no students were admitted who could not qualify for the regular college work; and so the total registration for that year was 8 less than for the previous year. Deducting the number of subcollegiate students, the actual enrollment of students of college grade was 95 in 1919-20; and the increase for the following year was 23.

1911-12	38
1912-13	53
1913-14	38
1914-15	48
1915-16	62
1916-17	58
1917-18	31
1918-19	37
1919-20	126
1920-21	118

The irregularity of the increases shown above needs a few words of explanation. The sharp decline in attendance for 1917-18 was clearly due to the World War. The slight increase in the following year can be accounted for by the number of students who returned to the University after being discharged from the Army. In 1919-20 colleges and universities throughout the country gained very largely in attendance. Our own registration in the College of Agriculture showed an increase of 340 percent. Part of this gain has already been accounted for; and the remainder can be explained by the more general recognition of the value of college training for men entering the various agricultural pursuits, the more extended knowledge of the character of the instruction offered, and the increased population of the State.

AGRICULTURAL EXTENSION WORK

What has been said thus far relates to the campus teaching of the College of Agriculture. Developments during the past ten to fifteen years have made it necessary to distinguish between the resident teaching and the extension of the agricultural colleges. It has come about that a very large part of the teaching efforts of the College of Agriculture are put forth throughout the State; and at the same time a smaller portion of the teaching work is done within college classrooms and laboratories. This is as it should be. The people of the farming communities recognize their need of instruction, and they as frankly ask that the college extend its activities to every part of the State where farmers and their families can come together to receive instruction.

Practically every man and woman on the farms of Arizona knows of the work of the County Agricultural Agents and the Home Demonstration Agents who are working in the agricultural counties of the State. Not all of them realize that these men and women are members of the teaching faculty of the College of Agriculture. Increasingly, however, the people are becoming aware of the purpose of the College to teach agriculture and home economics wherever country communities are willing to organize to receive instruction. So the work of agricultural education is widening its field of influence; and the instructors at the University and among the farms and farm homes of the State are finding the people becoming more responsive to intelligent instruction and readier to do their share to make cooperative agricultural extension work more genuinely cooperative and, therefore, more effective in promoting profitable farming and more wholesome home and community life in the open country.

The report for the preceding year announced the appointment of Mr. W. M. Cook as Director of the Agricultural Extension Service of the College of Agriculture after he had served two years as County Agent Leader. After a year of work as Director, Mr. Cook has his organization well in hand, with the hearty support of every member of the Extension Service. In spite of many obstacles, the work is making real progress, and seems to be better established in the interest of the people than ever before.

THE AGRICULTURAL EXPERIMENT STATION

Primarily, this is a Report of the Agricultural Experiment Station; but it is proper in an administrative report to discuss the Experiment Station as one of the divisions of the College of Agriculture. The Station is an investigational and research agency. It conducts experiments to test old knowledge in its applications under new conditions; it plans other experiments in its search for new facts; it studies old knowledge in relation to new and different surroundings; and it publishes the results of its investigations and studies in order that teachers of agriculture and farmers may make use of old facts and old meanings and new meanings in the operations which we call agriculture—farming, fruit-growing, stock-raising, and all of the various activities of the men and women whose business brings them into contact with growing plants and breeding and caring for animals.

In Arizona we have been used to a form of organization which assumes that it is necessary that we have an Agricultural Extension Director able to devote his full time to the administration of agricultural extension work; but we have not realized that the work of the Agricultural Experiment Station needs to be supervised by a Director able to give his full time to the work of the Station. Our research work has been important enough for a number of years to require the leadership of a competent man able to give it his entire time and strength. Not, however, until the present year was nearing its end had the way become clear to provide for a Director of the Agricultural Experiment Station who should be without other administrative or teaching duties.

The Dean and Director, who gives up his directorship in order that the work of the Experiment Station may increase in effectiveness, commends to the readers of this Report the man who has been known to many of them for twenty years or more as Professor J. J. Thornber. The work of the Experiment Station should show almost immediate improvement under his administration; for he has the good fortune to begin with adequate preparation and the hearty support of all his associates.

A NEW DEPARTMENT

With the development of the agriculture of Arizona, there came the introduction of many plant diseases and an increase of injury from native diseases of plants. For a number of years it had been apparent that the Experiment Station needed to give serious study to these diseases and methods of controlling them. It was found possible to support the work needed; and the Board of Regents authorized a Department of Plant Pathology.

Effective July 1, 1920, Mr. J. G. Brown, who had been Assistant Professor of Biology in the College of Letters, Arts, and Sciences for a number of years, was made Professor of Plant Pathology in the College of Agriculture, with the corresponding title of Plant Pathologist in the Experiment Station. One year of work by the new department has more than justified the action of the Board.

CHANGES IN PERSONNEL

The strength of a college is due in part to the character of the men and women who constitute its staff of workers; and in part it is due to the length of their service and the security they feel in their positions. In the Thirty-First Annual Report may be found two paragraphs which will gain in interest by repetition here as follows:

> "The College of Agriculture has been fortunate in being able to retain the services of strong men for many years. Three heads of Experiment Station departments have been connected with the University from fifteen to twenty years. Three others have been in service from five to seven years. Too much emphasis can not be placed on the importance of keeping high-class men. The State of Arizona is to be congratulated on supporting a University policy that enables the administrative officers of the University to secure strong men

and to keep them after they have learned Arizona conditions so well as to be of the maximum service to the State.

"One reason why we are able to keep men of ability is found in the fact that the Regents have pursued a liberal policy in regard to salaries. Another reason is found in the opportunity Arizona gives strong men to do their best. High-grade scientific men need freedom in their work and the kind of support that will give them outlet for their energies and ambitions. They need tools and materials to work with. So that the workers of the College of Agriculture may continue to work most effectively, it is necessary that the State pursue its established policy of providing liberal financial support."

Resignations

July 31, 1920: J. W. Longstreth, County Agricultural Agent, Yuma County.

August 31, 1920: Mrs. Mary P. Lockwood, State Leader of Home Demonstration Work.

August 31, 1920: Francis R. Kenney, Poultry Husbandman.

August 31, 1920: Stuart W. Griffin, Assistant Agricultural Chemist.

December 31, 1920: Nydia M. Acker, Home Demonstration Agent, North Counties.

February 28, 1921: Hazel Zimmerman, Home Demonstration Agent, South Counties.

March 31, 1921: F. H. Simmons, Foreman Yuma Date Orchard and Horticultural Station.

June 30, 1921: H. H. Gibson, Professor of Agricultural Education. On July 1, 1921, the Department of Agricultural Education was transferred to the College of Letters, Arts, and Sciences.

June 30, 1921: W. E. Schneider, Instructor in Animal Husbandry.

Appointments and Promotions

July 1, 1920: J. G. Brown, Professor of Plant Pathology; Plant Pathologist.

August 16, 1920: E. S. Turville, County Agricultural Agent, Pinal County.

September 1, 1920: R. B. Thompson, Associate Professor of Poultry Husbandry; Poultry Husbandman.

September 1, 1920: Miss Grace Ryan, Home Demonstration Agent, Cochise and Pinal Counties.

September 16, 1920: M. M. Winslow, County Agricultural Agent, Yuma County.

October 1, 1920: Miss Alice V. Joyce, State Leader of Home Demonstration Work.

January 1, 1921: W. E. Schneider, Instructor in Animal Husbandry.

March 1, 1921: A. B. Ballantyne, promoted from County Agent Graham and Greenlee counties, to Assistant in Club and County Agent Work.

April 1, 1921: Leslie Beaty, transferred from foremanship of Prescott Dry-Farm to foremanship of Yuma Date Orchard and Horticultural Station.

May 1, 1921: Carl Clark, Foreman Prescott Dry-Farm.

June 1, 1921: Miss Rosa Bouton, Home Demonstration Agent, Apache, Coconino, and Navajo counties.

June 16, 1921: Miss Edna Ladwig, Home Demonstration Agent, Pima and Santa Cruz counties.

PUBLICATIONS

Bulletin No. 91, "Fattening Native Steers for Market: 1920," by R. H. Williams, September 1920, (6000).
Bulletin No. 92, "The Supply, the Price, and the Quality of Fuel Oils," by G. E. P. Smith, January 1921, (5000).
Thirty-First Annual Report, by the Station Staff, January 1921, (6000).
Circular No. 31, "Making Cheddar or American Cheese on the Farm," by R. N. Davis, August 1920, (6000).
Circular No. 32, "Hog Cholera in Arizona," by R. H. Williams, November 1920, (6000).
Circular No. 33, "Hegari in Arizona," by G. E. Thompson, April 1921, (5000).
Circular No. 34, "Sweet Clover in Arizona," by S. P. Clark, April 1921, (5000).
Circular No. 35, "Sudan Grass in Arizona," by R. S. Hawkins, May 1921, (6000).
Circular No. 36, "Rhodes Grass in Arizona," by S. P. Clark, May 1921, (6000).
Circular No. 37, "The Production of Clean Milk," by R. N. Davis, May 1921, (6000).
Circular No. 38, "The Adobe Milkhouse," by C. B. Brown, June 1921, (6000).
Circular No. 39, "Selecting Laying Hens," by R. B. Thompson, June 1921, (6000).

TECHNICAL PAPERS

"Irrigation by Flooding and the Efficiency of Irrigation." G. E. P. Smith Publication of the Southern California Associated Pipe Manufacturers. September. 1920.
"Caesarian Operation on *Lepus Alleni* and Notes on the Young." C. T. Vorhies. Journal of Mammalogy. Vol. 2. No. 2. May. 1921.
"The Changing Composition of Salton Sea Water." A. E. Vinson and S. W. Griffin. Carnegie Institution of Washington. Year Book No. 19. 1920, page 75.

PROJECTS

AGRICULTURAL CHEMISTRY

A. E. VINSON, C. N. CATLIN

Alkali Investigations: Concomitant soil conditions that affect the toxicity

of black alkali, and means for the amelioration of the effects of alkali on soil and plant (Adams).
Study of colloidal swelling of dry soil when wetted: The colloidal swelling of soils and the correlation of colloidal swelling to other soil properties (Adams).
Gypsum treatment of black alkali land at the University Farm (State).
Irrigating waters and soils (Hatch).
Meteorological Observations (Hatch).

AGRONOMY

G. E. THOMPSON, R. S. HAWKINS, S. P. CLARK

Continuation of Studies at the Prescott Dry-Farm (State).
Continuation of Studies at the Sulphur Spring Valley Dry-Farm (State): This project and the preceding one include varietal tests, rate and date of seeding tests, methods of planting tests, inoculation of legumes —tests designed to determine whether dry-farming is feasible in the particular localities indicated.
Varietal and cultural tests of legumes (Hatch) (State).
Varietal and cultural tests of corn and the various sorghums (Hatch) (State).
Varietal and cultural tests with cotton (Hatch) (State).
Varietal and cultural tests with winter and spring grains (Hatch) (State).
Effect on field crops of dynamiting subsoil (State).
Varietal and cultural tests of grain, grass, and miscellaneous crops (State).
Cooperative crop experiments (State).
Study of Indian agriculture (State).
Alfalfa seed certification (State).

ANIMAL HUSBANDRY

R. H. WILLIAMS, E. B. STANLEY, W. E. SCHNEIDER

Feeding cottonseed products to range steers (Hatch) (State).
Feeding cottonseed to pregnant ewes (State).
Alfalfa hay alone as a ration for beef cows (State).
Two methods of raising and maintaining brood sows (State).

BOTANY

J. J. THORNBER

An economic study of the grasses and grass-like plants of Arizona (Hatch).
Poison plants of our grazing ranges (Hatch).
Range improvement through fencing (Hatch).
Trees and shrubs for ornamental planting (Hatch) (State).
Study of jujube plants (Hatch) (State).
Study of pistasch trees (*Pistacia vera*) (Hatch) (State).
Study of species of mulberries (Hatch) (State).
Study of tamarisks, particularly *Tamarix articulata* (Hatch) (State).

DAIRY HUSBANDRY

W. S. CUNNINGHAM, R. N. DAVIS

Sudan grass versus alfalfa hay for dairy cows (Hatch) (State).
Green alfalfa versus alfalfa hay for dairy cattle (Hatch) (State).
Milk substitutes for feeding calves (Hatch Sales) (State).

ENTOMOLOGY

C. T. VORHIES

Study of range rodents with special reference to the kangaroo rat, *Dipodomys spectabilis* (Adams).
Arizona (or Thurberia) boll-worm, *Thurberiphaga catalina*, life history and relation to cultivated cotton (Adams).
Collection and preservation of Arizona insects, especially the economic forms (Hatch) (State).
General observations of variable factors and conditions in bee-keeping, honey plants, etc. (State).

HORTICULTURE

F. J. CRIDER, A. F. KINNISON, D. W. ALBERT

Dates: A study of the culture and management of date orchards with special reference to propagation and to the improvement of fruit (State).

Citrus fruits: A study of cultural practices including varietal tests, bud selection studies, methods of pruning, propagation, soil improvement by use of cover crops, time and method of planting, effect of stable manure and commercial fertilizers; and a study of effect of temperature and atmospheric humidity (Hatch) (State).

Olives: This project includes study of sterility, cultural practices such as pruning, irrigation, etc. (Hatch) (State).

Pruning studies: Effect of different methods of pruning upon deciduous fruits (Hatch).

Study of the water requirements of fruits (Hatch) (State).

Walnut and pecan studies: In this project special attention is given to top grafting Juglans major with cultivated varieties (Hatch) (State).

Irish potato studies: Study of conditions affecting the production of potatoes in Arizona (Hatch) (State).

Sweet potato studies: A study of cultural and storage methods (Hatch) (State).

Spinach: Varietal tests to determine what varieties are most satisfactory as a market garden crop for southern Arizona (State).

Miscellaneous horticultural studies (Hatch) (State).

IRRIGATION

G. E. P. SMITH, W. E. CODE, H. C. SCHWALEN

Groundwater investigations: Principles of groundwater recharge, movement, and escape or use, especially escape through transpiration (Adams) (State).

Pumping Machinery: A study to determine fundamental facts relating to the action and efficiency of various types (Adams).

Evaporation and duty of water (Adams).

Water supplies and irrigation in Cochise County (State).

PLANT BREEDING

W. E. BRYAN, E. H. PRESSLEY

Alfalfa: A study of heritable characters in pure lines of alfalfa (Adams) (State).

Wheat: Factors controlling milling and baking qualities in wheat. (Adams) (State).

Corn: Breeding a high yielding, heat resistant field corn (State).

Cotton: Selections within the Pima variety in order to improve the variety in earliness, percentage of lint, yield, and form of plant. Selections from the best short-staple upland varieties in order to produce a suitable short-staple variety for those sections of the State which seem best adapted to this sort of cotton. (Adams) (State).

Beans: The object of this project is to produce an edible field bean which can be successfully grown as a summer crop. (Adams) (State).

PLANT PATHOLOGY

J. G. BROWN

Date rot: This project consists of inoculation and spraying experiments. (Adams).

Influence of alkali on the susceptibility of cotton to black arm and angular leaf spot. (Adams) (State).

Influence of alkali on the susceptibility of cotton to Texas root rot. (Adams) (State).

Miscellaneous plant disease studies (State).

FINANCES

Table I following shows receipts and expenditures for the Agricultural Experiment Station as reported to the Director of the Office of Experiment Stations of the United States Department of Agriculture. Table II gives a complete statement of receipts and disbursements for the College of Agriculture, including the Experiment Station and the Agricultural Extension Service. It does not include amounts spent by the Federal Department of Agriculture in partial support of cooperative agricultural extension workers. These items are shown in detail in the separate report of the Extension Service.

TABLE I.—SHOWING EXPERIMENT STATION EXPENDITURES BY FUNDS AND SCHEDULES FOR THE YEAR ENDING JUNE 30, 1921

Abstract	State Fund	Sales Fund	Hatch Fund	Adams Fund	Total
Salaries	$18,373.82	$ 267.71	$13,248.73	$14,328.84	$46,219.10
Labor	9,617.43	6,432.14	65.12	....	16,114.69
Publications	2,981.97	....	....	....	2,981.97
Postage and stationery	156.87	189.57	76.10	27.61	450.15
Freight and express	414.13	504.47	18.67	4.26	941.53
Heat, light, water, and power	515.42	4.00	....	....	519.42
Chemicals and laboratory supplies	....	....	93.64	83.44	177.08
Seeds, plants, and sundry supplies	1,755.36	1,540.47	56.90	49.42	3,402.15
Fertilizers	1,220.67	469.82	....	....	1,690.49
Feeding stuffs	2,027.55	909.03	....	....	2,936.58
Library	....	....	5.00	2.87	7.87
Tools, machinery and appliances	1,111.47	906.61	....	24.00	2,042.08
Furniture and fixtures	82.80	212.40	53.40	....	348.60
Scientific apparatus and specimens	....	....	366.42	78.16	444.58
Livestock	432.50	1,415.25	800.00	....	2,647.75
Traveling expenses	2,298.95	1,559.85	130.70	165.40	4,154.91
Contingent expenses	524.32	80.20	....	....	604.52
Buildings and lands	10,644.08	8,818.96	85.31	236.00	19,784.35
Balance forward to 1921-22	1,029.86	*1,987.53	....	....	*957.67
Totals	$53,187.20	$21,322.95	$15,000.00	$15,000.00	$104,510.15

* Overdraft.

TABLE II.—SHOWING RECEIPTS FROM ALL SOURCES AND DISBURSEMENTS FOR ALL PURPOSES ON ACCOUNT OF THE COLLEGE OF AGRICULTURE FOR THE YEAR ENDED JUNE 30, 1921

Fund	Balance	Receipts	Total	Disbursements	Balance
College of Agriculture—Maintenance	$........	$20,798.17	$20,798.17	$20,798.17	$........
Morrill	....	8,079.01	8,079.01	8,079.01	....
Farm Maintenance	....	12,500.00	12,500.00	12,500.00	....
Farm Improvement	2,408.95	2,250.00	4,298.95	4,298.95	....
Printing	....	2,981.97	2,981.97	2,981.97	....
Improvement	....	11,394.86	11,394.86	11,394.86	....
Plant Introduction	*896.17	4,260.00	5,156.17	4,260.00	*896.17
Tempe Date Palm Orchard Fund	*.05	2,575.00	2,575.05	2,575.00	*.05
Yuma Date Orchard Horticultural Station	....	4,825.00	4,825.00	4,825.00	....
Dry-Farming Fund	*975.30	4,500.00	5,475.30	4,500.00	*975.30
Prescott Dry-Farm Fund	1,384.03	5,690.00	7,074.03	6,168.07	905.96
Salt River Valley Farm	226.97	12,510.00	12,736.97	12,736.97	....
Sulphur Spring Valley Farm	*14.04	4,540.00	4,554.04	4,416.10	(*14.04) (123.90)
Surface Water Investigation	13.79	3,000.00	3,013.79	3,013.79	....
Underflow Water Investigation	*107.85	2,400.00	2,507.85	2,400.00	*107.85
Experiment Farm Sales	8,850.50	10,036.90	18,887.40	20,874.93	†1,987.53
University of Arizona Farm Sales	2,694.92	10,630.78	13,325.70	13,325.70	....
Hatch Sales	696.17	1,739.38	2,435.55	2,435.55	....
Adams	....	15,000.00	15,000.00	15,000.00	....
Hatch	....	15,000.00	15,000.00	15,000.00	....
Student Fees	†57.55	608.50	550.95	123.39	427.56
Smith-Lever	....	18,863.27	18,863.27	18,863.27	....
State Extension	....	17,949.30	17,949.30	17,949.30	....
County Extension	647.04	11,831.12	12,478.16	8,271.74	4,206.42
Cooperative Agricultural Extension	....	10,000.00	10,000.00	10,000.00	....
Citrus Investigation	393.95	5,000.00	5,393.95	5,393.95	....
Date Palm Orchard and Horticultural Station Land and Improvement Fund	1,900.28	....	1,900.28	1,900.28	....
Cochise Water Investigation Fund	6,759.36	15,000.00	21,759.36	10,064.78	11,694.58
Total	27,609.37 —57.55	233,963.26	261,515.08	244,150.78	19,351.83 —1,987.53
	27,551.82				17,364.30
Grand Total	$261,515.08				$261,515.08

* Returned to State Treasurer.........

† Overdraft.

AGRICULTURAL CHEMISTRY

A. E. Vinson, C. N. Catlin

The work of the Department of Agricultural Chemistry during the year ended June 30, 1921, has been continued along the lines of projects defined in former reports. This work is divided into research, miscellaneous analytical work, and teaching.

RESEARCH

SWELLING COEFFICIENTS OF DRY SOILS WHEN WETTED

The method of determining the swelling coefficient of dry soils when wetted, which was originated in this department, was given further study; first to obtain satisfactory duplicate determinations, and second, to compare the swelling coefficient with other physical constants dependent on the texture of the soil. A technical paper covering the details of the method and duplicate determinations will be prepared by the department during the coming year. The following table, however, is given here to show the correlation between the swelling coefficient as determined by our method in the case of a few soils of widely varying texture and the mechanical analysis and moisture equivalent of the same soils.

TABLE III—COMPARISON OF SWELLING COEFFICIENT WITH OTHER CONSTANTS

Mechanical Analysis	Muck	Rillito clay	U. of A. sandy loam	Maricopa gravelly loam	Calcareous gravelly loam
Fine gravel 2-1 mm.	....	....	.4	2.3	3.6
Coarse sand 1-.5 mm.	1.0	1.2	1.7	9.0	16.1
Medium sand .5-.25 mm.	.4	7.6	3.5	8.9	16.2
Fine sand .25-.10 mm.	19.7	6.2	21.9	20.4	18.8
Very fine sand .1-.05 mm.	19.6	7.5	45.4	39.7	25.5
Silt .05-.005 mm.	25.7	21.5	11.3	7.6	10.6
Clay below .005 mm.	30.3	55.1	15.8	9.7	6.0
Total	99.7	99.1	100.0	97.6	96.8
Loss on ignition	9.71	11.14	12.76	3.93	3.54
Moisture equivalent	33.0	34.8	8.0	9.0	7.2
Swelling coefficient	181.4	173.7	67.5	74.6	60.0

ALKALI STUDIES

Field studies of the treatment of black alkali soil with gypsum have been continued at the University Farm. A good stand of barley was obtained over the most alkaline portion of the plot that had always been barren before gypsum treatment. These studies, which extend over a period of years, have been put in manuscript form and crop maps have been prepared for publication.

INFLUENCE OF CONCOMITANT CONDITIONS OF THE TOXICITY OF BLACK ALKALI

The work has been in progress for several years as an Adams fund project. In the pot culture phases of this investigation interesting and suggestive results have been obtained with winter cultures of wheat and barley. Attempts with summer cultures so far have failed almost entirely. In 1920, tepary beans and cotton were used, but neither proved of value for pot cultures. This year milo, hegari, and Mexican June corn are being used. Corn is doing fairly well, but the first planting of milo and hegari failed to come up or died immediately in the same pots where wheat and barley had given fair returns the previous winter. Even in the low concentration, .05 and .075 percent sodium carbonate, these sorghums made very weak growths and were nearly destitute of chlorophyll. The pots have been replanted with the same sorghums. Milo and hegari have behaved almost the same way on the black alkali plots on the University Farm where barley made a good winter growth. Check pots with sweet soil are giving good growths with both of these sorghums. It is difficult to find a crop suited to summer pot culture work with alkali under the climatic conditions prevailing at Tucson. Rhodes grass, however, on strong black alkali soil at the University Farm is making a fine growth. It may prove of value for pot culture.

With winter cultures wheat proved much more resistant to black alkali than barley, which is contrary to the generally accepted belief. It may be a matter of variety, however, for the wheat used was Sonora and the barley was ordinary six-row. Six series of cultures were run with both wheat and barley in which the concentration of black alkali was the only factor varied. Barley failed absolutely in .25 percent (by analysis of the natural soil) sodium carbonate, while wheat made a slight growth. Barley made a very weak growth in .20 percent sodium carbonate and wheat a fair growth. In weaker alkali both wheat and barley made satisfactory growth for experimental studies on soil of the University Farm type. Very little difference was discernible in the weaker black alkali cultures as judged from general appearance, but the grain yields were reduced materially by .075 percent sodium carbonate. The main purpose of this series of cultures was to determine the percentage of alkali in this particular type of soil, but the experiment was adapted to the study of the influence of other conditions. With this percentage fixed and held constant through the series, other conditions will be varied. Such observations have been made on the influence of texture in soils containing .2 of one percent and .15 of one percent of sodium carbonate. A very strong black alkaline soil was selected and mixed with sand and with clay in order to reduce the alkalinity; then combinations of the two mixtures were made so as to give one series of .2 of one percent and another of .15 of one percent sodium carbonate, the two series varying only in texture. Sand greatly intensified the toxicity of the black alkali, while clay (or muck in one series) largely neutralized the effect of the alkali. Other similar series, in which the original sodium carbonate is held constant but wholly or in part neutralized by gypsum, aluminum sulphate, mineral and organic acids, are planned. A few preliminary trials along this line have shown some very interesting results which will be carefully checked with larger series next winter.

THE TEMPE DRAINAGE DITCH

Monthly samples of water from the Tempe Drainage Ditch have been collected and analyzed. The study has now extended over a period of four years and shows interesting results. Since January 1920, there has been very little change in the composition of the water. This may possibly be due to the long period of drought through which we have just passed. Table IV gives the composition of water for each month from July 1920, to July 1921.

TABLE IV.—MONTHLY VARIATIONS IN COMPOSITION OF WATER FROM TEMPE DRAINAGE DITCH. 1920-1921 PARTS PER 100,000

Date 1920-1921	Total solids	Chlorids as NaCl	Hardness (permanent) $CaSO_4$	Hardness (temporary) $Ca(HCO_3)_2$	Alkalinity Na_2CO_3	SO_4	CaO	MgO
July	273.4	191.0	13.3	50.1	....	Str	Str	Str
August	262.6	113.0	89.7	73.7	....	Str	Str	Str
September	222.6	143.0	8.9	67.2	....	Mod Str	Mod Str	Mod Str
October	171.4	136.0	....	84.2	8.7	Mod Str	Mod Str	Mod Str
November	274.2	179.5	6.3	68.0	....	Mod Str	Mod Str	Mod Str
December	253.2	168.0	3.5	69.2	....	Mod Str	Mod Str	Mod Str
January	210.8	135.0	....	65.4	1.7	Mod Str	Mod Str	Mod Str
February	207.8	135.0	....	55.8	4.2	Mod Str	Mod Str	Mod Str
March	209.6	135.0	....	73.0	9.3	Mod Str	Mod Str	Mod Str
April	207.6	133.0	....	61.9	3.4	Mod Str	Mod Str	Mod Str
May	203.0	129.0	....	60.1	5.1	Mod Str	Mod Str	Mod Str
June	203.0	131.0	....	59.7	5.1	Mod Str	Mod Str	Mod Str

The average monthly composition for the four years ended January 1, 1921, was as follows:

	1917	1918	1919	1920
Total solids	308	266	262	256
Chlorides	209	182	173	158

During the year 1920, the sample for April is missing. It would appear that a marked and steady improvement in the drainage from this very alkaline area is taking place. Further discussion of this project will be found in the Twenty-Seventh, Twenty-Eighth, Twenty-Ninth, Thirtieth, and Thirty-First Annual Reports of this Station.

PRUSSIC ACID POISONING BY JOHNSON GRASS

In June, 1921, Mr. William H. Griffin of Cornville, Arizona, reported to His Excellency, Thomas E. Campbell, Governor of Arizona, the sudden death of three head of cattle and sent samples of the Johnson grass they had been eating. The letter and samples were referred to this department. We had been called upon previously to examine Johnson grass that was believed to have caused the death of hogs; but the analyses were always negative, although there was little doubt but that the hogs died of prussic acid poisoning, and it had been shown in Bulletin No. 90, Part IV, 1905, of the Bureau of Plant Industry, that Johnson grass did sometimes cause such poisoning. The samples in this case contained surprisingly large amounts of prussic acid, but no quantitative determination was made. The following description of the death of the animals is taken from Mr. Griffin's letter:

"I have lost three head of cattle the last two months by eating this grass. The first was a two-year-old steer that broke through the fence, stayed in the pasture about one hour, then came back to the fence and died in a few minutes. The next was a milk cow that came fresh in the morning and stayed about the corral all day. We gave her a good handful of the Johnson grass and she died in less than an hour. The last was a milk cow that broke into the horse barn and got a small amount which was left by the horses. I milked this cow at eight o'clock and she was in good health. At a quarter to nine we heard her calling and before nine she was dead, in less than an hour after eating the grass."

Since other cases of this kind are likely to occur, it is well to call attention to the best known treatment of sorghum poisoning in cases where the animals are not beyond help. Glucose, best known in the form of Karo corn syrup, greatly lessens the toxic effect of prussic acid. It should be administered freely. Milk sugar is also an antidote, and whole or skimmed milk should be given freely. Animals that have just received a good grain ration are much less susceptible to sorghum or Johnson grass poisoning. Hay that is cured quickly is more apt to retain dangerous amounts of prussic acid than hay that is cured slowly. It is generally believed that the sorghums are likely to be poisonous when the growth is stunted by drought. Crawford in Bulletin 90, cited above, quotes a California correspondent: "This plant is poisonous when grown on irrigated as well as on non-irrigated lands, but especially so when grown on irrigated lands, and the growth has become rank. It has been shown that sorghums grown in Florida under humid conditions also contain hydrocyanic or prussic acid. Great care should be exercised in feeding Johnson grass or other sorghums. especially after the sudden or mysterious death of any animal that has had access to these forages."

MISCELLANEOUS

A large number of samples of irrigating water and of soil for alkali have been analyzed during the year. The Chemist made one visit to the Casa Grande Valley and in company with County Agent Turville examined several alkaline districts. One case in particular was of interest. The soil, which was wet and sticky, even after a long dry period, was found to be heavily impregnated with calcium and magnesium chlorides. The native vegetation over this area was mostly saltbush.

Twenty-four samples of water from the Agua Fria River, representing the daily flow from January 5 to February 13, 1920, with a few omissions, were analyzed. The samples were all of excellent quality, although they carried a small amount of black alkali.

A number of samples of feeds, guanos, manures, rocks, insecticides, linseed oils, medicinal herbs, and other materials were examined and reported on, although in only a few cases were quantitative determinations made with this class of materials. One sample of so-called boiled oil which killed two valuable horses proved to be commercial rosin oil.

AGRONOMY

G. E. THOMPSON, R. S. HAWKINS, S. P. CLARK

During the period covered by this report, all the projects discussed in the report of the previous year have been continued, and no new projects have been added. A small amount of miscellaneous laboratory and office equipment has been purchased but no items of great importance have been added.

On the various Experiment farms where agronomic work is carried on, a number of improvements have been made. On the Salt River Valley Farm a substantial brick cottage has been built as a foreman's residence, and a large, well-constructed brick barn has just been completed. This barn houses the work stock of the farm, provides storage room for hay, and two seed rooms, all of which will be of material advantage in handling the work of the farm. On this farm considerable work has been done in the leveling of land, thus making it possible to do more accurate experimental work; and about one thousand dollars have been spent in improving and extending cement ditches.

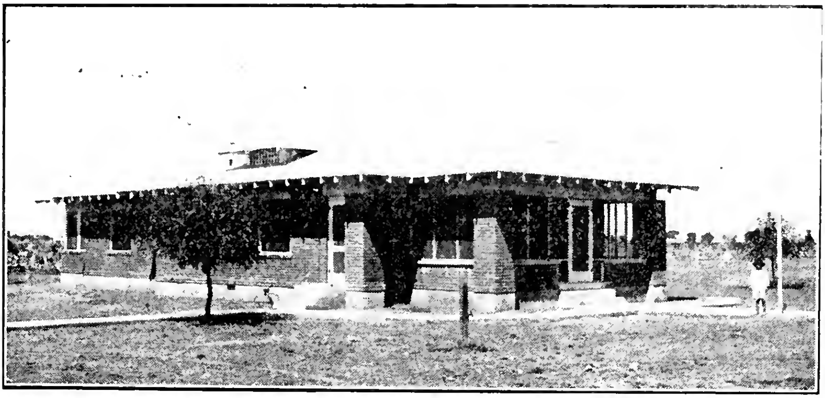

Fig. 1.—Salt River Valley Farm: Foreman's house completed September. 1920.

On the Prescott Dry-Farm a good general barn and machinery shed has been built and plans have been prepared for the construction of a new cottage for the farm foreman.

PROJECTS

I. CONTINUATION OF STUDIES AT THE PRESCOTT DRY-FARM

The work of this farm has been continued without any change from the plans of the previous year. Mr. Leslie Beaty resigned as foreman March 30 and was succeeded May 1 by Mr. Carl Clark, a 1916 graduate of the University of Arizona College of Agriculture.

The summer and fall of 1920 were unusually dry, and the winter of 1920-21 and the spring of 1921 have likewise been below normal in the amount of precipitation. Consequently, we are starting the cropping season of 1921 under unfavorable conditions. However, the ground has been carefully worked and sufficient moisture has been stored to enable us to secure good stands of all crops planted, and with a normal summer rainfall we expect average returns for the present year.

Silage produced and stored in the fall of 1920 was not used for stock feeding experiments because of the high price of feeder cattle and the probability of low markets later. The silage was sold to a neighboring rancher.

II. A CONTINUATION OF STUDIES AT THE SULPHUR SPRING VALLEY DRY-FARM

The growing season of 1920 was the most severe one experienced in Sulphur Spring Valley since the establishment of the Experiment Farm there. No grain yields of consequence were secured from any of the plantings made in 1920, and not more than 25 tons of silage were stored. Due to shortage of feed, no stock feeding experiments were conducted in the winter of 1920-21. In 1920, even tepary beans failed to make a satisfactory growth, which was the first failure of this crop recorded in Sulphur Spring Valley.

Conditions in the spring of 1921 have not improved over those of 1920. Dry-farm fields do not have sufficient moisture to cause germination of newly planted crops, consequently only those fields that are supplied with some irrigation water have been planted.

III. LEGUMES AND THEIR CULTURE FOR SOUTHWEST CONDITIONS

As in the previous year, plantings under this project were made on the five farms of the Experiment Station. These plantings covered experiments with velvet beans, soybeans, tepary beans, cowpeas, vetch, and a few miscellaneous crops. On the Salt River Valley Farm purple vetch made a larger and more satisfactory growth than any other variety, but it failed to set a good crop of seed. Hairy vetch made a very satisfactory growth and produced a considerable quantity of seed. Woolly-podded vetch made the third largest growth and produced a reasonable amount of seed. Bitter vetch, which in other years has been quite promising, did not make as satisfactory a growth as in 1920, although it yielded a good crop of seed. Bitter vetch planted with barley competed with it to such an extent that the barley crop was reduced materially.

Fig. 2.—Salt River Valley Farm: Field peas as a green winter manure crop.

Cowpeas planted in midsummer in Mexican June corn made an excellent growth and can be relied upon to increase the value of the corn crop for either silage or pasture.

Inoculation tests with cowpeas gave no conclusive results.

The vegetative growth of a number of varieties of soybeans was satisfactory, but the beans produced were very poor in quality, being shriveled and unmarketable. At the present time we are cooperating with the United States Forage Crop Office in making varietal tests of about twenty varieties of soybeans, and also in making tests with four of these varieties to determine the best time for planting. Plantings have been made at intervals of two weeks, beginning April 1, and continuing until August 15. This test is preliminary to a more extensive one for next year, which, we hope, will enable us to determine the causes of previous failures with soybeans and perhaps will give information that will finally lead to the successful handling of this crop under southern Arizona conditions.

Velvet beans did not prove satisfactory, due largely to the extreme difficulty in securing stands. Examination failed to show nodules on the roots of the velvet beans and it is possible that inoculation will be necessary to produce satisfactory growth.

Tepary beans proved a most excellent green manure crop for the Salt River and Yuma valleys. These beans, planted at the rate of one bushel to the acre, grew eighteen to twenty-four inches high and the yield was estimated at twelve to fifteen tons weight per acre.

IV. A STUDY OF THE VARIETIES AND METHODS OF CULTIVATION OF INDIAN CORN AND THE VARIOUS SORGHUMS

Of the various sorghums tested in 1920 hegari proved the most valuable from the standpoint of feed. Milo gave a slightly larger yield of threshed grain, but, because of greater fodder value, hegari is better liked by the average farmer. Feterita proved considerably inferior to either milo or hegari, and white milo proved a little inferior to ordinary dwarf yellow milo.

Sumac sorghum made an excellent silage crop, being slightly superior in leafiness to Orange sorghum, and because it is lighter and more easily handled, it is more satisfactory for silage than either Gooseneck or Honeydrip; these two latter varieties, however, will give larger tonnage.

Mexican June corn, or selections of it, proved superior to other varieties of corn, particularly in the Salt River Valley.

V. THE CULTIVATION AND FIELD MANAGEMENT OF EGYPTIAN COTTON

This project has been carried almost entirely on the Salt River Valley Farm near Mesa. In the fertilizer tests the following results were secured:

Treatment	Yield in pounds of seed cotton per acre
Barnyard manure 5 tons	1076
Barnyard manure 10 tons	1005
Barnyard manure 10 tons and acid phosphate 300 lbs.	875
Acid phosphate 250 lbs.	893
Acid phosphate 500 lbs. and nitrate of soda 200 lbs.	1225
Acid phosphate 500 lbs.	964
Acid phosphate 500 lbs. and cottonseed meal 450 lbs.	1130
Nitrate of soda 200 lbs.	820
Nitrate of soda 600 lbs.	1124
Commercial cotton fertilizer	918
Cottonseed meal 700 lbs.	856
Check—no treatment	981

THINNING AND TOPPING TESTS

Date of topping	Spacing of plants in row	Yields in pounds of seed cotton per acre
August 15	6 inches	904
Not topped	6 inches	949
August 15	12 inches	1195
Not topped	12 inches	1276
August 15	18 inches	1479
Not topped	18 inches	908

In the date of planting tests, cotton planted March 1 and March 15, 1921, was frozen and killed, and, as in previous years, it seemed that the best period for planting was during the last ten days of March or the first ten days of April. In the spring of 1921, cotton planted March 1 and 15 was seriously injured by frost, but enough plants were left to give a moderately good stand, and on June 30 the cotton of these plantings is showing a considerable amount of bloom and is in good condition.

VI. CULTIVATION AND MANAGEMENT OF WINTER AND SPRING GRAINS, INCLUDING WHEAT, BARLEY, OATS, AND RYE

The major part of this work has been done on the Salt River Valley Farm, although some experiments have been conducted on the Sulphur Spring Valley Dry-Farm. Yields for 1921 have not yet been obtained from the latter farm; these will not be very encouraging, due to extremely dry conditions during the growing season. At the Salt River Valley Farm work with wheat included fertility tests, rate of planting tests, and varietal tests with the following results for the harvest season of 1921:

FERTILITY TESTS

Treatment	Pounds of threshed wheat per acre
Manure, 5 tons per acre	2149
Acid phosphate 200 lbs. per acre	2150
Acid phosphate 86 lbs. and nitrate of soda 236 lbs. per acre	2804
No treatment	1974

RATE OF PLANTING TESTS

Rate of seeding	Pounds of threshed grain per acre
120 lbs. per acre	2200
105 lbs. per acre	1665
90 lbs. per acre	2260
75 lbs. per acre	2564
60 lbs. per acre	2002
45 lbs. per acre	1721

VARIETAL TESTS WITH WHEAT

Variety	Yield in pounds per acre
Early Baart	2002
Macaroni	1292
Kanred	962
Burbank's Super Wheat	919
Arizona 39	850
Lars Peterson	642
Turkey Red (Home grown seed)	641
Marquis	503

The barley experiments included varietal tests, barley planted with vetch, and rotation and nurse crops as follows:

VARIETAL TESTS WITH BARLEY

Variety	Yield in pounds per acre
Beldi	2528
Mariot	2429
Common six row	2307
Tennessee Winter	1744
Beardless	1678
California 4000	1523
Michigan Winter	1137

ROTATION, NURSE CROP, AND PLANTING WITH VETCH

Method	Yield in pounds per acre
Barley alone	2102
Barley 40 lbs., bitter vetch 40 lbs	1890
Barley 40 lbs., sweet clover 25 lbs	1285
Barley following sorghums for silage	2232
Barley following tepary beans for green manure	2553

Two one-acre plots were planted to rye. One plot was seeded with Abruzzes rye, which is a variety adapted to southern conditions. This acre yielded 816 pounds of threshed grain. The other plot was planted to Rosen rye, a variety bred in Michigan and not adapted to southern Arizona; the yield of this plot was but 153 pounds of threshed grain.

One and one-quarter acres of Texas Red oats were planted, which yielded at the rate of 1856 pounds of threshed grain per acre.

Fig. 3.—Varietal tests of barley in the Yuma Valley; common six row on left; beardless in the center; Mariot on right.

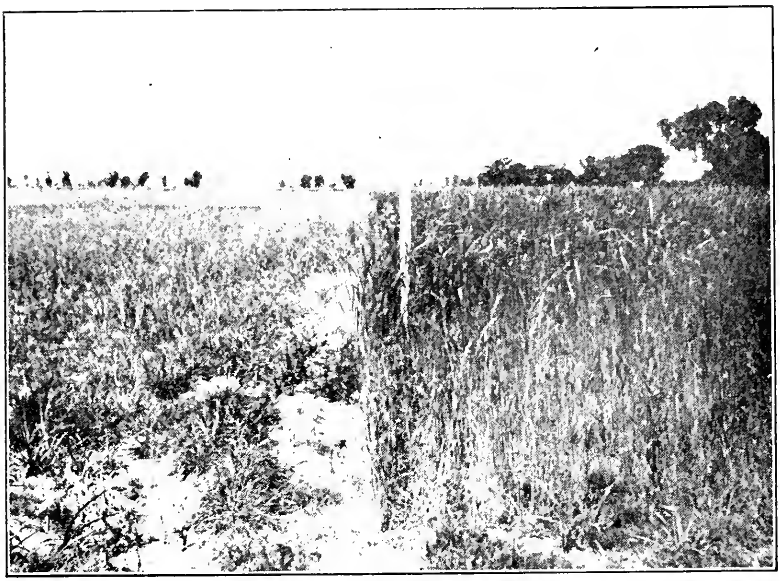

Fig. 4.—Salt River Valley Farm: Field tests with rye; Rozen rye on left; Abruzzes rye on right.

Beardless barley was sown in an alfalfa field which is to be plowed later in the season. This very materially increased the tonnage of hay obtained from this field. As a feed for horses this mixture of fairly well-matured barley and alfalfa has proved to be almost ideal.

VII. EFFECT ON FIELD CROPS OF DYNAMITING SUBSOIL

The results secured in 1920 with this project were the same as in 1918 and 1919, namely, there was no appreciable difference between crops grown in soil that was dynamited and in soil that was not so treated.

VIII. VARIETAL AND CULTURAL TESTS OF GRAIN AND FORAGE CROPS AND OF GRASSES AND MISCELLANEOUS CROPS

Under this project more extensive tests were made with Rhodes grass than in previous years. One planting on extremely alkaline soil has withstood two winters and is now starting the third summer with vigorous growth and a full stand. Rhodes grass promises to be of considerable value as a pasture crop on the alkaline soils of our lower valleys.

Napier grass gives a large yield, but because of its vigorous growth the stalks soon become hard and woody which renders them inferior for silage. This grass does not bear seed, but is propagated from cuttings, which makes it less desirable than the common varieties of sorghum.

IX. COOPERATIVE CROP EXPERIMENTS

This project enables us to distribute good seed to farmers who will give it good cultural treatment; it also enables us to test crops under different soil conditions and at various altitudes. Under this project four hundred and fifty lots of seed were supplied to farmers in various parts of Arizona during the growing season of 1920. In the spring of 1921 more than 600 lots of seed were supplied to cooperators. In a majority of cases cooperators have furnished satisfactory reports concerning the adaptability of varieties, hardiness, yield, and other data.

X. A STUDY OF INDIAN AGRICULTURE

In this project a detailed study has been made of the conditions under which different tribes of Indians carry on dry-farming operations. Considerable attention has been given to the soil types selected by these Indians. Photographs have been taken to illustrate the methods employed by the Indians in preparing ground for field crops and for gardens, and field notes have been taken to show the varieties used and the methods of planting. The results of these investigations will be published within the next year, and we believe this data will be of interest and value to dry-farmers.

XI. SEED CERTIFICATION WORK

For more than two years the Agronomy Department has cooperated with the County Agent of Yuma County in inspecting fields of alfalfa and certifying as to the varieties grown and their purity. This work has made it possible for the growers of alfalfa seed to market their product in such a way that it has brought many thousand dollars more than would have been possible without certification. This work was carried long enough to prove its value, and then it was taken over by the Yuma County Farm Bureau. The County Agent and the Agronomy Department continue to act in an advisory capacity.

EXTENSION WORK

Throughout the period covered by this report one-half of the time of S. P. Clark has been given to extension work along agronomy lines. This work has included writing newspaper articles, delivering lectures at institutes, farm bureaus and other public meetings, judging field crops at county fairs, visiting the various counties in the State, and making numerous farm tours with county agricultural agents. A total of 7093 miles was traveled on the railroad and 2722 miles by automobile. The head of the Department has also been called upon to do some extension work of a similar nature.

PUBLICATIONS

During the fiscal year closed June 30, 1921, the following publications have been prepared by the Agronomy Department:

EXPERIMENT STATION CIRCULARS

Sweet Clover in Arizona.
Sudan Grass in Arizona.
Hegari in Arizona.
Rhodes Grass in Arizona.

MIMEOGRAPHED EXTENSION LEAFLETS

Broomcorn in Arizona.
Tentative Agricultural Program for the Salt River Valley.
Green Manure Crops for Arizona Orchards.
The Pit Silo.

MISCELLANEOUS WORK

In addition to the Experiment Station work handled by the Department of Agronomy, the members of the Department have taught six classes in which were enrolled 123 students.

This Department has tested 22 samples of seed for germination and purity.

During this fiscal year 1200 letters were received and answered. In addition, a large number of telephone calls concerning crops and other matters were received and answered, and a considerable number of office consultations were held.

The Association of Western Agronomists will hold their annual meeting at Tucson, Arizona, in August, 1921. This Department has in charge the matter of preparing a program and planning for this meeting.

ANIMAL HUSBANDRY

R. H. WILLIAMS, E. B. STANLEY, W. E. SCHNEIDER

The livestock industry in Arizona during the past year has passed through one of the most critical stages of its history. Losses among range cattle and sheep were large, owing to the drought, and the calf and lamb crops were abnormally small. A prevailing shortage of feed placed stockmen in circumstances that made it necessary for them to ship their stock out of the State to pastures in Kansas, Texas, and California. Heavy losses of livestock during the periods of drought make it very plain that stockmen should avail themselves of every opportunity to provide feed for such emergencies.

Due to the uncertainty of the livestock market, fewer cattle were fed in the irrigated sections than during the previous year. A few feeders were able to turn their steers at a small profit, but for the most part, cattle feeding proved unprofitable, due to a declining market. Normally, however, our livestock will furnish a remunerative market, and in many cases the only market, for our grains and roughages.

The serious setback to the cotton industry in the State emphasizes the need of a well-defined system of diversified farming. By using livestock to a greater extent on our farms to consume homegrown feeds, the farmer and the stockman will derive mutual benefit by a cooperation in their respective interests in livestock and crop production.

WORK OF THE YEAR

In the absence of Dr. R. H. Williams, who is taking his sabbatical leave, the work of the department was carried on by Mr. E. B. Stanley until January 1, at which time Mr. W. E. Schneider was engaged to assist with the teaching and office duties.

The major portion of the work carried on by the department consisted in giving instruction to University classes in animal husbandry. Aside from the regular routine of the office and instructional duties, trips were made to various parts of the State to give talks and livestock judging demonstrations and to advise with stockmen on different livestock problems. The department supervised livestock judging contests among the high-school students at the State Fair and during University

Week. A creditable showing of University stock was made at the State Fair, and assistance was given in the livestock judging work there.

Two registered Poland-China gilts were added to the swine herd during the past year. These animals were prize winners at the Arizona State Fair, and were owned by Omer McCullough of Mesa, Arizona. The limited number of animals at the University Farm does not provide a representative selection of each breed, and thereby handicaps the teaching and investigational work. The Hereford breed of cattle and the Rambouillet breed of sheep should be further improved and built up.

FEEDING COTTON SEED TO RANGE STEERS

Numerous inquiries from farmers and stockmen throughout the State regarding the feeding value of cotton seed and its products, together with a lack of experimental data on feeding work in Arizona, prompted the department to conduct a steer feeding experiment at the Salt River Valley Farm. The purpose of the test was primarily to ascertain the relative feeding values of cotton seed and cottonseed meal when fed with a basal ration of alfalfa hay and silage. Fifty head of common bred two-year-old range steers were used in the experiment. They were divided into six separate lots and fed five different rations for a period of ninety days. The results of this test are specifically set forth in Bulletin 93. The following is a brief summary of the results:

Cottonseed meal as compared with cotton seed gave uniformly better results as was evidenced by the greater gain, smoother finish, and higher dressing percentage of the steers.

When a basal ration of alfalfa and silage is fed to two-year-old steers, 100 pounds of cottonseed meal are equal to 170 pounds of whole cotton seed. Cotton seed at $17 per ton is equal to cottonseed meal at $30 per ton. It was found that the use of cotton seed in a crushed form was not warranted.

When fed with cottonseed meal, corn silage gave larger and more uniform daily gains than did the ration of cottonseed hulls and cottonseed meal. Cattle fed a ration of cottonseed meal and cottonseed hulls made good daily gains for the first 60 to 80 days, after which time the gains began to diminish rapidly. If the roughage is silage instead of hulls, the meal may be fed for a longer period of time without ill effects.

The lack of finish of the steers receiving cottonseed meal indicated that it would have required a feeding period of 120 days to put them in good marketable condition, and 150 days for those receiving cotton seed, had they continued to make the same rate of gain.

FEEDING COTTON SEED TO PREGNANT EWES

Twenty head of pregnant ewes were fed a daily ration consisting of ¾ pound of cotton seed with a liberal allowance of corn silage for a period of three weeks prior to lambing. Cowpea straw was available at all times, and the ewes had the freedom of a scanty pasture along an enclosed ditch bank. No scouring or other ill effects resulted. The ewes remained in thrifty condition and raised healthy, vigorous lambs.

The Hereford heifer which is being maintained on an exclusive ration of alfalfa hay, dropped a calf on February 11, 1921. Both animals are doing nicely with no indication of any ill effects from the hay ration. It is planned to carry on this test for several years to study the effect on the progeny of the heifer of the continuous use of alfalfa hay as the sole feed.

The crop of wool produced this year is the largest that has been sheared from the University flock, in point of individual production. The Rambouillet ewes of all ages gave an average fleece of 12.8 pounds, which is 22 percent more than the average production of the Shropshire ewes; while the Rambouillet rams yielded an average fleece of 15.2 pounds, or 38 percent more than the Shropshire rams. Sheepmen will be interested in following these records from year to year.

BOTANY

J. J. Thornber

The year ended June 30, 1921, was one of the driest in the history of the stock-raising industry in Arizona, the drought being especially severe in the southern half of the State. The rainfall at Tucson, Arizona, for this twelve-month period was 6.32 inches which is slightly more than one-half the yearly average for this location. Of this amount, 4.38 inches or 69.3 percent fell during the summer growing season, July to October inclusive, and 1.72 inches or 28.2 percent during the winter and spring months, November to April inclusive. At Tucson no rain fell in May and but .22 inches in June. Similar conditions prevailed generally throughout southern Arizona. Rains varying from one to two or three inches in depth fell in various parts of central and northern Arizona late in the winter and spring months. Only at altitudes of 5500 feet and above, however, were these rains sufficiently heavy to make possible a fair growth of the spring grasses and similar plants. This growth was particularly good in the country about Flagstaff and Williams. The precipitation for the year came generally as showers which, though beneficial to plant growth, were not lasting in their effects, since the moisture did not penetrate to any considerable depth in the soil and hence was soon dissipated by the dry winds.

EFFECTS OF SCANT RAINFALL

As a result of the scant rainfall noted above, growth on the grazing ranges during the summer and fall of 1920 was greatly reduced, being generally not more than twenty-five to thirty-five percent of the average, while practically no growth took place late in the winter and spring months, except as already noted at the higher altitudes. It was to be expected, therefore, that heavy losses of stock through starvation would result on the ranges. In the southern and eastern parts of the State in particular, with a shortage of both feed and water, losses on many grazing ranges were heavy. It is stated that in some instances as high as thirty-five to fifty percent of the stock died and that many of the remaining animals were left in an emaciated, half-starved condition.

CHARACTER OF ARIZONA RAINFALL

The character of the rainfall for the two years just ended is, in general, what stockmen should count upon and plan for in the future, if their business is to be run on a moderately safe basis—very heavy for one year and very light for the following year or two years. In the proper sense of the term we do not have in Arizona what may be called a "normal" rainfall. The rainfall for one year cannot be taken as any indication of what may be expected the next year. Years of average rainfall may be followed by dry years or wet years. The rainfall at Tucson for the year ended June 30, 1920, was 20.54 inches or more than three times the amount for the twelve months just closed. The former was the heaviest annual rainfall for this location during a perior of thirty-nine years, the latter the lightest rainfall over a period of seventeen years. Other years or seasons within the memory of Arizona stockmen that were nearly or quite as dry as the one just ended, with the usual heavy losses of stock from starvation, are as follows: 1894-1895, with a rainfall at Tucson of 5.65 inches; 1899-1900, with a rainfall at Tucson of 7.42 inches; 1901-1902, with a rainfall at Tucson of 6.99 inches; and 1903-1904, with a rainfall at Tucson of 6.26 inches.

BROWSE PASTURES VERSUS GRASS PASTURES

The present drought has taught some good lessons relative to forage conservation during periods of abundant feed and to the classes of grazing ranges that in the long run are most desirable for general grazing purposes. Losses of stock were relatively light and in addition the animals mostly came through the year in fair condition on ranges having a growth of browse plants along with the usual growth of grass and miscellaneous herbs or weeds. This was noticed on ranges in southern Arizona where such plants as scrub-oak, mesquite, cat's-claw, mesquitilla or ramita (*Calliandra*), deer browse (*Cercocarpus*), and bear grass (*Nolina*) were abundant; also on grazing ranges in central and northern Arizona, in particular, those about Mayer, Prescott, Payson, and Grand Canyon, where the growth of such shrubs and small trees as scrub-oak, (*Quercus turbinella*), post-oak (*Quercus utahensis*) and (*Q. submollis*), mulberry (*Morus celtidifolia*), hackberry or palo blanco (*Celtis reticulata*), Apache plume (*Fallugia paradoxa*), cliff rose or quinine bush (*Cowania Stansburiana*), deer browse (*Cercocarpus*), and service berry (*Amelanchier*), was often abundant and diversified. At Grand View on the rim of Grand Canyon in June, 1921, cattle were looking well and were subsisting almost entirely on the leaves and twigs of post oak, cliff rose or quinine bush, deer browse, and two species of service berry. Generally, these shrubs were closely browsed to a height of six feet or as high as the animals could reach. During June and even as late as the middle of July the growth of grasses on these ranges had scarcely started, nevertheless the stock were in fair to good condition. Browse plants and shrubs are deeper and more permanently rooted and hence can endure dry weather better and continue growth longer during a drought than grasses or other herbs. As stated in an earlier report, under favorable conditions the pure grass ranges very likely give larger yields than the mixed forage ranges, i. e., those with a growth of browse and grass, but they do not give as continuous a supply of feed throughout the year.

In marked contrast with the condition of stock on the browse-grass grazing ranges was the pitiable condition of stock on the prairie grass lands having little or no growth of browse plants and on areas where drought or frost had retarded the growth of browse. Not alone was the percentage of losses heavy, but the animals that survived came through the year generally in very poor shape. Even with the return of favorable rains, such animals must continue to be a liability for months to come.

During the year a remarkably small number of instances of losses of stock from poison plants have been reported. This is not unusual during long droughty periods, since at such times the poison plants make little or no growth.

INSTRUCTIONAL DUTIES

During the year just ended, as head of the Department of Biology, the writer has found it necessary to give a larger proportion of his time than heretofore to instruction in the department. This was due to the large increase in the number of students in the department, to the writer's giving full time, in the absence of an instructor, to instruction for one month at the beginning of the regular school year at the University, and one-half time during the remaining eight months. In addition to the above, the writer taught six weeks at the University Summer School, Flagstaff, Arizona.

PREPARATION OF BULLETINS

The larger part of the writer's time in Experiment Station work was spent in the preparation of a bulletin on the grasses of Arizona. A small amount of work remains to be done on this publication. Additional study has been made on the poison plants of our grazing ranges. This applies in particular to the loco weeds, larkspurs, death camas, and the whorled milkweed.

A bulletin on the cultivated ornamental shrubs of Arizona is in process of completion. This treats of about one hundred and twenty-five species and varieties of deciduous and evergreen shrubs and includes a brief description of each one, together with a discussion of the soil, temperature, altitude, and cultural conditions best suited for its successful growth. This work is being done in collaboration with Miss Ethel Pope, an advanced student who has made a careful study of our ornamental plants. It is planned to follow this publication with a similar study of our ornamental trees and vines. The work in ornamental plants has developed to its present importance through studies in plant introduction and ornamentation both in the Experiment Station and the Department of Biology in the University.

DAIRY HUSBANDRY

W. S. CUNNINGHAM, R. N. DAVIS

The outlook for dairying in Arizona is much brighter than it was a year ago. The industry is reviving in the Salt River Valley, where many dairy herds were disposed of in 1918, 1919, and 1920, and it is expected that there will be a large increase in the number of cows in that valley during the next year. Dairying is also becoming a major industry in Cochise, Pima, Pinal, Graham, Navajo, and Apache counties.

One Jersey cow, Aldan's Oxford Nora, and a Jersey bull, Oxford Nora's Fox, have been added to the Jersey herd at the University Farm. A well-bred Holstein-Friesian bull, Changeling Pontiac De Kol, owned by B. Coman of Phoenix, was loaned temporarily to the University.

A number of the Holstein-Friesian cows on the University Farm were tested officially for Advanced Registry during the year. The following official records were made:

Seven-day records	Milk Pounds	Butterfat Pounds
Theresa Belle 3rd., 236394	790.5	23.503
Madison Martha 2nd., 307782	698.0	16.613
Theresa Belle De Vries., 315926	554.8	15.916
Josephine Arizona Maid 2nd., 286131	511.6	14.166
Moensje Jess Aspirante 2nd., 453163	296.1	10.813
Thirty-day records		
Theresa Belle 3rd., 236394	3262.6	99.027
Moensje Jess Aspirante 2nd., 453163	1273.3	44.750
Sixty-day record		
Theresa Belle 3rd., 236394	6097.2	192.450

The above named Holsteins and one Jersey, Arizona's Butter Girl, No. 378677, are on semi-official test. The other cows in the herd will be put on semi-official test during the present year.

Daily records were kept of the milk yield of all the dairy cows, and a two-day composite sample of milk was tested each month to get an estimate of the fat production. This report covers the period from July 1, 1920, to June 30, 1921, and does not give the production for exact lactation periods. Some of the cows were dry for a portion of the year. Table V. gives the milk and butterfat production for the fiscal year.

TABLE V.—YIELDS OF DAIRY COWS AT UNIVERSITY FARM 1920-21

Name of Cow	Breed	Days dry before calving	Days in milk	Yield in pounds		Av. % butter-fat
				Milk	Butter-fat	
Childeberte	Jersey	39	330	7730:5	444.42	5.75
Arizona's Butter Girl	"	23	342	5838.0	353.68	6.06
Arizona Gypsy Draconis	"		365	7763.3	397.83	5.12
Aldan's Oxford Nora	"		334	4125.5	272.04	6.59
Average for Jerseys			342	6364.3	366.99	5.77
Josephine Arizona Maid	Holstein-Friesian	31	365	12200.2	342.53	2.86
Theresa Belle 3rd.	"	52	313	20252.6	626.89	3.09
Josephine Arizona Maid 2nd.	"	53	230	7166.5	201.85	2.82
Madison Martha 2nd.	"	92	272	10683.1	279.45	2.62
Miss Pell Pietertje	"	126	365	10175.6	356.73	3.51
Johanna Madison Pauline	"	107	365	8823.6	239.16	2.71
Theresa Belle De Vries	"	105	260	12602.7	371.30	2.95
Madison Hengervelt Martha	"		365	10710.7	326.80	3.05
Moensje Jess Arpisante 2nd.	"		178	6980.5	235.04	3.37
Average for Holstein-Friesians			301	11066.2	331.08	2.99

SUDAN GRASS HAY VERSUS ALFALFA HAY FOR DAIRY COWS

An experiment has been conducted to determine the value of Sudan grass hay in the ration of dairy cows. In addition to hay, silage and grain were fed in like manner to all the cows on test. The rations were computed so that each cow received at least the minimum amount of digestible nutrients required by the Wolff-Lehman feeding standard.

The ration containing alfalfa hay produced about eleven percent more butterfat than the ration containing Sudan grass hay. After all factors are taken into consideration, this test would indicate that Sudan grass hay is worth less than three-fourths the price of alfalfa hay as a feed for dairy cows. Full data regarding this test will be published in a Timely Hint.

GREEN ALFALFA VERSUS ALFALFA HAY FOR DAIRY COWS

In Arizona, soiling of alfalfa is practiced to a considerable extent where pasturing is not possible. Many believe that cows will not do as well on dry hay as on green feed, and that if cows cannot be pastured, the forage should be cut and fed green. While soiling is considered to be too expensive as a general practice, the soiling of alfalfa may have some merit under Arizona conditions, if labor is not too expensive. A test has been started to secure data on the relative feeding values of green alfalfa and alfalfa hay; to determine the relative amounts of feed obtained per acre by soiling and by making hay; and to determine, as far as possible, the relative economy of the two methods of feeding when production is considered.

MILK SUBSTITUTES FOR FEEDING CALVES

Three new calves have been added to this project, which was described in the Thirty-First Annual Report. Two of these calves are in Group 3, and are being fed a ration of commercial calf meal; the other calf is in Group 4 and is being fed commercial calf meal plus homemade calf meal.

Some changes have been made in the methods, in that Group 4 will be fed on commercial calf meal for two months and on homemade meal for the following three months.

The homemade calf meal contains the following ingredients:

Cornmeal	3	parts
Wheat bran	2	parts
Linseed oil meal	1	part
Blood meal	1/2	part
Ground bone meal	1/5	part
Wheat middlings	3	parts

ENTOMOLOGY

C. T. VORHIES

During the fiscal year 1920-1921, the investigation work of the life history of the banner-tailed kangaroo rat (*Dipodomys spectabilis*) has been completed. This work has been carried as an Adams fund project. The life-history phase of the investigation has been written up in co-authorship with Dr. Walter P. Taylor of the United States Biological Survey and will shortly appear as a joint publication of this Station and the Bureau of Biological Survey, United States Department of Agriculture.

WORK ON ARIZONA PINK BOLLWORM

In August, 1920, a new Adams fund project was inaugurated. This is an investigation of a native insect which exists on the Arizona wild cotton (*Thurberia thespesioides*). In its larval or grub stage this pest lives in and eats out the bolls of the wild cotton to the number of several bolls for each larva. It is, therefore, in fact a native bollworm, more destructive to its normal host than the Arizona boll weevil. It has been called the "Arizona pink bollworm" and may continue to be so called, since it is distinctly pink in color. It should be kept clearly in mind, however, that this is neither the ordinary bollworm nor the corn ear-worm, already infesting cultivated cotton in Arizona; nor is it the same as the Egyptian pink bollworm, which dreaded pest does not yet occur in this State. These two pink bollworms belong, in fact, to different families of moths. The insect now under consideration does not occur as yet on cultivated cotton anywhere, but must be recognized as a potentially dangerous insect. The investigation now under way is designed to determine whether the Arizona pink bollworm is adaptable to cultivated cotton, and also whether it is likely to become a dangerous pest of that crop. We have already proved that this insect can live its entire larval life in the bolls of Pima cotton.

WHEAT INJURY DUE TO *HYLEMYIA CILICRURA*

In December, 1920, samples of seed wheat, which had almost wholly failed to germinate in certain fields, were brought in by Mr. F. L. Ginter of Safford, Arizona. The grains, recovered from the soil of the affected fields, were found to be infested and eaten out by numerous small fly larvae. From these "maggots" there were reared in January a number of specimens of small *Diptera* (true flies) resembling very small house flies. Specimens sent to Washington were determined by a specialist, Dr. J. M. Aldrich, to be *Hylemyia cilicrura* Rdi. This is an insect occasionally reported as injurious in several other states, and known under various common names, but usually designated as the seed-corn maggot. It has been found infesting turnips, radishes, seed-corn, roots of beets, planted seed potatoes, beans (cotyledons and young shoots), and peas, but only once previously in wheat. Available data seem to indicate that damage most often occurs under conditions leading to decay of the affected plants or seeds, the infestation being secondary and therefore of little consequence. There is no certain evidence offered that seed grains are attacked while sound. In the present case, however, there seems to be no good reason to suppose that the seed wheat was in other than sound condition when attacked. A sample of the grain used in seeding the fields affected was clean and no insect eggs or other infestation could be discovered, indicating that eggs or larvae were in the soil, a conclusion verified by the available reports on the life history.

WORK WITH BEES

A record of the 1920 season with the University bees presents points of some interest for this report. Throughout the school year 1919-1920, thus extending into the 1920 season, these bees were used for instruction in bee-keeping, and partly for experimental reasons were divided into two small groups of hives, one on the campus, well removed from mesquite and cat's-claw in quantity, the other at the University Farm in the bottom land of Rillito River, where these plants are plentiful and within easy reach of the bees. The nine colonies were large and flourishing before the end of March, and began early in April to store some surplus honey from a wide variety of wild flowers. Slow accumulation of surplus honey continued until mesquite and cat's-claw (*Prosopis velutina* and *Acacia Greggii*) began to blossom, about May 15 to 20, when the flow increased. Mesquite proved to be practically without nectar, though blooming profusely, with the result that the flow, which at this time of year is generally mixed mesquite and cat's-claw was nearly pure cat's-claw and of excellent color and flavor. On May 29, the first extracting cleared out all of the mixed wild-flower honey. During the next ten or fifteen days the flow was nearly pure cat's-claw, and at the next extracting period on June 15 and 16 the finest honey of the year was secured. One colony had stored 81 pounds in this period.

This proved to be practically the close of the commercial honey flow for the season. Normally the summer rainy season brings on a second blooming of mesquite, but the 1920 rains failed for July and were below normal for August, resulting in complete failure of second bloom for this plant. The campus colonies secured no surplus honey after the June extracting and required feeding this spring (1921), a condition which was even worse than was anticipated because of failure of winter rains, and consequent lack of early flowers for spring upbuilding. The bees at the University Farm had, close by, forty or more acres of yellow bee-flower (*Wislizenia refracta*) on which they concentrated, and from which they secured a surplus of about thirty pounds per colony. This honey was light amber, of rather inferior flavor, not to be compared with the cat's-claw honey taken in June, and it was retained for feeding purposes. Considering the area and the rank growth of the bee-flower the yield was small. This plant is of interest in that it grows on "black alkaline" soil—indeed is an alkali indicator. For instructional purposes comb-honey supers were carried on two hives through the best of the flow.

Summarizing the results of the season, we find that the nine colonies produced 968 pounds of extracted honey, and 127 sections of comb honey. The extracted honey was sold locally at 20 and 22½ cents per pound in 60-pound cans, the cat's-claw moving readily at the higher price. The comb honey graded and sold as follows: 43 one pound sections at 30 cents; 22 fancy at 35 cents; 11 extra fancy at 40 cents; and the remainder graded as No. 2 and culls, sold at 25 and 20 cents. Actual sales averaged $21.50 per colony, omitting account of honey fed back to bees as well as a considerable amount distributed to farm employees as a part of their labor compensation.

The maximum production figures were 170 pounds extracted honey for colony No. 9 and 112 pounds of extracted and 55 sections of comb honey for colony No. 1, both located at the University Farm.

The autumn season was very dry. Desert broom (*Bac-*

charis sarathroides) and Bata mota (*B. glutinosa*) yielded but little nectar though they were heavily worked, since other honey flowers were scarce. These plants bloom at the end of October and in early November, and in good years yield a fine flow for filling the hives with winter stores.

A species of palo verde, of which there are many trees on the University campus, blooms profusely in May and June and is much worked by bees. It seems certain that a considerable proportion of the first crop from the campus colonies was from this so-called "Mexican palo-verde" or "bagote" (*Parkinsonia aculeata*); the honey was of good quality, in no way inferior to the rest of the mixed light amber honey of that period of the year, and superior to some of the local honey of other apiaries produced at the same time. This tree, where abundant, appears to be a honey plant of no small importance; however, it is a native of Mexico, and extends into Arizona only a little way in the extreme southwestern part of the State, its natural range ending about 40 miles southwest of Tucson.

MISCELLANEOUS

Considerable progress in systematizing the insect collection has been made in the past year. The insect cases already provided are nearly filled and more will be purchased immediately.

No Station publications have been issued by this department in the past fiscal year. A short technical article, "Caesarian Operation on *Lepus alleni* and Notes on the Young," was published in the Journal of Mammalogy, Vol. 2, No. 2, May 1921.

HORTICULTURE

F. J. CRIDER, A. F. KINNISON, D. W. ALBERT

For the past few years the Department of Horticulture has concerned itself with the more fundamental phases of horticultural investigation. An important part of this work has consisted in establishing orchards and vineyards composed of the leading adaptable varieties of fruit at all of the branch Experiment Stations in the State. These plantings have now reached the stage of development where they are beginning to yield interesting and valuable data. The increasing number of inquiries for information based on sound experimental practices shows the need for this work. The distinct natural advantages for commercial fruit and vegetable culture found in Arizona are coming more and more to be realized, as is manifested by increased activities in these lines, carrying the compelling suggestion that investigational work in horticulture must embrace constantly broadening fields.

The progress made in the work on projects with the general subjects under investigation during the fiscal year ended June 30, 1921, is given below:

CITRUS FRUITS

NEW PLANTINGS

Five acres of oranges of the Washington Navel variety were planted at Yuma Mesa Farm on August 4, making a total of ten acres that was set during the summer of 1920. This planting was enlarged on June 9, 1921, to include a collection of twenty-eight different varieties. The trees were planted "open rooted," and the temperature on the day they were set reached a maximum of 106 degrees. In ten days from the time of planting the trees had started into growth.

Following is a list of the varieties used: Eureka, Lisbon, Rialto Seedless, and Villa Franca lemons; Marsh, Foster, and Duncan grapefruits; Malta Blood, Valencia, Washington Navel, Mediterranean Sweet, Navelencia, Ruby Blood, Lue Gim Gong, and Satsuma oranges; Dancy Willow-Leaved, King and Algerian tangarines; Mexican Sweet, Rangpur, Thornless, and Bearss Seedless limes; Sampson Tangelo; and Cedrola.

The following varieties were planted at the Salt River Valley Farm on April 29: Homasasses, Valencia, Thompson Improved, Mediterranean Sweet, Ruby Blood, Joppa, and Lue Gim Gong oranges; Tahiti lime; and Sampson tangelo.

THE EFFECT OF FERTILIZERS AND COVER CROPS ON TREE GROWTH AND YIELD

Results secured during the past two years failed to show any material difference in tree growth and yield as influenced by the use of different kinds of commercial fertilizers. However, a very marked effect of the previous summer's cover crop on the foliage of four-year-old grapefruit trees was observed during the past fall and winter. Parts of the orchard where cowpeas had been turned under showed a distinctly green color; whereas the foliage of other parts of the orchard where no cowpeas had been plowed under was decidedly yellowish in appearance. The experiment indicates that leguminous cover crops have a beneficial effect on the growth of citrus trees, not found in the use of stable manure or commercial fertilizers. The orchard in which the test was conducted had been liberally fertilized with stable manure annually, previous to the use of the summer cover crops.

The excellent growth of leguminous cover crops on virgin soil, between the rows of young citrus trees suggests the possibility of building up and maintaining the fertility of orchard soils on the Yuma Mesa without the use of more expensive fertilizers. In view of the extremely light character of the soil of this district, this is an important matter. Sour clover (*Melilotus indica*), common vetch, and hairy vetch, planted on November 3, made a growth of twelve to eighteen inches by the end of May. It might be noted further that the value of inoculating leguminous orchard cover crops in this district was clearly demonstrated by the remarkably greater growth of inoculated clovers and vetches as compared with the growth of similar crops planted without treatment. The leguminous crops that were not inoculated were an absolute failure.

An experiment was recently started on the Yuma Mesa to determine whether there is any advantage in attempting to build up orchard soils through the use of cover crops before the trees are planted. As a first step in the operation, a summer cover crop of cowpeas was planted on June 21. This will be followed by a winter legume crop.

THE EFFECT OF TEMPERATURE AND HUMIDITY

The purpose of this experiment, which is being conducted in the Camel Back district of the Salt River Valley, is to determine the effect of temperature and atmospheric humidity on citrus trees, as reflected through intercultural practices. Standard meteorological instruments consisting of air and soil thermographs, hydrographs, and atmometers have been placed in two adjoining orchards, one with clean cultivation, and the other with an alfalfa cover crop. Accumulated data at present indicate a difference in both atmospheric and soil temperatures of approximately five to six degrees F., the cover-cropped orchard having the lower temperatures. Hydrographic records show the atmospheric humidity to be approximately fifteen percent higher in the orchard containing a cover crop; whereas the atmometer readings show a correspondingly lower percentage of evaporation.

DATE STUDIES

Progress on this project has been considerably retarded on account of the necessity for "torching" in order to control an outbreak of scale, *Parlatoria blanchardi*, which has occurred at both the Tempe and Yuma stations during the past year. The general condition of the orchard at Tempe, however, is quite satisfactory, as the palms, since the beginning of warm weather, have recovered very rapidly from the effect of the "torching" or burning. The stronger trees have been allowed to carry from two to three bunches of fruit. It might be noted that the weaker trees failed to set fruit well, even when the flower clusters were pollinated. The orchard at Yuma has not recovered so rapidly from the treatment, and in fact several valuable palms died during early spring. This orchard was "torched" later in the summer than the Tempe orchard, giving the palms less time to recuperate before winter, which may account for the weakened condition of many of the palms.

PROPAGATION OF OFFSHOOTS

During the month of May eighty offshoots of the Deglet Noor variety were taken from palms at the Yuma Station and set directly in the field on the Yuma Mesa, in an effort to determine the practicability of this method of propagation where large suckers are used. It is too early for the test to show definite results, but the offshoots making the best growth thus far are from the stronger type of parent trees.

Further work in propagating offshoots has consisted of making four series of plantings, using clean sand as a rooting medium, as follows:

(a) Planted in 12-inch earthen pots in the greenhouse;
(b) Planted in 12-inch earthen pots in the open ground;
(c) Planted directly to the greenhouse bench;
(d) Planted directly in the open ground.

The range of temperature to which the offshoots in the greenhouse are exposed varies from 60 degrees F. at night to 120 degrees F. during the hottest portion of the day. At the present time eight weeks from planting, a number of the suckers show evidence of rooting.

In connection with this phase of the date project, nine large bearing palms of the Deglet Noor variety (weighing from 1500 to 3700 pounds) were transplanted to the Yuma Mesa, having been transported a distance of nine miles from the date orchard in the Valley.

THE OLIVE

Sterility studies have been conducted with the olive during the past two years, seventeen varieties being available for the test. The results obtained for the two seasons are somewhat at variance, in that some varieties that indicated self-sterility last spring showed an opposite tendency this year. The tests will be continued for further confirmation of results.

During the blossoming period an attempt was made to determine the effect of irrigation upon fruit setting, the work being done at the Yuma Station. The data obtained indicate that a less amount of fruit set on the trees that were watered while in blossom than on those allowed to stand without irrigation, but the results are not considered conclusive.

In tests to determine the effect of pruning upon the growth of trees and the yield of fruit, a difference in fruit setting has been observed in the case of five-year-old trees. Trees that were pruned according to the "long" method have set a considerably larger amount of fruit than those handled by the "short" method; whereas unpruned trees of this age have a still larger crop.

WATER REQUIREMENT STUDIES

The purpose of this project is to further the development of fruit growing in sections of the State having a comparatively heavy rainfall. It is divided into the following special lines of investigation:

To determine: (a) the actual water requirement of fruits; (b) the effect of pruning on the water requirement of fruits; (c) the effect of special cultural practices on the water requirement of fruits; (d) the environmental factors concerned with plant growth.

Work on the phase of this project dealing directly with field practice was started in the spring of 1920 at the Prescott Dry-Farm, as outlined in last year's report. However, investigations relative to the actual water requirement of fruits were not begun until February of this year. Because of early bearing and adaptability to a wide range of territory, the peach and grape were chosen for use in the experiment. The plants are confined in waterproof cement tanks constructed and handled so that the amount of water used by each plant can be accurately determined. The pruning factor will be embodied in the experiment as soon as the plants have reached the proper stage of development.

PRUNING STUDIES

This project, conducted at the Salt River Valley Farm, deals largely with deciduous fruits and involves eight distinct methods of pruning. Two standard varieties of the peach, apricot, plum, and apple are used in the experiment; and it was enlarged during the past spring to include the Thompson Seedless and Emperor varieties of grapes. In the case of the grape, six different methods of pruning and training are being followed. The fruit trees passed their formative stage of growth last season and have been handled since that time according to the several methods of pruning provided for in the outline of the experiment. The work has not reached the point where it can be expected to yield results.

THE WALNUT AND PECAN

Progress on this subject has consisted largely in top-grafting commercial varieties of the walnut and pecan upon native walnut stock. The work was started early in the spring, as soon as the bark would slip, and is being continued at intervals of two weeks throughout the summer with scion wood held in a dormant state and with fresh wood when it becomes available. In addition to the work done at the University, a number of grafts have been made on native walnut trees in different parts of the State, particularly at Prescott and in several of the wooded canyons in the Santa Rita, Chiricahua, and Santa Catalina mountains.

IRISH POTATOES

The most conspicuous work with Irish potatoes comprises a comparative test of the ridge and the level methods of culture conducted at the Yuma Station. The main point of difference between these two methods lies in the fact that with the former the seed potatoes were planted on rather high ridges which prevented the irrigation water from coming in direct contact with the tubers of the plants. In the level method of culture the tubers formed on the level with or a little below the irrigation water line.

The results of the test are summarized in Table VI.

TABLE VI.—COMPARISON OF THE RIDGED AND THE LEVEL METHODS OF CULTURE FOR IRISH POTATOES

RIDGE METHOD

Variety	Date of harvest	Yield acre basis	Percent culls
Peach Blow	May 16	7602 lbs.	25
White Rose	May 16	1504 "	12
Early Rose	May 10	2457 "	48

LEVEL METHOD

Variety	Date of harvest	Yield acre basis	Percent culls
Peach Blow	May 25	5901 lbs.	25
White Rose	May 25	1428 "	15
Early Rose	May 17	3730 "	30

It will be noted that the Peach Blow variety yielded 1701 pounds and the White Rose 75 pounds more per acre under the ridge method of culture, while the Early Rose produced 1273 pounds less. However, the most important fact brought out by the experiment, which holds true for all varieties used, is that with the ridge method the crop matured earlier. This is a valuable factor as viewed from the standpoint of marketing. In the case of the Peach Blow and White Rose a difference of nine days and in the case of the Early Rose a difference of seven days in favor of the ridge method is shown.

A test similar to the above with a larger number of varieties is being conducted at the University Farm under somewhat different soil conditions, but the crops are not yet ready to harvest. Comparative tests with thirty varieties are also being made at the University Farm, the Cochise Dry-Farm, and the Prescott Dry-Farm.

SWEET POTATOES

Work with sweet potatoes has consisted largely in storage tests. The adobe house, so designed as to embody the main principles of successful sweet potato storage, has given most gratifying results. A test conducted at the Salt River Valley Farm during the past winter was entirely successful, the potatoes keeping from November until April with a loss of only two percent. A small lot was held over until June 16, at which time the only sign of deterioration that could be detected was a slight pithiness of the tubers. Cooking tests showed that the potatoes still retained good quality. The Porto Rico variety was used in making the test.

A shrinkage test with sweet potatoes in storage was made at the University Farm with two varieties—the Porto Rico and Nancy Hall. The potatoes were placed in storage during the month of October, and on March 2, the Porto Rico variety showed a loss in weight of 13.8 percent, and the Nancy Hall of 15.1 percent. It was noted that the greatest shrinkage occurred in the case of the smaller potatoes.

A test to determine the amount of sweet potatoes required to produce plants to set an acre showed that 175 pounds is a sufficient quantity where the potatoes are planted whole and the plants set 18 inches apart in the row with 3½ feet between the rows. The Nancy Hall variety was used in making the test.

VARIETY TESTS OF ORCHARD FRUITS

VARIETIES AT THE SALT RIVER VALLEY FARM

The orchard at the Salt River Valley Farm, which contains over four hundred varieties of deciduous fruits, is now in its third growing season, and while the trees could not be expected to set heavily, a number of varieties have borne satisfactory crops. Had it not been for a severe freeze, occurring when the blossoms of some varieties were very susceptible to injury, there would have been comparatively heavy yields of all the stone fruits.

The following varieties have ripened during the period covered by this report: Apricots—New Castle, Royal, Blenheim, Hemiskirke, Cluster, Tilton, and Russian; plums—Beauty, Shiro, Excelsior, Santa Rosa, Simon, Climax, Eagle, Wild Goose, Gonzales, and Burbank; peaches—Mayflower, Greensboro, Triumph, Oklahoma Beauty, and Oklahoma Queen.

VARIETIES AT THE YUMA STATION

The orchard at the Yuma Station is now in its fifth year and except in the case of some varieties of peaches, the trees should produce good crops this season. The varieties that have ripened during the period covered by this report are: New Castle, Royal, Blenheim, Moorpark, and Hemiskirke apricots; Climax, Gold, Burbank, Santa Rosa, and Gonzales plums; Mayflower peach; Wilder pear; and the Transcendent crab apple.

Detailed records of all the varieties of fruit are being kept. It might be noted at this time that in a general comparison of varieties the New Castle, Royal, and Blenheim apricots stand out as distinctly commercial sorts where earliness is desired, and the Hemiskirke where a later maturing variety is sought. The Tilton and Russian varieties are not desirable for commercial use. With respect to plums, the Shiro and Climax varieties appear most favorable for market purposes—the former on account of its extreme earliness, fine flavor, and good shipping quality, and the latter because of its attractive appearance, excellent flavor, and fairly good keeping quality.

On account of severe freezes which occurred when the trees were in blossom, no fruit was produced this year in the variety orchards at the Prescott and the Cochise dry-farms.

VARIETY GRAPE VINEYARDS

Over one hundred varieties of grapes are in bearing this season at the Salt River Valley and Yuma farms. The Thompson Seedless, Persian 23, Kahlala, and Sweet Water varieties ripened before the close of the period covered by this report.

BUSH FRUITS

The adaptability of bush fruits to different conditions found in Arizona is being studied. The test includes currants, gooseberries, blackberries, raspberries, and a number of other bush fruits that are of less importance. A collection of the leading varieties of these fruits planted at the Prescott Dry-Farm during the past spring has not come into bearing. At the University Farm the Early Harvest blackberry proved an abundant yielder; and in fact, it was the only one of a collection of ten varieties that bore a satisfactory crop. The Gregg and Kansas black cap raspberries bore fairly good crops, while the red varieties set only a few scattering fruits.

NEW FRUITS

A number of little known fruits and nuts that appear promising under Arizona conditions are being tested in different parts of the State. Among these are the jujube, Feijoa, loquat, white sapote, Hovenia, medlar, pistach, guava, paw paw, and avocado. The jujube and Feijoa have done well at the Yuma and Salt River Valley farms and at the University Farm, the former bearing fruit the second season from planting. The white sapote was killed to the ground during winter at the Salt River Valley Farm the second year from planting, but at the Yuma Farm it has not been injured by cold. The avocado stood the winter temperatures at both the Yuma and Salt River Valley farms but died during the summer. It has been difficult to get the loquat to succeed in summer under ordinary field conditions.

GRAPE ANALYSES

Very interesting and valuable data are being obtained from samples of grapes secured from different parts of the State and tested for their sugar content. According to the Balling test, about one-fourth of the crop in some vineyards in southern Arizona had a sugar content of twenty percent on June 30, 1921. It thus appears that grapes grown in southern Arizona mature considerably earlier than the same varieties do when grown in some other commercial grape centers.

VARIETY TEST OF BEETS

The results of a variety test with beets are given in Table VII. Cooking tests showed the Basano to be of superior quality, in point of flavor and texture, to the other varieties, with the crimson Globe a close second.

TABLE VII.—VARIETY TEST OF BEETS (PLANTED NOVEMBER 4, 1920; HARVESTED APRIL 4, 1921)

	Shape	Size	Amount of foliage	Percent stand	Yield (200 ft. rows)
Basano	Roundish-oblate	Medium	Small	96	106 lbs.
Crimson Globe	Globular	Large	Heavy	100	120 "
Early Crosby	"	"	Medium	100	117 "
Eclipse	"	"	"	100	149 "
Blood Turnip	"	Medium	"	92	98 "
Long Blood	Long tapering	"	"	35	34 "
Crimson Globe	Globular	Large	Heavy	100	155 "
Early Flat Egyptian	Flattened	Medium	Medium	100	100 "
Detroit Dark Red	Globular	"	Heavy	95	99 "

IRRIGATION INVESTIGATIONS

G. E. P. SMITH, W. E. CODE, H. C. SCHWALEN

The last annual report of this department covered the progress of investigations up to the end of the calendar year, as had been the custom in former years. This report, therefore, covers the period from January 1 to June 30, 1921.

GROUNDWATER STUDIES

A survey of the water table in the Casa Grande Valley was made in midwinter and another survey in June to determine the recovery from the severe pumping draught of 1920 and the subsequent depression due to the much lighter draught of 1921. The fact that in the main pumping district there was a residual loss in the supply at the beginning of the 1921 season is evidence that the rate of pumping in 1920 exceeded the normal recharge and that the total water supply pumped in 1920 represented quite closely the capacity of the groundwater supply. However, it has been proved by the well records that there is an important gain or recharge due to irrigation from the Florence Canal, and the recent completion of the concrete diversion dam at the head of that canal, to replace the temporary brush and gravel wing dams used heretofore, will undoubtedly augment the groundwater recharge from this source.

The extensive information concerning the groundwater supply in the Casa Grande Valley that has been collected by this department has been furnished the Land Classification Board of the United States Geological Survey for its use.

A possible groundwater irrigation project of modest proportions in the San Simon Valley is being studied. A contract for a well for exploratory purposes in the vicinity of the Cienega has been let, the location being the southeast corner of Section 34, Township 15 South, Range 32 East, on State land. The well is within the terrace which delimits the Recent valley fill, and, besides showing the pressure conditions at considerable depth, will furnish data for estimating the probable yield of individual wells and the possible groundwater development by pumping in that district.

The St. David-Benson artesian district has been studied by means of a survey of the artesian wells, their locations, pressures, and yields. Piezometric lines show conclusively that the sources of the artesian waters are the lateral flows from the sides of the valley and that the longitudinal movement in the valley is quite negligible, except for the underflow in the Recent deposits of the San Pedro flood plain. A similar study of the Hereford artesian district has been begun.

Knowledge of the relation of groundwater supplies in the valleys of southern Arizona to the various components of the valley fills has been handicapped by the uncertainty regarding geologic relationship of the valley fills. Occasionally some essential information becomes available. For example, a well just completed in Section 28, on the Rillito bottomlands four miles northeast of Tucson, has penetrated 192 feet into the older valley fill, which is believed to be of Pliocene age. The well is 420 feet deep, and is the deepest in the Rillito Valley. The older fill at this point is pinkish-gray clayey silt and is uniform in character throughout the depth penetrated. It is much indurated, with calcareous cementation, and is quite impervious. Outcrops of the formation have been known for many years to exist close to the base of the Santa Catalina Mountains. The corresponding formations in the San Pedro and San Simon valleys form the artesian caps of those districts. Until recently it has been held that the Rillito Valley fill to great depth was of Pleistocene age.

ADDITIONAL WATER SUPPLY FOR THE UNIVERSITY CAMPUS

For six years the University has been dependent upon a single well situated in the basement of the Agriculture Building. It was imperative that an alternative supply be developed, both to relieve the danger of water famine in case of a breakdown, and to increase the supply during the months of maximum demand. A site was selected near the east edge of the campus and a well has been drilled to a depth of 320 feet. The well has a concrete-lined pit to the water level with a station room large enough for a pump and motor at that depth. Special methods were used to insure the thorough development of the well, and after completion a test indicated that the capactiy is 40 gallons a minute per foot of drawdown. A 2½-inch motor-driven pump of new design has been purchased, designed to deliver 400 gallons a minute on a lift of 130 feet. The pump, though small, has a horizontally-split casing and single end suction, and has a guarantee of 67 percent efficiency.

FUEL OILS FOR PUMPING

The results of studies of fuel oils, both in the laboratory and in use at pumping plants, have been published as Bulletin 92, under the title "The Supply, the Price, and the Quality of Fuel Oils for Pump Irrigation." This bulletin has proved to be of much value to fuel oil users in obtaining their supply for this season, and has done much to improve the quality of the fuel oils shipped into the State. Furthermore, it has directed the attention of refining companies of the Oklahoma and north Texas oil fields to this important market for moderately heavy distillates, with the result that many of them are now furnishing an excellent engine fuel oil, which they have named "Arizona gas oil." The bulletin has assisted, also, in the settlement of freight claims arising from confusion in the classification of distillation products.

Additional tests of fuel oils are being made from time to time as samples are submitted. Two new flash-point testers have been added to the equipment, a Tagliabue tester for light fuel oils and a Pensky-Martens tester for heavy oils.

STREAM-FLOW MEASUREMENTS

The Irrigation Department is maintaining fourteen stream-gaging stations in Cochise County, two in Pima County, and several in Pinal County. The records of stream flow are obtained with special reference to source, distribution in time, and the seepage losses which go to recharge the groundwater supplies.

EFFECTS OF THE TRANSPIRATION OF TREES ON THE GROUNDWATER SUPPLY

Seven years ago it was suggested that the loss of water through transpiration of trees constitutes the largest groundwater loss in many valleys of southern Arizona. If, therefore, the transpiration loss could be measured, it would provide a means of estimating the groundwater supplies in such valleys as the Santa Cruz and the San Pedro. In 1916, investigations to determine the relation of tree transpiration to groundwater were initiated at Redington, where exceptionally large and uniform forests of mesquite and cottonwood exist. The investigations were interrupted by the war. They were again started in February of this year and results of much value are being obtained.

Wells were dug in the midst of two forests, one of mesquite and the other of cottonwood. The wells were equipped with autographic water level recorders, the record sheets of which are changed weekly. For several weeks the slight fluctuations were found to correlate quite closely with barometric pressures but after the growth of leaves the fluctuations became much more pronounced, and the effects of transpiration produced a daily cycle consisting of the transpiration drop by day and the recharge curve at night. After the beginning of the summer rainy season, additional correlations were obtained, notably those of light, temperature, and humidity.

SOIL SURVEYS

The soil surveys in the San Simon and San Pedro valleys, begun in October, 1920, have been completed. The surveys were conducted by the United States Bureau of Soils and the Irrigation Department jointly, each party furnishing one field man and the field expenses being divided equally.

METHODS OF IRRIGATION IN CASA GRANDE VALLEY

Owing to the difficulty experienced by many farmers in the Casa Grande Valley in the irrigation of alfalfa, considerable time has been given to the problem of the best method of irrigation. On some farms the alfalfa lands have been laid out along the contours, and are, therefore, terraces, usually of irregular shape. The borders are high and meander along the contours, and the land is difficult to work with farm implements. There does not seem to be any merit in this method of laying out the lands for irrigation.

Tests of absorption were made on two ranches. The soil moisture to depths of four to six feet was determined both before and after irrigation, and the quantity of water applied was measured. The distribution of the water over the land was found to be quite uniform, much more so than was found in similar tests in the Santa Cruz Valley described in 1913.* It was demonstrated that on the McClellan loam it is practicable to run the water down the slope of the land in long lands, and this method has important advantages over all other methods. Adjustment of the velocity of the flow and of the duration of the period of wetting can be made by varying the length and width of lands and the head of water turned into each land.

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*Arizona Agricultural Experiment Station, Twenty-Fourth Annual Report, page 283.

PLANT BREEDING

W. E. Bryan, E. H. Pressley

ALFALFA

Pure-line studies with alfalfa have been continued as outlined in the Thirtieth Annual Report of the Arizona Agricultural Experiment Station. Owing to the cost of individual plant cages, funds were available for the construction of only fifty. Since this number of cages limited the pure-line studies to a single variety, the Hairy Peruvian was chosen for the past season's work. This is one of the most important varieties of alfalfa in the State. Notes were taken during the early blooming stage on each of the caged plants as follows:

Stems: Size, color, upright or reclining, height, and extent of branching.

Leaves: Size, hairiness, and extent of leafiness.

Flowers: Number of open clusters, color and distribution.

The cages were placed over the plants on May 15, 1921, care being taken to remove the flowers which had already opened. By June 4, a large number of flowers had appeared on several of the plants; the cages were then removed from the plants, and the flowers of each plant were hand pollinated (selfed) by rolling each flower cluster between the thumb and fingers. The cages were immediately replaced after each plant was pollinated and the hands of the person were dipped in a solution of mercury bichloride, 1 to 1000, and thoroughly dried before beginning with the next plant. From observations made on the amount of seed set on the plants under the cages, as compared with that set on uncaged plants, it is evident that caging interferes to some extent with seed setting. However, there is considerable difference between the amounts of seed set on different plants under the cages.

COTTON

There is a distinct need in Arizona for a premium staple upland cotton which will mature a profitable crop in those regions which have a growing season too short for the American-Egyptian cotton. A cotton breeding project was therefore planned and begun in the spring of 1921 for the purpose of breeding up such a cotton. As foundation stock for this work twelve short and long staple upland varieties have been imported and planted in the vicinity of Tucson outside the quarantine area.

Selection work is also being carried on with three strains of Pima cotton for the purpose of reducing the amount of fuzz on the seed. These three strains were obtained from the United States Department of Agriculture through the courtesy of Dr. T. H. Kearney.

WHEAT

As stated in previous annual reports of this department, the object of the wheat project is to produce an early bread wheat suitable for growth in the irrigated valleys of southern Arizona. Early Baart is still our best bread wheat, although the local millers speak of it as a soft wheat and claim that its flour lacks the baking strength of the hard wheat flour of the Middle West. Millers are, therefore, blending the hard wheats of the Middle West with the locally grown Early Baart in the milling of our best flours. The number of irrigations probably affects the quality of the flour produced to a greater extent than is generally recognized. Some varieties can stand more irrigation than others and still produce grain of fair quality, and the Early Baart is probably the most tolerant to irrigation of any bread wheat grown in the State. This is partly due to hereditary qualities of the grain and partly due to its early maturity. It matures about thirty days earlier than the Red Turkey, thus saving one or two irrigations each season. However, even the natural grain quality of the Early Baart has been changed to such an extent by heavy, late irrigations that its loaf volume as bread was smaller than that of the softest wheat that had been irrigated more lightly. Thus at the Yuma Horticultural Station in the spring of 1914 the grain of the heavily irrigated Early Baart produced flour whose loaf volume was 1780 cubic centimeters, while the loaf volume of the lightly irrigated Sonora was 1900 cubic centimeters, the same quantity of flour being used in each case. It is apparent that of the varieties of wheat which have a tendency to produce hard grains, those maturing early, and therefore requiring less irrigation, will have the best opportunity for developing the hardest grains. In addition to requiring one or two fewer irrigations than late wheats, the early varieties are more likely to escape insect and disease injury and also to give more time for the succeeding summer crop. In the wheat breeding work at this Station, an early maturing wheat has, therefore, been considered as important as one which produces hard grains. For these reasons the hard, late maturing wheats of the wheat belt have been crossed with the local soft early maturing wheats, with the idea of combining hardness of grain and early maturity in a high yielding bread wheat. The inheritance of grain texture of these crosses was presented in the Thirty-First Annual Report of this Station. The inheritance of earliness through four generations is briefly stated as follows:

INHERITANCE OF EARLINESS IN WHEAT

The Sonora-Turkey cross illustrates the manner of inheritance of earliness (or lateness) in crosses between the early and the late maturing varieties. In comparing the earliness of these wheats, the date of appearance of the first head on each plant has been used. The mean heading date of 92 pure Sonora plants in the spring of 1918 was April 7, while that of 90 pure Turkey plants, which were planted at the same time, was May 1. The mean heading date of 30F_1 plants of the cross between these two varieties the same season was April 18, which is almost exactly intermediate between the two mean parental heading dates. The standard deviations of the heading dates of the pure Sonora, pure Turkey, and their F_1 plants were 1.403‡0.070, 2.055‡0.103, and 2.128‡0.254, respectively. Fig. 5A. presents curves showing the range of heading dates for the parents (Sonora and Turkey) and their F_1 plants. Thirty families, containing altogether 4892 plants, were grown in the F_2 generation, and the range of heading dates of these second generation plants covered a period of 36 days, which is three days greater than the period between the date of appearance of the earliest head on the early parent (Sonora) and that of the latest head on the late parent (Turkey). Fig. 5B. shows the range of heading dates of family No. 2 consisting of 275 plants, and also the range of heading dates for the original parents for the same season. Only 66 of the F_2 plants headed as early as the latest head on the early parent (Sonora), while 1435 F_2 plants headed as late as the earliest head of the late parent, leaving 3391 F_2 intermediate plants with heading dates on days when neither parent was heading. In making selections for later plantings, a plant was classified as early if its

‡Signifies plus or minus.

heading date fell within or earlier than the range of the heading dates of the early parent (Sonora), and late if within or later than that of the late parent (Turkey), the remainder being classified as intermediate. Ninety-eight F_3 plants were grown from seed of the early F_2 plants of family No. 2, and the mean heading date was March 27, while that of 143 plants of the early parent (Sonora) was March 25. (See Fig. 5C.).

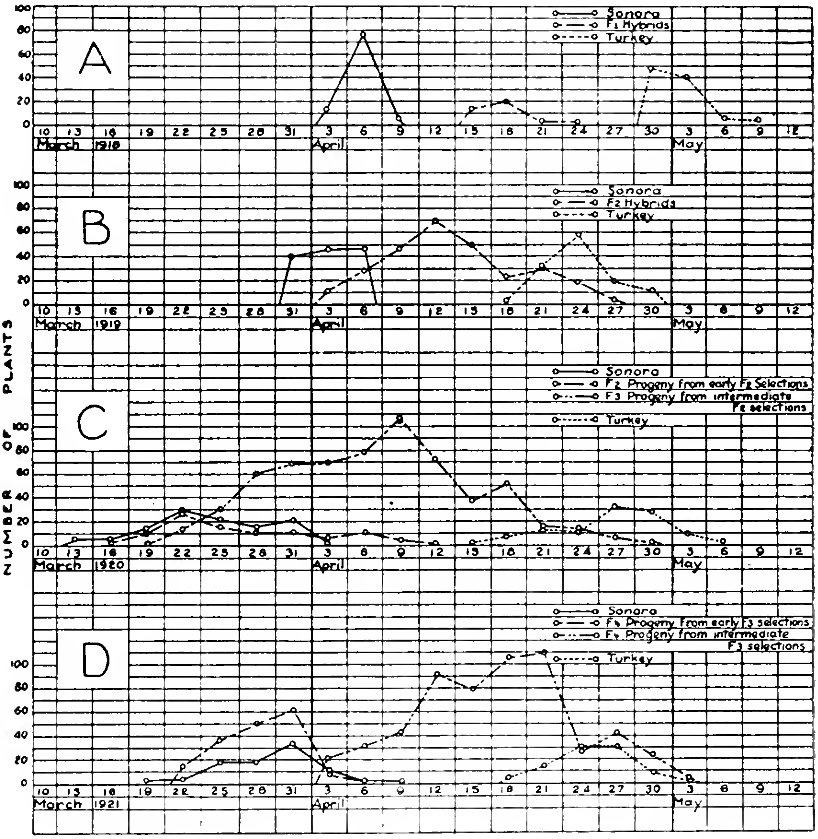

Fig 5—Curves showing inheritance of earliness (as indicated by date of appearance of first head) through four generations of a cross between an early (Sonora) wheat and a late (Red Turkey) wheat.

During the season of 1920-21, 173 F_4 plants were grown from seed of F_3 early plants of family No. 2, and the range of heading dates was five days narrower than that of the original early parent (Sonora). (See Fig. 5D.). Intermediate selections in both the F_3 and F_4 generations had ranges of heading dates which were approximately the same as that of the F_2 generation. Late selections were also made in planting the third and fourth generations, and late races have been separated which are as late as the late parent (Turkey). A large number of true breeding intermediate races have also been separated, indicating that it is possible to fix a race with any degree of intermediacy with regard to earliness, provided a sufficiently large number of F_2 plants are grown.

PLANT PATHOLOGY

J. G. BROWN

Recent agricultural developments within the State have emphasized the economic importance of plant diseases and have correspondingly increased the demands made on the Agricultural Experiment Station. Formerly, requests for assistance in combating diseases of plants were referred to the Station Botanist, but in time the volume of work became so large that it was necessary to establish a Department of Plant Pathology, which was done July 1, 1920. Since the annual budget had already been prepared and adopted, the work of the new department has been somewhat handicapped by the lack of funds for purchasing needed instruments and apparatus.

WORK OF THE DEPARTMENT

The most pressing plant-disease problems have been taken up in the form of projects; miscellaneous studies of infected plants which have been sent in from various agricultural districts of the State have been made; information has been published from time to time in the form of leaflets dealing with diseases prevalent in the State and describing the latest methods for controlling these diseases; a plant survey of the State has been carried on in cooperation with the Federal Plant Disease Survey.

DATE ROT

An important disease known as date rot confronts the Arizona date grower. This rot is so extensive during unfavorable years that as high as 95 percent of the crop is damaged. Processing the fruits saves a part of the crop if it is treated in time, though the quality is impaired by the disease. Usually before ripening has sufficiently progressed to warrant harvesting, a large part of the crop falls to the ground.

Date rot is characterized by two main symptoms: very small chocolate-brown spots appear on the fruit, finally coalesce, and eventually cover one side. In other cases minute spots having a watersoaked appearance, form, gradually enlarge, and finally unite to make a blister. In the development of both kinds of spots the protective layers of the fruit become ruptured, resulting in drying and mummification. The mummified fruit may remain hanging to the clusters or it may fall to the ground. During the progress of the disease the brown spots take on a light cream color in the center. Both kinds of spots occur on the leaflets, and the brown spots are found on leaf petioles and the stalks and branches of flower and fruit clusters, but blistering does not occur on these more woody organs.

Fig. 6—Effects of date rot disease; note mummies still hanging to tree and on ground.

Laboratory cultures of tissues from diseased leaves and fruits have produced several organisms including *Macrosporium*, *Alternaria*, *Helminthosporium*, *Aspergillus*, *Penicillium*, *Sterigmatocystis*, and a bacterium forming brown colonies on date agar. *Macrosporium*, *Alternaria*, and *Helminthosporium* have been shown by inoculations to be actively parasitic on the unripe fruit. It is probable that these fungi break the protective outer layers of the fruit and leaves, and thus open the way for the attack of *Aspergillus, Penicillium* and other more or less saprophytic organisms. *Sterigmatocystis* has appeared in a very few cultures. Inoculations which will determine the nature of the bacterium are under way.

Histological studies explain the symptoms observed in connection with the date-rot disease. Cells at and near the surface of an attacked spot develop a brown pigment. In the meantime, the parasitic hyphae advance through and between the cells, branching freely and becoming swollen where they lie in the protoplasmic contents of the cells which they soon destroy. The advance toward the center of the fruit is checked for a time when the tannin layer of the date fruit is reached, but the hyphae now spread more rapidly parallel with the surface of the fruit, entirely destroying the parenchymatous tissue and leaving a cavity under the cuticle and epiderm which fills with air and results in the blistered appearance. By the time the tannin layer is penetrated the blister is usually very large. As previously stated, several infected spots may coalesce to form one large spot. Lateral growth of the hyphae just beneath the surface in some cases is rapid, resulting in an extensive browning of the fruit before blisters appear. After a blister has

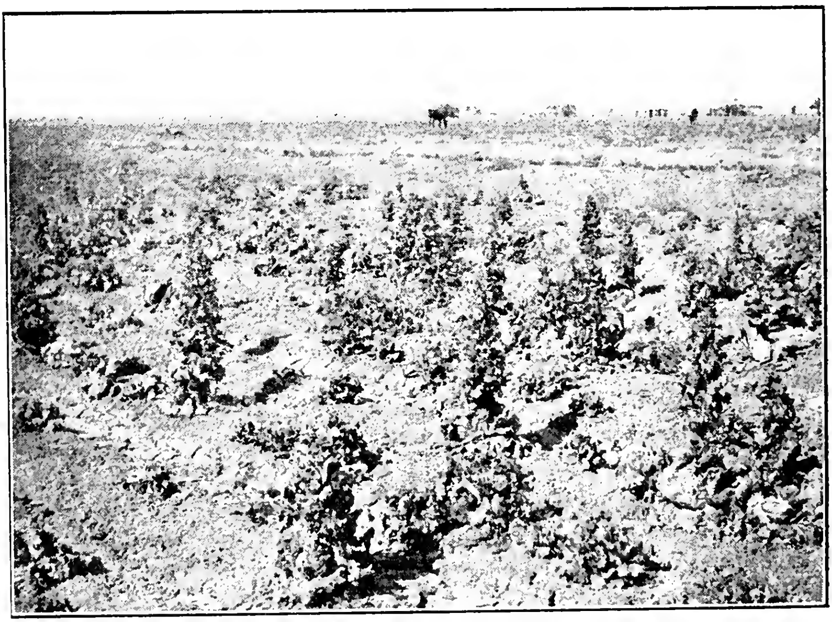

Fig. 7.—Field of lettuce near Toltec, infected with bacterial rot.

formed, the surface soon cracks enough to permit drying of the mesocarp beneath. Some of the hyphae in contact with the tannin layer finally succeed in penetrating the tannin cells in which they may actually be found embedded. Other hyphae pass through natural breaks in the tannin layer and the mycelium eventually reaches the endocarp.

SUSCEPTIBILITY OF VARIOUS DATES TO DATE ROT

No variety of date appears to be entirely immune to the attack of date rot fungi so far as our Arizona orchards are concerned. The Deglet Noor, the most valuable of the varieties in cultivation here, is probably the most susceptible.

CONTROL

Owing to the torching of the date palms in the Yuma and Tempe orchards for the eradication of scale, control measures for date rot could not be undertaken during the season of 1920. Fruit clusters sprayed this season with 4-4-40 Bordeaux mixture have remained free from date rot fungi thus far.

COTTON BLACK ARM AND ANGULAR LEAF-SPOT

Black arm and angular leaf-spot were present in nearly every field of Pima-Egyptian cotton in the State last season. Injury to the crop included the usual stem lesions, destruction of leaf tissue and leaves, boll spotting, premature ripening, and fiber staining. Some fields were reported to be practically ruined. The appearance of the disease in fields newly cleared of mesquite added to the evidence that the casual organism, *Bacterium malvacearum*, is carried by the seed. Unfortunately, cotton growers are slow to adopt the method of seed treatment with sulphuric acid which, in the South, has proved to be an efficient control.

Considerable areas of alkali land lie within the cotton districts of Arizona and alkali is brought into fields in irrigation water. The question has arisen as to whether alkali influences the susceptibility of cotton to the black arm organism. Under a cotton project, this Department is attempting to answer the question. Duplicate plots of Pima-Egyptian cotton have been planted at Sahuarita on alkali-free soil and at Yuma on alkali soil, with untreated seed, seed treated with concentrated sulphuric acid, seed treated with sulphuric acid and then with hot water, seed treated with concentrated sulphuric acid and then with mercuric chloride, seed treated with mercuric chloride, and seed treated with formalin. The study should not only afford information regarding the relation of alkali to susceptibility of black arm and leaf spot in cotton, but also facts bearing on the value of different disinfecting agents for use in treating cotton seed.

MISCELLANEOUS STUDIES

LETTUCE ROT

A bad outbreak of bacterial rot of lettuce occurred at Casa Grande and Toltec early in the spring of 1921. The disease usually affected first the outer leaves of the head, causing a brown discoloration of the fibrovascular bundles, then of the entire leaves, and eventually turned the head into a dark wet, slimy mass. One entire field of 60 acres near Toltec was lost.

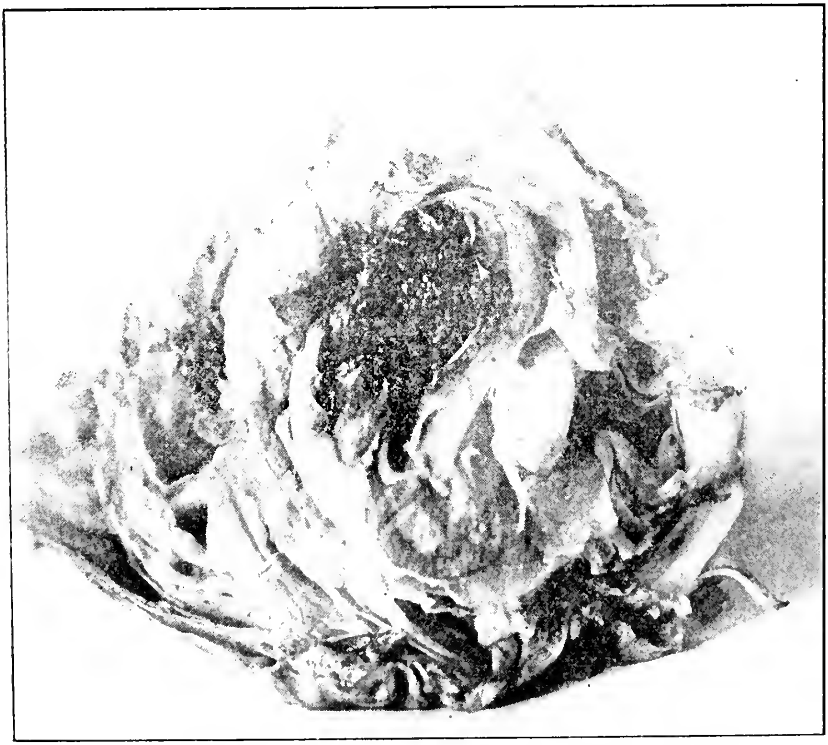

Fig. 8.—Head of lettuce from the market, inoculated in the laboratory with bacterial rot from diseased plants taken from field near Toltec.

Growers almost invariably attributed their losses to frost injury, but laboratory studies revealed the presence of two bacteria which were capable of completely rotting healthy heads of lettuce. Inoculated heads were usually reduced to a black liquid within two or three weeks. Studies are in progress to determine the identity of the bacteria and the source of infection. Bacterial rot of lettuce has been reported from eastern states and the infection there has been attributed to poorly rotted manure used in fertilizing lettuce fields. In Arizona the fields attacked consist of silt, and no manure of any kind has ever been used.

Among other diseases determined in infected plants sent in by county agents, farmers and others, or collected by the Department, are the following:

FIELD CROPS

Alfalfa.

Leaf spot caused by *Pseudopeziza medicaginis*, from Salt River and Yuma valleys.

White spot, physiological, from Yuma and Salt River valleys.

Bacterial blight caused by *Bacterium medicaginis*, from Salt River and Rillito valleys.

Girdle, cause unknown, from Yuma, Casa Grande and Mesa.

Rust caused by *Uromyces striatus*, from Yuma, Casa Grande, and Mesa.

Barley.

Leaf-spot caused by *Helminthosporium sativum*, from Agua Caliente.

Covered smut caused by *Ustilago hordei*, from Mesa.

Cotton.

Sore shin caused by *Rhizoctonia* sp., from Salt River and Santa Cruz valleys.

Wilt caused by *Fusarium vasinfectum*, from St. David.

Black arm and angular leaf spot caused by *Bacterium malvacearum*, from Salt River and Santa Cruz valleys.

Root rot caused by *Ozonium omnivorum*, from Salt River and Santa Cruz valleys.

Watermelon, Cantaloupe.

Anthracnose caused by *Colletotrichum lagenarum*, from St. David and Jerome Junction.

Potato.

Blackleg caused by *Bacillus phytophthorus,* from St. David.

Scab caused by *Oospora scabies,* from Santa Cruz Valley.

Rhizoctoniose caused by *Rhizoctonia solani,* from Santa Cruz Valley.

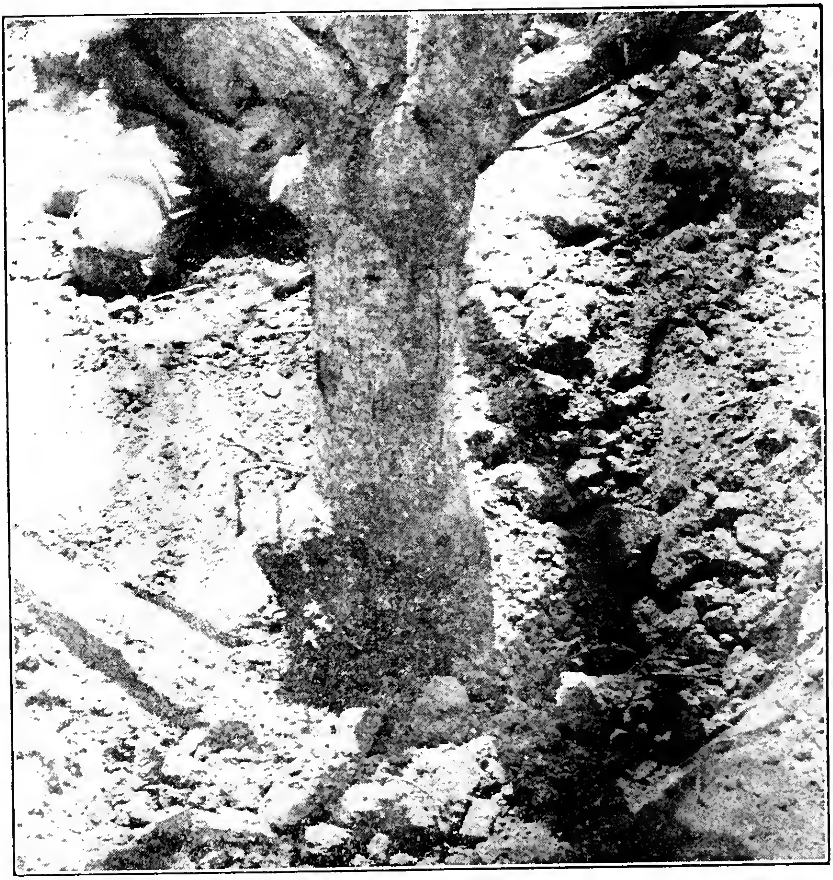

Fig. 9.—Trunk of peach tree killed by crown gall. Note the large gall at base of the trunk on the left side.

ORCHARD TREES

Apple.

Die-back caused by *Cytospora rubescens,* from Apache County.

Fire blight caused by *Bacillus amylovorus*, from Aravaipi Valley, St. David, Nogales.

Crown gall caused by *Bacterium tumefaciens*, from Dewey.

Peach.

Bacterial leaf spot caused by *Bacterium pruni*, from Tucson and Douglas.

Crown gall caused by *Bacterium tumefaciens*, from Casa Grande, Yuma, Winkelman, Tucson.

Frost injury, from Tucson and Willcox.

Pear.

Black mold caused by *Alternaria* sp., from Tempe.

Fire blight caused by *Bacillus amylovorus*, from Oracle, Phoenix, St. David.

Orange.

Die-back, from Yuma.

Date.

Leaf spot caused by *Macrosporium* and *Alternaria*, from Yuma and Tempe.

SMALL FRUITS

Gooseberry.

Powdery mildew caused by *Sphaerotheca mors-uvae*, from Navajo County.

Grape.

Mildew caused by *Plasmopara viticola*, from Inspiration.

Grape rot, cause unknown, first reported last year. Unripe fruits of white varieties become spotted with soft, brownish, semi-translucent areas. Shrivelling and rotting begin and the spots become bronzed, later turning to purple. Drying proceeds more rapidly on one side than the other so that the outline of the seeds shows. Often the berry remains normally green excepting for one sunken spot. The appearance of the tissues in histological preparations strongly suggests a parasite, but cultures made from surface-sterilized fruit usually show no growth. A few have given a species of *Gloeosporium* with spores much larger than those of any species hitherto reported on the grape.

Crown gall caused by *Bacterium tumefaciens*, from several localities.

Raspberry.

Crown gall caused by *Bacterium tumefaciens,* from Jerome Junction.

Strawberry.

Leaf spot caused by *Mycosphaerella fragariae,* from Jerome Junction.

GARDEN VEGETABLES

Lettuce.

Bacterial rot caused by undetermined bacteria, from Casa Grande, Toltec, Tucson.

Root knot caused by *Heterodera radicicola,* from Thatcher.

Root rot caused by *Ozonium omnivorum,* from Thatcher.

Okra.

Root knot caused by *Heterodera radicicola,* from Thatcher, accompanied by

Root rot caused by *Ozonium omnivorum.*

Spinach.

Rust caused by *Puccinia subnitens,* from Clemenceau.

Downy mildew, caused by *Peronospora effusa,* from Tucson.

Tomato.

Wilt caused by *Fusarium* sp., from Winkelman, and St. David.

Wilt caused by *Bacillus solanacearum,* from Jerome and Jerome Junction.

Blossom drop caused by unfavorable weather conditions, from Dos Cabezas.

ORNAMENTAL PLANTS

Ash.

Phyllactinia leaf spot caused by *Phyllactinia corylea,* from Tucson.

Oleander.

Gall caused by *Bacterium savastanoi,* from Tucson.

Pepper tree.

Hypertrophy and timber rot caused by Inonotus sp., from Tucson, Tempe, Florence.

Rose.

Crown gall caused by *Bacterium tumefaciens,* from Tucson.

Powdery mildew caused by *Sphaerotheca pannosa,* from Bisbee.

Snapdragon.

Rust caused by *Puccinia antirrhini,* from greenhouse in Tucson.

OTHER ACTIVITIES

During the year two scientific meetings were attended without expense to the State, one at Chicago and the other at El Paso. At the latter, two botanical papers were read. Traveling within the State necessitated by date and cotton projects and other studies amounted to about three thousand miles.

At the time the Department was organized, a preliminary paper was published on date rot. In addition to this, about two thousand sheets on plant diseases of Arizona have been issued for the use of the farmers of the State.

POULTRY HUSBANDRY

R. B. THOMPSON

The following projects were formally approved for the Poultry Department on June 28, 1921:

Poultry Breeding
Poultry Breeding Contest
(Egg Laying Contest)
Date of Hatching
Chick Feeding and Brooding
Broiler Production.

Of these projects some work has already been done on the Poultry Breeding Project. Desirable pullets were selected in the fall of 1920 and trapnesting has been done since that time. All chicks hatched have been pedigreed. All other projects will be inaugurated as soon as the Poultry Department is established in a larger and more desirable location. The mortality of the brooding stock has been above normal during this year due to the use of crowded temporary quarters.

In the Annual Report for the year ended June 30, 1920, the 1800-egg incubator was reported as not having been a success on account of improper coal and poor conditions for operation. The proper grade of coal was secured and the incubator given a series of trials. By operating different sections with different ventilation and moisture it was determined that the incubator was entirely unsuited to this climate.

Francis R. Kenney, head of the Poultry Department, resigned effective August 31, 1920. Although a new head of the Department was secured to take the work on September 1, the change made readjustment in the work necessary and, therefore, the advancement of Experiment Station work was but slight during this year. The head of the Department has done instruction work in the College of Agriculture and has been Poultry Specialist in the Extension Service and, accordingly, has not been able to devote more than part time to any one branch of the work. Definite plans for the future development of the Department, which will be effective with the inauguration of the new poultry plant and with the addition of instruction and extension help, have been formulated.

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INDEXED BY NELLE NESBITT, M. A.

Titles of Bulletins, of Experiment Station Circulars, and of Timely Hints for Farmers are printed in capital letters. Scientific names are in italics. Numbers of Bulletins, of Experiment Station Circulars, of Timely Hints for Farmers, and the dates of Annual Reports are printed in heavier type than page numbers.

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