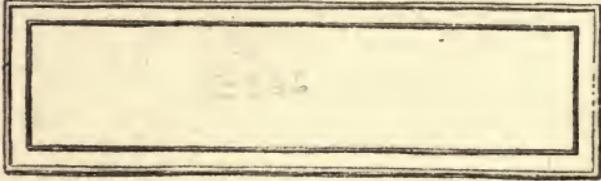
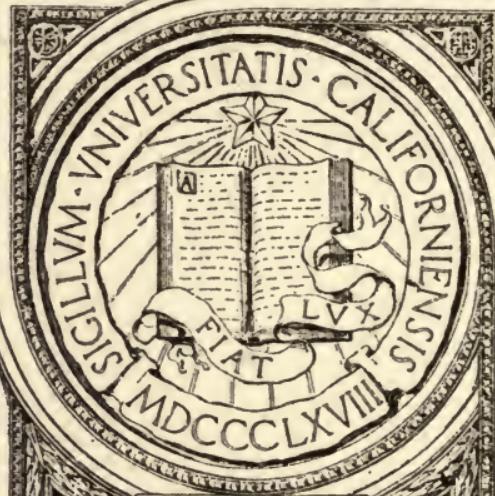


DRY LAND FARMING

THOMAS SHAW





LOUIS W. HILL

PRESIDENT GREAT NORTHERN RAILROAD SYSTEMS

Dry Land Farming

By

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*Late Professor of Animal Husbandry at the
University of Minnesota*

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**The Study of Breeds, Animal Breeding, Feeding Farm Animals,
The Management and Feeding of Cattle, Grasses and
How to Grow Them, Clovers and How to
Grow Them, Etc.**

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[TO

LOUIS W. HILL

PRESIDENT GREAT NORTHERN RAILROAD SYSTEMS

THIS BOOK

IS RESPECTFULLY DEDICATED

INrecognition of the great work he is doing for the
development of the agricultural resources
of the American Northwest

355431

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THE AUTHOR'S PREFACE

What may be termed the dry land area of the United States and Canada embraces approximately not fewer than five hundred million acres, all of which may be tilled, and nearly all of which is unusually rich in the elements of production. Because of the limited amount of rain that falls, this immense area can never be tilled successfully by the methods of farming ordinarily practised in humid areas. Within a comparatively recent period, however, it has been ascertained that nearly all of this area may be made to produce good crops, and with reasonable certainty, by what are known as dry land methods of tillage.

The existence of this immense agricultural domain, as yet largely unoccupied, is now being widely proclaimed. Settlers are rushing into it, the greater portion of whom have previously lived in humid or sub-humid climates. They are much prone to begin the tillage of the land by methods that are adapted to humid conditions. It is a foregone conclusion that such methods will fail. Dry land farming can only succeed through methods that are adapted to dry land conditions.

This book has been written in the hope that it will furnish information that may be safely followed by the dry land farmer in the prosecution of his work. When writing it, special consideration was given to the crops that may be successfully grown in the various sections of the dry land area, and to the best methods of growing them. That the dry land farmer may find the book helpful to him in the prosecution of his work is the earnest desire of the author.

THOMAS SHAW.

St. Anthony Park, Minnesota, 1911.

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CHAPTER I

WHAT IS MEANT BY DRY FARMING

The term "Dry Farming" is now applied to the growing of crops in all areas where the precipitation is so light that special methods of tillage have to be resorted to in order to grow crops with a reasonable measure of success. In a sense it is a misnomer. To those who may not understand the way in which it is used, the hazard is present that it will convey the impression that it refers to farming that is conducted in the absence of moisture. Many have objected to the term for the reason given above, and for the further reason that its use tends to prejudice those who are seeking homes with reference to land that must avowedly be farmed on the dry farming plan whatever that may mean.

The effort has been made to change the name, but without success, and it has failed for the following reasons: (1) The term is in itself essentially correct, as it refers to farming under dry conditions. Every one knows, or ought to know, that farming cannot be conducted in the absence of moisture. (2) It carries with it the idea that the precipitation is less than that which ordinarily falls in humid and sub-humid climates, a truth that one seeking a home in such areas ought to know before he makes his choice, otherwise he is going to be disappointed and possibly to the extent of being discouraged. (3) It would seem to be almost impossible to substitute a name that will so well characterize the class of the farming that is to be pursued in these areas.

What dry farming does not mean.—Of course dry farming does not mean the growing of crops without moisture. That would be an absurdity. But it does mean growing them with a less amount of moisture than would be successful in producing them without resorting

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to special methods of cultivation. It rather means growing them under varying degrees of precipitation, running all the way from a little below what is normal to the lowest quantity that will result in production by any method of tillage that may be adopted.

It does not mean the growing of crops in all areas where precipitation falls. In some of these the precipitation is so light that even tilled crops cannot be successfully grown. The degree of the precipitation essential to the growing of paying crops in dry areas is a greatly varying factor, since it is influenced by the character of the soil and the nature of the evaporation.

It does not mean the growing of tilled crops every year on the same land. This, though quite feasible in humid climates, is not entirely so in dry areas. In these, under some conditions, it is possible to grow only one crop in two years. Under other conditions the number of the crops grown in succession is increased. It does not occur very often, however, that crops can be obtained every year. In nearly all instances it is necessary occasionally to devote one season to the storing up of soil moisture in the soil and subsoil, as a reserve for the needs of the crops that follow.

It does not mean the growing of crops to the exclusion of live stock. It would not be quite correct to say that the grazing of live stock on the open range comes under the head of dry farming, for farming includes the idea of cultivating the soil. On the other hand, the keeping of live stock is not only not incompatible with dry farming, but is in a certain sense supplementary to it. The dry land farmer is not only a grower of grain and other products, but he may be also a grower of live stock.

The food that he grows may be, and is in many instances, used in feeding live stock grazed on his own arable farm, or on rugged lands adjacent thereto. In some

areas the keeping of live stock may with propriety become a feature of dry land farming from the very outset.

Nor does dry farming mean the growing of all crops proper to the latitude. Some of these may succeed admirably in a certain latitude when the rainfall is normal, and yet they may partially or entirely fail when it is less than normal. Other crops, even of the same species, may succeed because of greater inherent ability to withstand drought and hard conditions generally. Such crops only should be grown in dry areas as may show reasonable adaptation for the same.

What dry farming does mean.—Dry farming means : (1) growing crops under semi-arid conditions ; (2) growing crops where the moisture is normally deficient ; (3) growing them where moisture is temporarily deficient, and (4) growing special crops by special methods. Shortage in the moisture supply is the dominant thought that underlies any definition that may be framed regarding dry farming.

Where arid conditions prevail, crops cannot be grown successfully without the aid of irrigation. In such areas there may be rain, but it is not enough to produce vegetation that is of any special value without the aid of man, and even with his aid it cannot be made profitable in the absence of irrigation. Where semi-arid conditions prevail, nature unaided produces growth, but it is sparse and deficient rather than generous and ample. Under these conditions, however, growth may be made so to aid nature in her effort, that production sparse and niggardly may be supplemented by production generous and even bountiful within certain limitations. In some of these areas the farmer has been able to grow more than 70 bushels of No. 1 hard wheat per acre on land that called for 10 to 20 acres of pasture to carry a cattle beast weighing 1,000 pounds through the year. The border line between arid and semi-arid production runs

along between areas where the precipitation is so short that man cannot secure profitable production therefrom in the absence of irrigation, and where he can secure the same, notwithstanding the shortage in the precipitation. This border line is not alone determined by the amount of precipitation, but also by the season when it comes and by the soil, subsoil and climate. The precipitation that forms this dividing line, therefore, cannot be stated precisely in inches, as it will vary with the conditions. It is not far, however, from 8 to 10 inches.

Where dry farm methods are practised, the precipitation is usually so short that special methods of cultivation are necessary in order to produce good crops. But some seasons it may be enough to grow such crops without resorting to these methods. Since it cannot be known beforehand when such seasons will come, the land in those areas should be tilled every season with a view to meet the exigencies of a dry season the following year should it come. Even though it should not come the labor thus expended will not be lost, because of the helpful influence that such careful handling of the soil will have on the production. The amount of the precipitation that will make production profitable cannot be stated definitely in inches, as it will vary from the same causes that lead to variation under arid conditions. Good crops can be grown almost any season where the normal precipitation runs, say, 10 to 15 inches. These figures, however, are not given as the minimum or maximum of the precipitation called for as essential to the growth of crops in semi-arid areas.

While the practise of dry farming methods has, until the recent past, been confined wholly or almost wholly to areas where the normal precipitation is more or less deficient for the best needs of the crops every year, it is now coming to be practised in modified form in areas where the annual precipitation is enough or more than

enough to meet the needs of the crops were it properly conserved. Nearly all areas, howsoever large the rainfall may be, have a dry period more or less prolonged during the season of growth in the crops. To provide for such periods, more or less moisture should be conserved, and the methods for conserving it are essentially the same as for conserving moisture in dry areas.

All the species of crops that may be grown successfully in a certain latitude where the rainfall is ample cannot be grown with the same success, if, indeed, they can be grown at all, under dry farming methods. The same is true of varieties of the species. The crops grown must be special, as it were; that is, those must be given the right of way which show the highest adaptation, as it were, for the conditions under which they are grown, nor can these be grown by the same methods as obtain in the growing of the same varieties when moisture is abundant. These special crops and the special methods of growing them will be discussed at length in another place (see chapter X).

Growing special crops.—The crops grown by dry farming methods must in a sense be special. This means they must to some extent at least be special with reference: (1) to class and to variety; (2) to drought-resisting qualities; (3) to capacity to gather food; (4) to early maturity, and (5) to methods of cultivation.

All classes of crops that have adaptation for being grown in a certain latitude have not by any means the same adaptation for being grown under semi-arid conditions. It would be vain to try to make a marked success of growing such species in these, (1) as flourish best in a moist atmosphere; (2) that call for much precipitation relatively while they are growing, and (3) that make the larger portion of their growth late in the season. The common vetch furnishes an example of the first, clover of the second and certain field roots of the

third. The same is true of many varieties within the species. They may not have the staying qualities which enable them to endure what may be termed trying conditions for growth, while these may be possessed by other varieties of the same class and which may be less valuable than the former, when grown under favorable conditions. This explains in part at least why in the dry country some rugged varieties of spring wheat are gen-



DRY LAND GRAIN GROWN NEAR PALOUSE, WASHINGTON.

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erally preferred to varieties which may have superior milling qualities.

It is essential that the crops grown shall be drought-resistant in a marked degree. The difference in plants in this respect is very marked. It explains why certain species of sage brush flourish where the most drought-resistant grasses may fail, and why Kafir corn and Milo

maize may succeed. Alfalfa, because of its power to resist drought, will through all time be one of the most important crops that will ever be grown in semi-arid areas. The difference in the drought-resisting qualities within the species is very considerable, as in the far greater power that western rye grass has to resist drought than timothy. But the difference in these qualities between species is even greater, as sage brush will cling to life where western rye grass could not survive.

The difference in the ability of plants to gather food in the soil is very marked. This difference may arise: (1) from the character of the root development; (2) from the area in which they feed, and (3) from the power which inheres in them to gather food. The roots of alfalfa go far down into the ground, hence it can gather food from an area beyond the reach of the roots of many other plants. This area is also frequently relatively well supplied with moisture. Some plants produce the larger portion of the growth not far from the surface, as timothy for instance, hence these are ill adapted to dry conditions. Other plants have more inherent power to gather food from a given soil area, as rye of the winter or spring varieties, hence they have relatively higher adaptation to dry conditions. This goes far to explain why rye may succeed under conditions that would not suffice to produce a paying crop of wheat.

Under nearly all conditions in the semi-arid country the weather becomes very dry as the harvest season approaches, and in consequence crops that mature late may be seriously harmed by this condition. Because of this, crops that mature early are relatively better adapted to dry areas than those that mature late. This fact cannot be disregarded when deciding as to the species and varieties that shall be grown. The earlier that the dry period usually comes the more important it is that the crops grown shall mature early. This explains

why in the semi-arid areas winter crops are chiefly grown when the rainfall is greatest in winter, and is followed by dry weather by the time when summer arrives. They mature in advance of the coming of the dry weather.

The methods of cultivation by which crops may be grown have a marked influence on the choice of the crops to be grown. Those that may be given the largest amount of cultivation during growth, other things being equal, are the most likely to succeed. Because of this such crops as corn and sorghum are most likely to succeed. Next to these are crops that may be disced or harrowed more or less while they are growing, such as alfalfa and the small grains. The most difficult crops to grow in dry areas are grasses, since they are given little or no cultivation while they are growing. From what has been said it is evident that in a dry country the range of the crops grown is less wide than the same in a humid country.

Growing crops by special methods.—In dry areas crops are usually grown by special methods, that is by methods that differ more or less from the methods usually followed in humid areas. The methods relate: (1) to the preparation of the soil; (2) to sowing or planting the crop; (3) to the cultivation given subsequently to planting, and (4) to the order in the succession in which they are grown. The methods to be followed in preparing the soil and in planting and cultivating the crops will be given in detail later. At this time the aim will be simply to call attention to the sense in which these operations are special.

The preparation of the land is special in the pains taken to increase the moisture supply in the soil, and to hold it in the same until it is needed for the crops. In humid climates but little attention is paid to increasing the moisture content in the soil. Generally speaking the supply is ample in these to germinate the grain.

It is not so in semi-arid areas. The special methods resorted to in the latter thus to increase the moisture supply include, deepening the tillage by plowing and sub-soiling, packing the soil when plowed, and maintaining on it a dust mulch, and by observing much precision as to timeliness in performing all these operations. They may be practised more or less in humid climates, but in these they are much less needed, and when called for there is much more of latitude as to the time when the work shall be done. In the latter they may be largely omitted or carelessly done, and yet a crop of considerable value may be reaped. In the former such omission or carelessness would almost certainly be followed by failure. In humid climates an excess of water reaches the soil, insomuch that special means must be resorted to with a view to remove it. These include the making and maintaining of open ditches and the construction of underdrains. These are seldom or never wanted in dry areas; on the other hand, measures are frequently adopted to prevent water from running away should it come in the form of a downpour, an occurrence that is not infrequent in some parts of the arid country.

The methods of planting are special with reference to the time of sowing the seed, to promptness in sowing the same, to the quantity that is sown, and to the manner of sowing. In humid climates, the time covered by the season for sowing or planting is relatively long; in dry areas it is short, as, unless the crop is sown at the right season, the dry weather that invariably comes later may damage or destroy the crop. The seed called for in dry areas is much less than in humid areas to meet the conditions of growth that the moisture supply will best maintain. In dry areas the seed must go down to moist soil or germination is pretty certain to fail, a result which is much less likely in humid areas.

In humid areas cereal crops are not usually given

any cultivation after they are planted. In dry areas it is the exception to grow these without some cultivation. It is usually given in the form of harrowing. Harrowing the crop after it appears may make the difference between securing a fair crop and virtually no crop at all. The management of cultivated crops is not greatly different in humid and in dry areas, save in the degree of the same called for. The cultivation called for in the latter is considerably greater in degree than in the former. It may also be profitably extended to the alfalfa crop.

In all areas a certain order of succession in the crops is helpful. In those that are humid the succession is much wider than in those that are arid. The rotations in the former may be varied, and yet each may prove satisfactory. In dry areas it is very different. The rotations peculiar to and also suitable to each are restricted. This arises from the limited amount of the moisture that is available. In some dry areas but one cereal crop can be grown in two years. In others two crops may be grown in three years, and in yet other instances three crops may be grown in four years (see p. 397). But in all these instances, special methods of cultivation are called for.

How climates may be classified.—With reference to precipitation and production, climates may be classified: (1) as arid; (2) semi-arid; (3) sub-humid, and (4) humid. It is not possible to state in figures, other than in an approximate way, the amount of the precipitation that properly belongs to one or the other of these classifications, since precipitation is by no means the only factor that influences production. It is greatly influenced by soil conditions and by the dryness or the humidity of the atmosphere, in other words by the degree of the evaporation.

An arid country is one in which paying crops cannot

be produced by the ordinary processes of cultivation. The degree of the aridity may be partial or total. It may produce sparse growing shrubs as sage brush and greasewood and even grass, but the production of grass will be quite limited. Even the shrubs that can stand drought best will not grow closely together, as, if they should start thus, the moisture supply would not be enough for each. It may be arid: (1) because of the scant precipitation that falls on it; (2) because of the lack of plant food in the soil; (3) because of the presence in excess of certain substances in the soil, as alkali, which are so unfavorable to plant life as to make it impossible to produce, until the substances inimical to vegetation are removed or modified in their chemical properties. These influences may act separately or in conjunction. The more nearly they act in conjunction, the greater is the degree of the aridity. More commonly however, aridity is caused by an insufficient precipitation. In the major portion of the area that is arid in the western states, the soil is not only rich in the elements of plant food, but it is in many instances remarkably so. This is especially true with reference to the mineral constituents, and it arises, first, from the store of these in the original rock constituents from which the soils were derived, and, second, from the little loss in the same through leaching. Soils of this class are greatly productive when irrigating waters are intelligently applied to them.

The amount of the precipitation that results in aridity is much influenced by the physical character of the soil, by the degree of the evaporation, and by the season at which the bulk of the precipitation falls. A soil unduly porous calls for more precipitation to render it productive than one that has an amount of porosity most favorable to the retention of moisture, without being antagonistic to aeration. The longer the season for

growth and the drier and warmer the climate, the more rapid is the evaporation. The less the precipitation during the period of growth, the more of the same that is called for to carry production beyond the point of aridity. The amount of the precipitation that will limit aridity, therefore, cannot be exactly stated; it is a shifting quantity. In the northern states the country is classed as arid when the annual precipitation is not more than, say, 7 to 8 inches on the average. In the mountain states far south it would seem correct to say that from 8 to 10 inches would be called for to effect the same end. The maximum limit of rainfall in arid America is not far from 9 inches.

A country may be classed as semi-arid when it will produce paying crops, but only by what may be termed special processes of tillage. It may produce trees of such species as are able to endure hard conditions, shrubs possessed of similar characteristics, and also grasses that grow but for a limited portion of the period of possible growth. The influences that qualify semi-aridity are the same in kind as those which determine aridity, but they are less in degree, hence it is not easy to define the limits of semi-aridity in terms of the degree of the precipitation. Ordinarily a country may be classed as semi-arid when the annual average precipitation is not less than 9 inches nor more than 18 inches. When the annual average precipitation is not more than 15 inches, special methods of tillage are necessary in order to insure profitable production.

These methods, which are given elsewhere, have special reference to the conservation of moisture in the soil (see pp. 165-172). The production which may be secured, especially in the form of grain, is very gratifying. It is more easily obtained and is much greater in degree as a rule in areas where the natural precipitation is supplemented by subterranean water moving laterally in the

soil and so near the surface as to aid more or less the growing crops. In semi-arid areas the precipitation some seasons may be so increased as to render them sub-humid for the time being. In such seasons production may be secured by the ordinary methods of tillage. In other seasons it may be so low as to render them for the time being in a sense arid, but both these extremes are exceptional. But since it cannot be known when they will come, the special methods of handling these soils when preparing them for being cropped should never be omitted.

Sub-humid areas are those in which crops may ordinarily be grown every year, but wherein some seasons the precipitation is so light that partial failure follows in the absence of special measures to conserve the moisture in the soil, and that which comes to it. The precipitation in sub-humid climates may run from, say, 18 to 27 inches. In these the precipitation may occasionally fall so low as to make them temporarily semi-arid. In other instances it may be so abundant as to carry them temporarily into the humid class. The aridity of these may in some instances be such as to make crop production difficult, and in other instances the humidity may be such as to call for drainage to carry away the excess of water from the soil. In cultivating these soils some of the practises followed in cultivating dry areas will render production more sure than it would otherwise be. Sub-humid areas have special adaptation for profitable production, as the precipitation is usually enough to produce a crop with proper tillage and it is seldom enough to destroy it or even to seriously harm it. Nor is it enough to remove very much fertility through leaching.

Humid climates are those in which the precipitation is such that production is reasonably sure every year from the ordinary processes of tillage. In these the precipitation is not only heavy, but in sympathy there-

with the dews are heavy and the air is moist. The rainfall is frequently so excessive that drainage in one form or another must be given the most careful attention by those who till the soil. In such areas the precipitation is 27 inches in the year and upwards. In some maritime areas it is as much as 70 inches and upwards. Where the precipitation is very heavy the loss to the soil in fertility through leaching is considerable, and the removal of soil by denudation is quite frequently very serious. Notwithstanding, in nearly all even of the areas that are humid there is a dry season in which the crops may suffer in the absence of measures to protect the moisture, that is, in the absence of some of the operations that apply in tilling semi-arid areas.

The influences that affect aridity.—Foremost among the influences that affect aridity is the amount of the precipitation. When this is too low for successful crop production under the conditions present, no matter how favorable the other qualifying influences are, the effort to grow paying crops must fail. These qualifying influences include: (1) the character of the precipitation; (2) the season of the same; (3) various influences that affect moisture evaporation, and (4) those which affect filtration and the leaching of moisture in the soil and subsoil. Because of these qualifying influences, the results to be expected from a given amount of precipitation cannot by any means be definitely forecasted. They will vary greatly. The amount that would suffice to produce a given result in one instance would be wholly inadequate in another instance, and yet it would seem safe to make the statement that crop production would be virtually quite safe and remunerative where the rainfall is not less than 15 inches on ordinary soils, and that it should be generally safe and remunerative where the rainfall is not less than 9 to 10 inches. These statements are based on experience and observation. Where the

rainfall is less than, say, 10 inches, the production is more or less uncertain.

The character of the precipitation is far-reaching in its influence. Should it come in the form of a cloudburst or even of a downpour which is not a cloudburst, the hazard is present that much of it will be lost by running away over the surface, and that it will carry to lower levels more or less valuable soil. Should it come in the form of snow, the benefit to the soil and crops will be governed largely by the condition of the soil when it melts, and by the manner of the melting. If the ground is frozen hard and deeply below the snow and it thaws quickly, only a small amount of it will reach the soil, but if on the other hand the ground is but little frozen, much of the resultant water will find its way into the soil, more especially when the soil has recently been stirred to a good depth. On the other hand, if it vanishes slowly in a dry atmosphere much of it will be absorbed by the same, thus never reaching the ground. Should the showers come very lightly and with considerable frequency, they may do but little good, as without an excessive amount of harrowing on cultivated land, the loss of moisture could not be wholly or even chiefly prevented. The greatest benefit results from the precipitation when it comes moderately and in considerable amounts at a time, and not too frequently. Nearly all the influences named, it will be observed, are quite beyond the control of man.

The season of the precipitation is quite as important as the character of the same, if not indeed more so. The greater the amount of the precipitation relatively that falls during the growing season, the greater is the production likely to be that arises therefrom. In much of the western portion of the semi-arid country, more than 50 per cent. of the precipitation comes during the season of growth. Westward in the same, more of it comes

relatively in the late autumn and in the winter months, which so far is less favorable to production except in the case of a limited number of varieties of cereals and grasses, but the loss is counterbalanced in a considerable degree by the relatively large proportion of the precipitation that falls in winter which may enter the soil at that season, because of the limited extent to which it remains frozen. Precipitation that is most timely, on the whole, is that which falls but lightly in the winter season and freely in the season of growth.

Prominent among the influences that affect the evaporation of moisture are: (1) winds; (2) abundant and hot sunshine, and (3) low humidity. The more dry and warm the winds that blow over a given area, the more forceful that they are, and the more constantly that they blow, the greater is the amount of the moisture that they remove from the soil.

In the arid and semi-arid areas, the air is much less moisture-laden than in humid areas; hence it takes moisture more readily from the soil. In much of the bench land and prairie areas, the winds blow with considerable force and with no little constancy, especially during the spring months. Unless it is prevented, they will carry with them much of the moisture that is in the soil. In the absence of preventive measures, so much will have been lost that before the summer is well under way the vegetation will languish. The hotter the winds the more rapidly do they draw on soil moisture, as transpiration from the plants is relatively more rapid. The almost constant sunshine tends to draw heavily on the moisture in the unprotected soil, and the heat of the same proportionately intensifies this condition. The heat of the summer sunshine is greatest in the valleys, hence the drain on moisture in these is relatively greatest; on the higher elevations the degree of the heat is

relatively less, and the drafts on soil moisture are relatively decreased.

The physical texture of the soil and subsoil exerts a marked effect on the filtration and leaching of water in the soil. Coarse sandy and gravelly soils lose water much more readily than soils that have a considerable clay element in them. Since more of the precipitation that falls on the former is lost through the downward movement of the waters, it follows that these are considerably less favorable to crop production in semi-arid regions than the latter. This also goes far to explain why it is possible to grow good crops on the bench lands more easily and surely than in the river basins of the west in the absence of irrigation. The soils in the latter are usually much more porous in texture. The larger the amount of humus in the soil the less will be the losses from filtration and leaching.

The dominant idea in dry farming.—The dominant idea in dry farming is in a sense two-fold. It seeks to secure to the greatest extent practicable the conservation and also the accumulation of moisture in the soil. To accomplish this end the soil is stirred deeply, whether by the aid of the plow alone or by following the plow with the subsoiler, or by using some other implement, as the deep tilling machine. The ground is compressed subsequent to plowing, and a dust mulch is maintained upon the surface. The increase of organic matter in the soil is also sought.

To say that dry farming seeks the conservation of moisture states only half the truth. Moisture cannot be conserved in the soil until it enters the same.

It is of prime importance, therefore, that the precipitation shall be made to enter the soil to the greatest extent possible under the existing conditions. It will be able to enter the soil when it falls upon it in proportion: (1) to the loose condition in which the soil is kept

on and near the surface; (2) to the depth to which it has been stirred by the implements of tillage, and (3) to the measures taken to arrest precipitation that is violent in character. When the soil is thus treated in semi-arid areas, there should be an accumulation of moisture up to a certain limit. The determination of that limit will depend upon such influences as the amount of the normal precipitation, the extent to which measures have been adopted for conserving the moisture, and to the extent to which the soil moisture is drawn upon by the crops that are grown. The increase of the moisture content in the soil and subsoil is clearly shown in a comparison made of soils in the semi-arid areas that have never been tilled and similar soils adjacent that have been tilled judiciously for a term of years. The increase of moisture in the latter is marked. The methods of conserving moisture are given in chapters VII and VIII.

The deep stirring of the soil and subsoil not only admits the moisture more readily, but it increases the holding capacity of the soil. When moisture falls it descends quickly in the spaces between the particles of soil in the cultivated section of the same, and but slowly in the undisturbed subsoil, that is, when the subsoil is naturally dense. If the soil has not been stirred at all, much of the precipitation that falls on such soils in semi-arid areas runs away over the surface. When stirred, the moisture enters the soil quickly as far as it has been stirred. In such instances the holding capacity of these soils is soon met, hence any excess of moisture falling at such a time runs away over the surface. Increase, therefore, in the depth to which the soil has been stirred within a comparatively recent period, means increase in the capacity of the soil to receive moisture. For the discussion on the deep stirring of the soil, see pp. 129, 133.

The object sought in compressing the soil is to prevent the escape of moisture from land that has been

recently plowed. The plowing causes the particles to lie loosely. The dry air enters readily and passes between them in its onward movement, and in its exit carries away more or less of the moisture. The more prompt and complete the compression, the less is the loss of moisture. The object of the soil mulch is to prevent the escape of moisture that moves upward in the soil, on the principle of capillarity. The dust mulch may be maintained most readily in land that is summer-fallowed, because of the unlimited opportunity given for renewing it. It may also be readily maintained in areas that are planted to crops which call for cultivation while they are being grown. It may be maintained in cereals in many instances until these become large enough to form for themselves what may be termed a shade mulch. Most difficult of all is it to maintain a dust mulch on grasses. In many instances it may be unwise to attempt this. For the further discussion of the retention of soil moisture, see pp. 165-172.

Organic matter in the soil increases its power to hold moisture and in a marked degree. In the process of decay it absorbs moisture as a sponge absorbs water, thus influencing its passage downward or upward. It tends to fill the soil spaces in leachy soils so that water cannot percolate down through them so readily. It has been said that in semi-arid areas a soil well supplied with organic matter will grow an equal crop on half the amount of the precipitation that will be called for by a soil similar in its physical constituents but destitute of organic matter. Organic matter also influences favorably the physical condition of the soil and furnishes food in a readily available condition for the feeding of crops. See also pp. 414-423.

Contrasted with farming in humid areas.—Dry farming differs from other farming in at least the following senses: (1) It is confessedly more difficult. (2) It calls

for more exact work. (3) It maintains superior cleanliness in the soil. (4) It is in a sense high-class farming. From what has been stated, the claim that is sometimes made that dry farming methods are essentially the same as those followed in other states is not tenable. Dry farming methods are essentially different in some respects from those practised in humid areas. In the latter in some instances the all-important idea is to remove moisture from the soil, whereas in the former it is to conserve moisture in the same.

That dry farming is more difficult than humid farming will be at once apparent from the consideration that the returns from dry farming rest chiefly on the extent to which moisture is conserved in the soil, whereas in humid areas but little attention is called for with reference to this phase of farming. The measures which secure the conservation of moisture call for the expenditure of added labor that in many instances is not necessary under the humid conditions. The excess of the labor thus called for increases with increase of the degree of the shortage in the normal precipitation. In humid areas the farmer may get a crop in a favorable season from very imperfect methods of cultivation. In semi-arid areas such a result very seldom follows. In humid areas defective methods of farming may result in more or less of a crop and is seldom followed by complete failure. In dry areas the hazard is very frequently present that such methods will be followed by entire failure in the crop. Some of the phases of dry farming are more difficult than others. This is especially true of the pasture problem because of the difficulty in applying methods that will conserve moisture in the pastures.

Farming in dry areas calls for more exact work than farming in humid areas: (1) in the preparation of the soil; (2) in the time of sowing the crop; (3) in caring for the same. In humid areas at least partial crops may

be secured from indifferent methods of soil preparation. In dry areas this result will seldom follow. In the former it is seldom necessary to conserve moisture to aid in growing the next crop. In dry areas it is indispensably necessary. In humid areas but little attention is called for in firming the seed bed by artificial methods, in dry areas such firming of the seed bed is essential to success.

In humid areas the season for sowing is much more prolonged both in the spring and in the autumn than in those that are dry, hence timeliness in sowing is relatively more important. In the former sowing or planting that is delayed beyond the usual time may not result in crop failure or even in greatly diminished yields in all instances. In the latter it will commonly result in failure that is absolute or approximately so. Early sowing, though important in all areas, is relatively less so in moist areas, as in these the moisture necessary to mature good crops is much more likely to be present than in dry areas. In the latter it is absolutely essential to sow crops in good season to avoid the hazard of failure.

When caring for the crops in humid areas, what is not done today may in many instances be done nearly if not quite as well tomorrow. The moisture content in the soil, especially in so far as it relates to a sufficiency for seed germination, is practically assured. In dry areas the moisture that is not conserved today may in a considerable degree be lost tomorrow. In humid areas it may not be necessary to compress and pack the lower surface of the soil when preparing the seed bed. In dry areas this may be greatly important. In humid areas it may not be necessary to harrow cereals after growth has begun. In dry areas this may be indispensable to success.

In the very nature of things dry farming will result in greater freedom from weed growth than farming in humid areas. In the former the natural conditions are much less favorable to germination and growth in weeds

than in the latter. The processes of cultivation that are absolutely essential to the conservation of moisture in dry areas are proportionately destructive to weed life. These processes include those involved in carefully summer-fallowing for certain crops, as wheat, when preparing the seed bed; careful attention when growing other crops, as corn; careful harrowing of cereals during the early stages of growth, and careful discing of the stubble land at some time previous to plowing it. In humid areas these processes are chiefly necessary for the purpose of cleaning the land, but in dry areas they are even more necessary because of their influence on the retention of moisture. Weeds that fail to mature may work but little harm in a summer-fallow in humid areas. In dry areas they may prove fatal to successful growth in the crop that follows.

That dry farming is in a sense high-class farming is evidenced: (1) in the skill that is necessary to so manipulate the soil that it will grow sure and paying crops; (2) in the carefulness that must be observed in these manipulations; (3) in the promptness that must be shown in every detail of the work.

The dry land farmer must understand the treatment that must be given to his particular class of soil, when the hazard if not the certainty of failure is to be avoided. He must give it such treatment, howsoever these manipulations may conflict with the practises followed when seeking simular results in humid climates. He must know the methods pertaining to soil preparation, planting and cultivating that will best meet the needs of the soil that he tills under the climatic conditions that are present; he must also know the succession in crop production that must be chosen or avoided to insure successful crop production. The carefulness that must be observed in these manipulations is shown in the necessity that is ordinarily present for packing the soil

at once when it is plowed, of deepening the cultivated area to increase its moisture-holding power, and of maintaining a smooth and fine surface mulch or one that is furrowed and uneven so as to best meet the conditions of the precipitation.

In every detail of the work the farmer must observe promptness. To defer plowing land for one week when it is in proper condition may make the difference between success and failure in growing a crop of winter wheat, howsoever carefully the land may be managed subsequently. The loss of one day in harrowing land after a considerable rain may result in the loss of a large part of the moisture that is brought to the soil. Neglecting to make a dust mulch on autumn plowed ground in the early spring, may result in a loss of moisture that may be followed by a loss of crop, a result that the timely establishing of such a mulch might have prevented.

From what has been said, it will be very evident that dry farming calls for a high order of intelligence in order to conduct it on the most approved lines. The careless farmer who follows shipshod methods may secure a livelihood after a fashion from the soil in humid areas, but he cannot do this in dry areas. It is a foregone conclusion that he will utterly fail. The great mistake of dry land farmers who come from humid areas is that of trying to grow crops by methods that brought them results in humid areas. These methods will not avail. Dry land farming is special farming. It is done by special methods, and the first duty of those who engage in it is to ascertain what those methods are.

CHAPTER II

THE ORIGIN AND HISTORY OF DRY FARMING

When dry farming began will never be known now. There are good reasons for believing, however, that it had its origin not far from where the human race was cradled, or at least not far from the mountain on which the ark rested soon after the flood. That region is dry now. There are no evidences to show that it was humid in the centuries that immediately followed the flood, and yet it was near Ararat that the peopling of the world began for the second time. It is not reasonable to suppose that those ancient peoples lived entirely on animal food, for many of them were not nomads. If other food was used, it was produced by the soil, and it is preposterous to suppose that it was all grown by irrigation.

The antiquity of dry farming.—That some of the greatest nations of antiquity practised dry farming cannot now be questioned. That they practised irrigation also cannot for one moment be doubted. That the area then that was dry farmed was vastly greater than the area that was irrigated was doubtless as true as it is to-day. The evidence is conclusive that centuries long before the Christian era dry farming was not only practised, but that the existence of populous nations depended upon crops grown mainly by dry farm methods.

The exact methods by which dry land crops were grown in the centuries of long ago is a secret that will never be revealed. It lies entombed with the men who grew the crops. That the method of growing them, however, was essentially the same as it is today cannot be doubted, for crops cannot be grown in the absence of irrigation in dry areas and in the absence of moisture conservation, and moisture conservation cannot be properly maintained unless the surface soil is frequently

stirred at certain seasons of the year. In ancient days, however, the work was chiefly done by hand labor, whereas now it is done by the aid of suitable implements drawn by horses or by other power.

Tunis furnishes an excellent illustration of the extent to which dry farming was practised by some of the nations of the old world long centuries ago. It was in ancient Tunis that the mighty and populous cities of Phoenicia rose and fell. According to Widtsoe the average rainfall in Tunis is about 9 inches. In some parts, however, it considerably exceeds that amount. History has made it clear that in the early centuries Tunis furnished the Roman Empire with immense quantities of wheat and olive oil. In the seventh century, Tunis had from two to three millions of olive trees in full fruitage in the absence of irrigation. Even today the agriculture of Tunis is large relatively and also in the aggregate.

While of course it can never be known fully where dry farming was and was not practised in ancient days, the evidence is conclusive that it was practised by many peoples. Both India and China were populous long centuries before the Christian era. In both of these countries there are wide areas in which large populations could not have been maintained in the absence of dry farming. Central Europe and Western Asia were inhabited and numerously before the Christian era. These areas are dry now and there are no good reasons for believing that the climate has materially changed. Portions of southeastern Europe and of Asia Minor were not favored with an abundant rainfall in ancient days nor are they now, and yet anterior to the Christian era they sustained prosperous communities. There are also good reasons for believing that the Indians of Mexico practised dry farm methods in the dry area of that country in the long-forgotten centuries.

Mistaken views as to its history.—The popular conception of dry farming with reference to the time when it began, the place where it originated, the area where it was first practised, and with reference to its early promoters is wholly at sea. That conception looks upon it as something that has originated within years of the recent past, that it originated in the western United States, and that it is, as it were, a discovery for which western America is entitled to a patent. It has also associated with these ideas the names of certain men now living, who are looked upon as the discoverers of the system of dry farming. It looks up to them reverentially as being the fathers of the system. Nothing can be farther from the truth than these mistaken conceptions.

It has been shown in the preceding paragraph that dry farming was practised even before the dawn of history. The popular conception of it would restrict it virtually to the past decade. With reference to the advanced methods observed in conducting it, this may be true, but the fact remains that the great nations of antiquity, with the exception of Egypt, were cradled in areas where dry farming was much practised.

The popular conception of dry farming looks upon the western states of the Union as the place where it has been cradled. It has already been shown that it was practised by the peoples of various nations even prior to the Christian era. It will also be shown in succeeding paragraphs that dry farming is today practised in certain extensive areas on each of the continents.

This conception would confine it mainly to western America, whereas in each of the continents, including Australia, is an area probably as large as that of the United States which must be farmed if farmed at all by the methods that obtain in dry farming. It is at least questionable if the land that must be farmed by the dry farming plan, if farmed at all, does not exceed the

area that is farmed or that may be farmed by the methods that obtain where humid farming is practised.

From what has been said, it will be apparent that it will never be known who were the originators of dry farming. It is more than probable that the methods followed originated at least to a considerable extent in the various countries in which they were practised. The claim of any one now living, therefore, to be the originator of dry farming methods is simply absurd, and the acknowledgment of that claim by the public shows an almost total lack of knowledge regarding the facts that bear upon its origin.

Widtsoe has made it clear in his admirable book "Dry Farming" that dry farming as practised in the western states was the evolution of an experience that does not in many instances go back beyond the middle of the last century. He has made it clear that this experience was gained independently and mainly in the four distinct centers, Utah, California, Washington and the Great Plains country. Further reference will be made to this evolution (see p. 35). The methods followed in these independent areas came to centre around a system that is practically uniform. This system included deep plowing, preferably fall plowing, conserving the moisture by surface cultivation, light seeding and devoting with more or less frequency an entire season to conserving moisture in the soil without cropping it.

These misconceptions have doubtless originated chiefly in the wide publicity given to the dry farming propaganda that is now being conducted with so much vigor in the states that lie to the west of the Mississippi river. For this publicity the "Dry Farming Congress" organized in 1907 is largely responsible. To the major portion of the people of the United States the conception is new, hence the conviction that the science itself is new. To this country, however, belongs the credit of

greatly improving the system and of reducing it, as it were, to a science and of riveting the attention of the outside world on the merit that inheres in these improvements.

Dry farming in the United States.—Dry farming as now practised in the United States has been evolved within the last 50 years. That the evolution took place in various centres acting independently and without inter-communication is accepted by those who know the facts. The chief centres of this evolution were Utah, California and the Great Basin area, the Great Plains country, the Mountain States, the Columbia river basin, and the Colorado and Rio Grande river basins. Although the methods practised were largely, if not entirely, of independent development, they all led to the one great central truth that underlies successful practise in dry areas, viz.: the conservation of the moisture that falls to the greatest extent that may be practicable.

It would seem fair to concede that Utah led in the introduction of dry farming. There is evidence to show that it was practised to some extent by the Mormons as early as 1855. In 1863 dry farming was begun by Scandinavians in the vicinity of Bear River City. A year or two later Christopher Layton began to grow crops on the Sand Ridge between Ogden and Salt Lake City, a region in which dry farm crops have been grown for many years. Simultaneously, or a little later, George L. Farrell introduced dry land farming into the Cache valley, where it has been practised with increasing success down to the present time. Gradually the work extended through other portions of Utah, insomuch that dry land farming is now the chief slogan of the Utah farmers.

For several decades dry farming has been practised with at least fair success in certain portions of California. The chief centres of such practise in former years were the valleys of the Sacramento and San Joaquin rivers, but

now it is practised more or less in various areas in the state.

In the Great Basin country with Nevada as a centre (see p. 52), are some areas where farming has been practised for more than 40 years without the aid of water. The products grown include grain, chiefly wheat, corn, some of the sorghums and fruit. The rainfall in much of this area is very light, in some places as low or lower



RANCH HOME, YELLOWSTONE COUNTY, MONTANA.

Courtesy Northern Pacific Railway Co.

than 10 inches, hence the extension of dry farming has not been so rapid as in areas that are favored with greater precipitation.

In the Great Plains area which drains from the Rocky Mountains into the Mississippi (see p. 50), dry farm crops have been grown with more or less success from the Canadian boundary to Texas, and in some locali-

ties for more than 30 years. In many instances, however, they have not been grown on the dry land plan, and, as a result, crop failure through drought and hot winds has led to the temporary abandonment of certain areas westward in the Dakotas, Nebraska and Kansas. These areas are now being farmed successfully by farmers who have learned something of the secret of conserving moisture. During all the years of failure there were individual instances of success, which makes it clear that much of the failure that resulted could have been avoided. The greater annual rainfall in much of this area did not emphasize the necessity of moisture conservation as it did in other areas. It was in this region in 1894 that H. W. Campbell began his work on its present basis, which he has since denominated "Scientific Soil Culture."

In the Inter-mountain states with Wyoming as a centre, dry farming has been successfully practised by individuals, but until a comparatively recent period, it was confined to limited areas. But there are isolated instances in which it has been practised for two to three decades.

In the Columbia river basin which has its centre in Washington (see p. 51), wheat has been grown successfully for many years and also many other crops. In the neighborhood of Walla Walla it has been grown for more than a generation and with practically undiminished yields. There is an immense area in this region which has become famous for growing wheat although the rainfall is very light.

In the Colorado and Rio Grande river basins (see p. 52), crops have been grown for many years in limited areas on the dry land plan. In New Mexico especially are groups of farmers who have farmed thus for a number of years.

In the face of these facts, it is incredible that any one man could have been chiefly responsible for introducing

this system into so many independent centres. It is true, nevertheless, that the drought that so generally prevailed during 1893-95, and especially in 1894, resulted in impressing upon the minds of western farmers, as never before, the absolute need of observing carefully the principles that must obtain where moisture is to be preserved. Those principles were largely evolved in those several communities from the chaos of repeated mistakes in farming the land.

Dry farming in Europe.—In western Europe, the precipitation is so great as to preclude the necessity for dry farming methods. In eastern Europe crops cannot be successfully grown by any other system. The same is true of certain portions of central and southern Europe.

The semi-arid portion of eastern Europe is practically confined to Russia. The area in which the precipitation is low is very large, not less, probably, than one-fourth of the entire country. In the southeastern portion the shortage is most marked. That part of Russia bears considerable resemblance to the Great Plains country in the United States. Dry farming methods have been more or less practised in Russia for many years, but the practise of these has been crude and imperfect. Recently, however, the government is introducing more advanced methods.

The areas of central Europe that call for dry farming are not nearly so extensive, nor is the shortage in the precipitation so great. One of the driest areas is found in certain portions of the Austrain Empire and the states that are adjacent thereto, more especially on the eastern border.

In some parts of southern Europe the normal rainfall is much less than could be desired. Because of this, irrigation is practised in various places in the Mediterranean countries where water is attainable. Where

it is not, there is much room for the practise of dry farming methods.

Dry farming in Asia.—In very large areas in Asia the annual precipitation is very light, hence crops, if grown at all, must be grown by dry farming methods in the absence of irrigation. These areas are found both north and south of the Himalaya mountains, and also in the southwestern provinces.

North of the Himalaya mountains are vast areas of semi-arid country, and considerable areas that are arid. The extent of these is not accurately known. The rainfall is very light, hence only such plants can be grown as are markedly drought-resistant. It is in this region that some of the hardiest of the alfalfa crops are found.

Large areas in India and China have a long season during which rain does not fall. In some of these, the precipitation at the usual season is plentiful, in others it is not copious. In either case, the necessity for practising dry farm methods is always present and in the latter instances it is imperatively necessary. In China especially, dry farming is of great antiquity, but even now the methods practised are crude.

In southwestern Asia there are very large areas that are semi-arid. This applies to all or nearly all of Asia Minor, Palestine and Arabia. Much of the latter country is positively arid. In all of these there is great room for the practise of dry farming. The areas that can be tilled by the ordinary methods in the absence of irrigation are very limited, and especially in Arabia are extensive areas that are positively and in many instances hopelessly arid.

Dry farming in Africa.—Dry farming has been practised in certain parts of Africa from the remotest times. Especially is this true of the states of northern Africa which border upon the Mediterranean, but it is also true

of south Africa and of other areas in the same dark continent.

The Mediterranean states are Morocco, Algiers, Tunis, Tripoli and Egypt. In Egypt rain is practically unknown. In the other states the rainfall is very light. In some parts of Tunis it is frequently below 10 inches, and yet in that country much attention is given to the growth of agricultural products, especially the production of wheat and olive oil. Notwithstanding the dry character of the climate in these states, they support a relatively high population.

In south Africa, especially in the Transvaal country, much attention is beginning to be given to dry farming methods. The rainfall in much of the Transvaal is below 20 inches, hence the necessity for practising these methods. McDonald has done and is doing much for the extension of dry farming in this part of Africa. In other areas of Africa and in various parts of the continent, the necessity for growing crops by these methods is imperative. It is from the dry regions of Africa that some of the most drought-resistant crops have been obtained, especially Milo maize and Kafir corn.

Dry farming in other areas.—In many other areas dry farming has been practised—in some for a longer or shorter period, in some instances for centuries. These include portions of the Canadian west, of Mexico and of the Central American states on this continent, and very large areas in South America and Australia.

In certain portions of the Canadian west, especially in southern Alberta and southern Saskatchewan, dry farm methods have been practised for about a quarter of a century and with much success. Notably is this true of the work done by Mr. Angus Mackay, the efficient superintendent of the experiment farm at Indian Head, Sask. No other station or farm in all the west has furnished a record for so long and continuous a period of the results

obtained from dry farming. The alternate fallow and crop system has been practised at that station since 1888 (see p. 392).

It was in southern Alberta that the growing of hard winter wheat under dry conditions was first introduced into western Canada. Not greatly distant from the Rocky Mountains, certain individuals have grown it there successfully for two to three decades.

Dry farming has been practised in certain portions of Mexico for centuries. When first visited by the missionaries of the Catholic church certain of the Indian tribes, especially those inland and in northern Mexico, practised dry farming. The methods then followed had evidently been practised during preceding centuries. It is the only method by which a large part of Mexico yet untilled can be reclaimed. The same may be said of certain portions of the Central American states.

In South America dry farming is now being practised both east and west of the Andes, and in states far to the southward. In Brazil especially, dry farming promises to be an important factor in the building up of that republic, which has a very large amount of arid and semi-arid land. The annual precipitation in much of this area is fairly liberal, but because of the heat, the loss of soil moisture unhindered in its movements, is equally large. Long centuries ago the inhabitants of Peru grew crops by dry farming methods, and the same is true of Chile and other states southward in the continent.

Very large areas of Australia are now coming to be worked on the dry farming plan. Two-thirds of this vast area has a rainfall of less than 20 inches, and much of the country lies under a tropical sun. In many sections the rainfall is less than 10 inches annually. To no one of the continents, therefore, are dry farming methods of so much importance. The dry farming propaganda is being vigorously pushed in many parts of the country and the

promise of results that will be greatly significant in the future is encouraging.

The promoters of dry farming.—That dry farming as now practised is comparatively recent in its origin will be apparent from what has already been said. That it is the outcome of the efforts of individuals in various states laboring simultaneously and in a tentative way has been shown. That these efforts all led to the one conclusion viz., that the keystone to successful dry farming is the proper conservation of soil moisture, has been made clear and in consequence no one individual can arrogate to himself the honor of having introduced this system by which the wilderness and the solitary place are to be turned into a garden of productiveness.

The efforts of those individual workers, however, would never in themselves have given dry farming the status that it has today. Organized effort was necessary to rivet the attention of the world upon the importance of the dry farming movement. This came with the organization of the dry farming congress. Men who were interested in the sale of lands in dry areas are to be credited in large measure with the launching of this movement which is destined to lead to material results such as are without parallel in the world at the present time. This is owing to the immensity of the area that will be affected by this movement.

The first dry farming congress was held at Denver, Col., Jan. 24-26, 1907; the second at Salt Lake City, Utah, Jan. 22-25, 1908, and the third at Cheyenne, Wyo., Feb. 23-25, 1909. At this Cheyenne congress foreign delegates were in attendance from Canada and the Transvaal, Australia and Russia and Brazil. It was decided at this congress that the time for convening should be changed from early winter to the autumn, and in consequence of this decision, the next congress convened at Billings, Mont., in October of the same year. The

fifth congress was held at Spokane, Wash., in October, 1910. At the meeting held in Utah, an exhibit of dry land products was made. This feature has been maintained at all the annual meetings of the congress that have since been held. The attendance at these meetings has been increasingly large, and the interest taken in them will be understood from the leading part taken in them by the governors of the various states in which they have been held.

The congress is fortunate in its secretary, Mr. John T. Burns, whose excellent management of the affairs of the congress has done much to bring it before the various nations of the world. The stimulus which this congress is giving to the dry farming movement in many lands cannot easily be measured. In several of the dry farming states, auxiliary branches of the congress have been organized. Utah led in these organizations, the first auxiliary having been established in that state in 1907.

The movement thus inaugurated by the dry farming congress has been given much aid by the public press, by certain of the railroads, by the United States Department of Agriculture, and by some of the experiment stations.

The press, and especially the agricultural press, has given wide publicity to the work of the dry farming congress from its first inception. It is now giving much publicity to dry farming methods, especially that portion of it located in the west. The dry farming congress has its official organ, and periodicals are now being introduced devoted entirely to the discussion of dry farm problems.

During recent years certain of the railroads have encouraged demonstration work along their several lines in the semi-arid country. This work had for its object: (1) to show conclusively that dry land crops could be successfully and profitably grown. That this was pos-

sible was stoutly denied by all or nearly all who were engaged in ranching in the several dry land states, and they based this denial on the ground that they had failed in their efforts to grow crops. In taking this stand they have only proclaimed to the world and for all time their ignorance of the principles that underlie successful dry farming. (2) To ascertain which crops could be grown the most successfully and profitably, and (3) to demonstrate the best methods of growing them.

The Northern Pacific railroad was one of the first to enter this field. In co-operation with the state of Montana, it sustained demonstration work in various parts of the state from 1906 to 1910. The Rock Island and the Milwaukee railroads and also certain lines of the Harriman system have during recent years been giving more or less aid to the encouragement of this work.

The work in this line, however, inaugurated by the Great Northern railroad in the spring of 1910, is the most extensive work of the kind ever undertaken by any one railroad system. Forty-five demonstration stations were conducted by this road in 1910, and 42 in 1911, nearly all of them being located along the various lines of the road in Montana. In 1911 the work was carried into North Dakota. These stations embrace from 6 to 100 acres, nearly all of them being of the former size. The railroad gave the farmer the seed, the crop when grown and \$10.00 for working each of the 6 acres of his own land. The work, however, was to be done according to instructions given by a representative of the Great Northern road.

Three men were thus constantly employed during the entire growing season. The Northern Pacific railroad also established work of this character in southeastern North Dakota in the spring of 1911.

The United States Department of Agriculture has shown much if not undue caution in instituting investi-

gations pertaining to the growing of crops in the arid and semi-arid west. Because of this, experiments conducted by individuals in several of the states where dry conditions prevail were much in advance of those instituted by the department during recent years. This extreme caution may have been based on the fear that homesteaders might thus be encouraged to locate in areas where they would find it very difficult to build and maintain homes. About the first work undertaken by the department with a view to aid in the development of the agriculture of this region was the search in other countries for plants that were markedly drought-resistant, with a view to their introduction in this area. The Bureaus of Plant Industry, Chemistry, Soils and Weather have also rendered substantial service. It was not until 1905 that a head was appointed to take charge of dry land investigations. An office for this department is now maintained under the Bureau of Plant Industry. During recent years a large number of stations have been established by the department in those areas for conducting investigations pertaining to dry land problems. Some of these are conducted in co-operation with the experiment stations.

Definite experiments with a view to the study of questions pertaining to the agriculture of dry areas in the United States were inaugurated by the Colorado Legislature. In 1893 it authorized the establishment of an experiment station at Cheyenne Wells. This action, however, was five years later than the establishment of the Canadian station at Indian Head in 1888.

Dry farming experiments by the Utah state station were begun in 1901. This state is the pioneer in systematic experimental work conducted on an extensive scale. Among the other states that have done excellent work in the study of dry land questions in an experimen-

tal way since 1901 are Montana, North Dakota, Wyoming, Nebraska, Colorado and New Mexico.

From what has been said it is very evident that no man can justly claim to be the originator of dry farming as now practised on the American continent. This claim has been virtually made for H. W. Campbell, now of Lincoln, Neb., and it has received the endorsement of an uninformed public both in this country and abroad. The facts that bear upon this question show that the claim is groundless. It is not only true that the Campbell system did not shape the method of dry farming as now generally advocated and practised, but it is also true that it is essentially based on the said practise and is in its main features the outcome of the same, as will now be shown.

The Campbell system as outlined by its author in his book "Soil Culture Manual" is, in its essentials, as follows: (1) To grow crops successfully in dry years it is necessary that water shall be stored in the soil by proper tillage. (2) Such tillage includes discing the land as soon as the crop has been removed, following with the plow sooner or later thereafter, using the subsurface packer after the plow and the harrow after the subsurface packer, and maintaining a dust mulch on summer-fallow land. (3) Sowing grain thinly and if too thick harrowing some of it out. This practise is founded on the fundamental principle that in dry areas it is absolutely necessary to retain by tillage as far as this may be practicable the moisture that falls, if crops are to be grown with success. As has been shown, this principle was recognized and acted upon by farmers in Utah, in some instances at least two decades before the Campbell system as now practised was evolved. This system, however, laid more stress on discing unplowed land and the subsurface packing of plowed land than had been previously accorded to those practises.

The weak points in the Campbell system include the following: (1) The insistence on discing land and following with the plow under all soil conditions. (2) The insistence on the use of the subsurface packer after the plow, without regard to the character of the soil. (3) The absence of any provision for the maintenance or renewal of fertility and humus in the soil. Moreover, in practise it is difficult to carry out certain of the methods recommended, as for instance always discing stubble before plowing and plowing summer-fallow in August, because of the season at which such work must be done.

The Campbell system is not what it was at the first. It began by sowing grain in rows in the early spring, far enough apart to admit of cultivation. This was abandoned because it was too costly. Even as recently as 1896 the farm paper which Mr. Campbell edited makes no mention of summer tillage when giving what is avowedly a full statement of the system. He admits that it was not until 1891 that he became positive that he could secure good crops under droughty conditions, and that the first victory of the Campbell method was won in 1894 in Brown county in South Dakota, when 142 bushels of potatoes per acre were grown in a very dry year. It should also be borne in mind that Mr. Campbell conducted his experiments near the eastern border of the semi-arid belt, where the more severe drought conditions do not prevail to the same extent as they do farther to the west. It is true, nevertheless, that Mr. Campbell has done much to rivet the attention of the public on the important place that must be assigned to dry farming in the agriculture of the future, by the persistency of his advocacy. For this he should be given the full measure of the credit which is his due.

The future of dry farming.—From what has been said it will be apparent that dry farming in the future will hold a wide place in the world's industries. It will be

the outstanding material interest of the immediate future. Although the exact facts are not fully attainable at the present time, it seems correct to say that more than half of the tillable area in the world can be made to produce crops only by resorting to dry land methods of cultivation. In the contemplation of this fact will be seen the momentous significance of a proper understanding of the principles of tillage which alone, when properly applied, will enable those who apply them to obtain maximum results from the lands which they till.

It is unfortunate that the principles which underlie successful tillage are so little understood by so large a percentage of those who live in dry areas, and that they are so seldom applied in a hearty and thorough fashion. Many of the newer settlers have come from humid climates. It seems preposterous to them, at the outset, that they should put so much labor on land in order to insure a crop, nor do they take kindly to the idea of not trying to grow a crop every season. The disposition that inheres in the average man to reach out largely in the line of acquisition is tempted in dry areas as in few other places, by the ease with which large holdings may be obtained. The further disposition that leads so many to gamble, as it were, for large results in the imperfect tillage which is given to large areas, oftentimes leads to crop failure. It is seldom that the average farmer will practise dry farming methods as he ought to, until he has felt the stiff jolt which extensive crop failure brings to him. Half-way measures in tilling the soil in dry areas will never prove successful save in exceptional seasons.

Evolution, however, in this as in other things, must be gradual. It is comforting to know that it has begun. There is satisfaction in the thought that the possibility of farming much of the dry area in the west is no longer in doubt. Only a few years since, a U. S. Senator from one of the dry land states expressed doubt as to whether a

homesteader could successfully start a farm on the dry lands of the west. This doubt was expressed at one of the meetings of the Trans-Mississippi Dry Farming Congress. The live stock ranchers were a unit in saying that it could not be done. Those doubts have been given their answer in the fact that it is being done, and in all the semi-arid states.

CHAPTER III

THE DOMAIN FOR DRY FARMING

This chapter will consider more particularly the domain for dry farming in the United States and Canada. The domain for the same, including all the continents, is very wide. Taking into consideration only the tillable portions of the earth's surface, it would seem safe to say that more than half the area, if farmed at all, must be farmed on the principles that underlie successful dry land farming. In the United States and Canada, it is not possible to determine with absolute precision at the present time the relative or even the absolute proportion of the tillable area that must be farmed, if farmed at all, on the methods that lead to success as practised in what are usually termed dry land areas. It would be safe to say, however, that nearly one-half of the tillable area in the United States must be thus farmed, if farmed at all, and the same is true of certain areas in western Canada. But in portions of western Canada in which trees grow in clumps in the depressions, it may be taken for granted that the annual precipitation is higher than in areas farther south, or the trees would not be in evidence. Wherever nature sustains such a vegetation, even in the depressions, the ability of the soil and climate to grow good crops need not be questioned.

Influences that bear upon dry farming.—In chapter I these influences are discussed to some extent when explaining the causes of aridity (see p. 14). They are enlarged upon here. The influences that bear upon dry farming include: (1) the amount of the precipitation; (2) the time at which the precipitation falls; (3) the character of the evaporation; (4) the temperature that is normally present, and (5) the character of the soil. The fact should never be overlooked when sitting in judgment on areas

that may or may not be farmed on the dry farming plan, that each of the factors named exercises an important influence on production. But it must be conceded, nevertheless, that the actual amount of the normal precipitation is the most potent influence in production in dry areas. Where the precipitation is below a certain amount, dry farming cannot be practised, though all the other considerations mentioned should be satisfactorily present.

The precipitation that will grow a good crop of grain depends: (1) on the preparation that has been given to the land; (2) on the season at which the precipitation falls as well as on the amount of the same; (3) on the extent of the evaporation; (4) on the temperature, and (5) on the soil. Of these influences the preparation that has been given to the land is the most important. If moisture has not been properly stored in the soil and subsoil, and a dry season follows, the favorable influence that may be exerted by all the other agencies combined will not insure a crop even under semi-arid conditions. Much less will these insure the same under arid conditions. It is very evident, therefore, that the amount of the precipitation alone does not determine the capacity of the land to grow crops in these areas.

It is also evident that the amount of precipitation that will suffice to grow a crop in one locality may not grow the same in another. Without knowing all the attendant conditions it is not possible to determine the amount of precipitation that will suffice to grow a good crop. It would seem safe to say, however, that on the parallel 45° north latitude a good crop of wheat may be grown on an annual precipitation of 6 to 8 inches on carefully summer-fallowed land, providing it has been summer-fallowed for one year. On an annual precipitation of, say, 12 to 15 inches, good crops of certain kinds of grain may be assured on properly summer-fallowed land.

With an annual rainfall of 15 to 18 inches, it is practicable to get two grain crops in three years. With a rainfall of 20 inches it is practicable to secure good crops every year from a properly adjusted rotation, on the assumption that a cultivated crop is one of the factors of the same. In the southern portions of the dry belt considerably more precipitation would be called for to secure these results, because of the higher evaporation.

The time at which the precipitation falls has an important bearing on the crops that may be grown. In the Plains region about 50 per cent. of the precipitation comes during the period of greatest growth. This means that the adaptation for spring cereals is relatively high. It also favors the successful maturing of winter grains where these have come through the winter successfully. In these areas, however, there may be difficulty in starting winter grains because of the lack of moisture. But since in this area the rains almost practically cease with July, it is important that the spring crops grown shall be of such species and varieties as mature early. In much of the Inter-mountain area the precipitation comes mainly in the late autumn and early spring months. The same is true of much of the Great Basin country. Because of this the adaptation is highest for autumn-sown grains, as these mature early and before the drought and greatest heat of summer is ushered in. They also get the full benefit of the winter rains. In areas where the highest precipitation occurs in the summer and autumn months, as in Oklahoma, Texas and New Mexico, it will be in order to grow late maturing cereals and such crops as corn and the sorghums.

The influence exercised on crop production by evaporation is very material. It increases (1) with increase in the dryness of the atmosphere; (2) increase in the summer heat; (3) increase in the dryness and velocity of the winds, and (4) with decrease in the humidity. It de-

creases (1) with an ascending latitude, and (2) with increase in the elevation. It is manifest, therefore, that the evaporation will be much greater in warm latitudes and depressed elevations because of the greater heat, than in elevations the opposite, and that it will be much greater in areas not tempered with humidity from the ocean than in areas so tempered. Where winds are constant, and the movement of the same is relatively high, evaporation will be proportionately increased. Such a condition occurs in certain portions of the Great Plains area. The influences named, in conjunction with variations in the precipitation, increase greatly the difficulty of formulating definite rules for the tillage of areas with practically the same average precipitation. The Bureau of Plant Industry found as the result of three years test at Dickinson, N. D., ending with 1909, that the average annual evaporation from a water surface was 31.4 inches, whereas from a two years test at Fallon, Neb., it was 51 inches. It is very evident, therefore, that a certain amount of rainfall at Dickinson will be more helpful to growing crops than a similar precipitation at Fallon, other things being, generally speaking, equal. It has been estimated that where the evaporation is 45 inches and where the summer rainfall is 18 inches, the larger portion of it falling in the summer, about one-half of it may be saved to the crops.

The normal temperature in dry areas greatly influences not only the crops that may be grown but the yields of the same. The temperature is, of course, influenced much by the elevation and by distance from the ocean. Naturally, increase in the elevation lowers the mean temperature, and increasing distance from the ocean results in still greater contrast between the degree of the heat of the days, as compared with that of the nights. In much of the dry area, the nights are relatively cool, and this is greatly favorable to increasing plumpness of the grain

in process of filling. In the higher elevations, and especially in proximity to the mountains, summer frosts do more or less harm, but the injury that would otherwise result is much neutralized by the dryness of the atmosphere. Hail also is to be reckoned with, but usually the area covered by hailstorms is not very extensive. Certain quick growing grain crops may be matured in the latitude of Denver, Col., at an altitude of fully 7,000 feet.

The influence of soils is also marked on production and on the relative amounts of rainfall called for to make production safe. For the further discussion of this question see chapter IV. From what has been said, it will be abundantly apparent that the adaptation of the various areas of the semi-arid country for the growing of crops cannot by any means be judged of correctly on the basis of the amount of the precipitation alone.

Arid and semi-arid America.—The area comprised as arid and semi-arid in the United States is not easily defined owing to the great variation in the conditions that lead to aridity or the opposite in the various states of the west. For instance, the rainfall in certain areas of a state usually considered arid may be such as to make these areas come within the sub-humid class. In those portions of Colorado where the normal annual rainfall runs between 15 and 20 inches, is Gunnison county, where an annual precipitation of 50 inches is reported. These marked variations may be found in all or nearly all of the arid and semi-arid states. They are caused in part at least by a difference in the elevation. The cooling of the moisture-laden air through expansion as it rises over a range of hills or mountains leads to precipitation. This explains in part at least why the precipitation is so much greater west than east of the Cascades. But this is not the sole explanation of the difference in the precipitation, as marked differences occur in the normal rainfall

of various localities in the Great Plains area in the almost entire absence of elevations of any great prominence. For instance, the normal precipitation at Chester, Mont., would appear to be considerably less than that of areas to the east and west.

Speaking in a general way, it would be correct to say that the semi-arid and arid regions of the United States and Canada lie between the meridians of 100 and 120 west longitude and between the parallels of 51 to 53 and 30 respectively north latitude. This immense area comprises approximately 1,400,000,000 acres.

The line which bounds the area on the east where the rainfall is not more than 20 inches is as follows: It begins in the northeastern part of North Dakota, not very far distant from the Red river, and bears slightly to the southwest until it reaches the Mexican border. This line cuts off to the westward more than three-fourths of North Dakota, about two-thirds of South Dakota, about one-third of Nebraska, about one-fourth of Kansas and Texas, and a small portion of Oklahoma. The line that bounds it on the west runs virtually not far distant from the western base of the Cascade and Sierra Nevada mountains, except in certain areas of California, where it runs still farther to the west.

The states included in the dry belt in whole or in part, are the following: North Dakota, South Dakota, Nebraska, Kansas, Oklahoma, Texas, New Mexico, Colorado, Wyoming, Montana, Idaho, Nevada, Arizona, California, Oregon and Washington, seventeen in all. Eastern North Dakota, South Dakota, Nebraska, Kansas, Oklahoma and Texas lie within the areas classed as sub-humid and humid, and the same is true of the western portions of California, Oregon and Washington. In parts of Colorado, New Mexico, Arizona, Utah, Wyoming, Washington, Oregon, Nevada and Lower California, the annual precipitation is less than 10 inches. In but a

very small portion of Washington, Oregon and Wyoming is the rainfall thus low. In practically all the intervening portions of the dry country it runs from 10 to 20 inches. The territory in Canada classed as semi-arid includes considerable areas in southern Alberta and Saskatchewan and a limited area in southwestern Manitoba. Canada has no land virtually that should be classed as arid. On the supposition that the arid and semi-arid area lies between the meridians 100 and 120 west longitude, and between parallels 53 and 30 north latitude, the width of this area is about 1,400 miles from east to west, and the length about 1,600 miles from north to south. Within this area are 1,436,000,000 acres. There is no means of knowing with certainty at the present time the relative proportions of this vast area that are untiltable, because rough, rocky and mountainous, but the estimate would seem low that would consider only two-fifths of the entire area tillable. Computing on this basis would give practically 573,000,000 acres of land in the dry country that is tillable. On the supposition that 73,000,000 acres of this land is in Canada, it would still leave 500,000,000 acres for the United States. Not more, probably, than 100,000,000 acres can ever be irrigated. This would leave 400,000,000 acres of tillable land in the semi-arid states of the west, which never can be farmed successfully except by dry farming methods. When it is further considered that nearly all of this land is of surpassing richness, the magnitude of the dry land farming question to the United States will be at once apparent. The estimate of Widtsoe is even more liberal. It places the entire area that may be tilled at 600,000,000 acres, of which not to exceed 5 per cent. will ever be irrigated.

Divisions of the arid and semi-arid areas.—The arid and semi-arid areas may be grouped as follows: (1) the Great Plains area; (2) the Inter-mountain region; (3) the Columbia river basin; (4) the Great Basin, and (5) the

Colorado and Rio Grande river basins. These divisions are based chiefly on the drainage features which they possess respectively, but each has distinctive features pertaining to precipitation, temperature and other weather conditions, and, therefore, also to production.

The Great Plains area includes parts of North Dakota, South Dakota, Montana, Nebraska, Kansas, Wyoming, Colorado, New Mexico, Oklahoma and Texas, also considerable areas in southern Alberta and Saskatchewan. This is the largest area by far of dry farming land found in the west, under what may be termed approximately uniform conditions. The drainage of this vast area is into the Saskatchewan, Red and Mississippi rivers, which means that it is essentially eastward, and it covers an area of not less probably than 450,000 square miles, thus embracing about 288,000,000 acres. This is the largest area of land found on the American continent under practically uniform conditions, and because of its extent and the character of its production it is by far the most valuable portion of the semi-arid country. From Canada to Texas the farmers have been successful in this area where they have followed approved dry farming methods. It has special adaptation to growing wheat and other grain, and in many portions thereof it will grow good crops of alfalfa, corn for fodder and to a less extent for the grain, also the sorghums and the millets. The entire region has shown special adaptation for the production of high class cereals.

The Inter-mountain states include a part of Montana, nearly all of Wyoming and Colorado, and part of eastern Idaho. As Widtsoe has stated, this region is located along the backbone of the Rocky Mountains. The farms are located chiefly in the river valleys and on the large and undulating table lands at the base of the mountains. Dry farming is already well established in certain portions of this area but the land brought under

cultivation is relatively very small when compared with the very large area that will in the near future be made to produce crops successfully. In this area small grains, alfalfa and many kinds of fruits have succeeded well.

The Columbia river basin includes a large portion of Oregon, a considerable portion of eastern Washington, the northern and western part of Idaho, and a part of western Montana and southern British Columbia. Within this region is the Inland Empire, covering 150,000 square miles or not far from 100,000,000 acres. In this



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area the chief crop is wheat, but in portions where the rainfall is highest fruits have been grown with much success. In parts of this area, wheat has been grown successfully, where, for many years, the average rainfall has not been more than from 10 to 11 inches per annum, and without apparent diminution in the yield. It is chiefly grown in alternation with summer-fallow, which was introduced about 1890.

The Great Basin country includes Nevada and the western half of Utah, and a small portion of the states of southern Oregon, Idaho and California. The characteristic feature of this region is that its rivers drain into salt lakes or dry sinks.

Within it are many valleys made up of nearly level land. This basin was at one time a great lake which drained into the Columbia river. The chief cereal production of this area is wheat, but it will also grow, with much success, corn, the sorghums and certain fruits, including grapes. In some parts of this basin dry farming has been conducted for 40 to 50 years. In many areas, especially in Nevada, the rainfall is even less than 10 inches per year. According to Hillgard, dry farming has been practised more or less since 1878, and Olin states that dry farming methods were practised as early as 1861.

The Colorado and Rio Grande river basins include the western part of New Mexico and Colorado, and the southwestern part of Texas. In those basins are considerable areas that are even now being successfully farmed on the dry farming plan. These will doubtless be greatly increased in the near future, notwithstanding the dryness of the climate. The chief of the dry farm products grown at the present time are wheat, corn and the sorghums, broom corn, millet and beans.

Precipitation in the various states.—Below is a statement (1) of the average annual precipitation in the several states that lie within the arid and semi-arid areas, in whole or in part, from all the stations reporting prior to 1909, (2) of the maximum and minimum precipitation in each, and (3) a reference in a general way to the area or areas within each state with an annual rainfall of 20 inches and over that amount, less than 15 inches and between 15 and 20 inches. The information is thus based on data furnished in Bulletin No. 188 issued by the

Bureau of Plant Industry, U. S. Department of Agriculture in 1910.

In **North Dakota** the average annual precipitation is 17.95 inches, the maximum 27.03 and the minimum 12.3. About one-sixth of the area, embracing the eastern and especially the southeastern portion of the state, has an annual precipitation of 20 inches and above that amount. About one-fifth of the area lying in the northwest and to a greater extent in the southwest, has a rainfall of 15 inches and less. The rest of the state has a precipitation of 15 to 20 inches. The lowest precipitation is in the southwestern counties, where it averages about 13 inches.

In **South Dakota** the average annual rainfall is 20.9 inches, the maximum is 29.7 and the minimum 9.7. Somewhat more than the eastern third has a rainfall of 20 inches and upwards, and the same is true of a small area in the Black Hills regions in the west. The greater portion of the western third is less than 15 inches. A somewhat limited area in the central western portion is from 15 to 20 inches.

In **Nebraska** the average annual precipitation is 25.79 inches, the maximum 35.8 and the minimum 13.3. Only in the western third of the state is the rainfall less than 20 inches, and in but few counties within that area is it less than 30 inches.

In **Kansas** the average annual precipitation is 29.05 inches, the maximum 44.5 and the minimum 16.1. Only in about one-sixth of the western portion is the rainfall less than 20 inches. The increase is gradual and continuous to the east. The southeastern part of the state has a precipitation of more than 40 inches annually.

In **Oklahoma** the average annual precipitation is 34.75 inches, the maximum 45.3 and the minimum 15.5. Only in the three most westerly counties is it less than 20 inches. In the eastern portion of the state and com-

prising more than one-third of the whole, it is more than 40 inches.

In Texas the average annual precipitation is 31.65 inches, the maximum 52.1 and the minimum 9.8. Approximately four-fifths of Texas has an annual precipitation of 20 inches and over, and much of the far eastern portion has more than 40 inches. The exception comprises two or three tiers of counties on the western side. Only in about six counties in the extreme southwest is it less than 15 inches.

In New Mexico the average annual precipitation is 13.38 inches, the maximum 25.1 and the minimum 5.1. In nearly all the western half of the state the rainfall is less than 10 inches, and in the larger portion of the eastern half it is more than 15 inches. In some areas in the central western portion the precipitation is from 12 to 15 inches, but in the extreme northwest and southwest the precipitation is very light. Several areas in the west are really arid, and this aridity is aggravated by the large evaporation.

In Colorado the average annual precipitation is 15.91 inches, the maximum 50.5 and the minimum 6.6. Only in one county, Gunnison, is the precipitation 50 inches, and curiously enough, in another part of the same county, it is only 9 inches. The second highest precipitation recorded is 28.7. In Colorado the areas of high and medium precipitation are very irregularly distributed, owing in some degree doubtless to the eccentricities of direction in the mountain ranges. Generally the precipitation over 15 inches is found in the north central and eastern counties, between 10 and 15 inches in certain of the central counties, extending from the southwest to the northwest, and under 10 inches in several of the southwestern counties, a few of which may be classed as arid.

In Wyoming the average annual precipitation is 13.53 inches, the maximum 18.8 and the minimum 5.8.

The southeastern and northwestern portions have the highest precipitation, and Bighorn county in the north and Sweetwater in the south the lowest. Only in portions of these counties can the country be classed as arid.

In Montana the average annual precipitation is 15.39 inches, the maximum 24.1 and the minimum 11.1. Only in a small portion of the northwest area is the rainfall 20 inches and over, and only along the Milk and Bighorn rivers and the country contiguous thereto is it less than 15 inches, except in a small area running diagonally across the central portion of the state. In none of the states of the semi-arid west are the conditions so uniform with reference to precipitation. Montana has practically no arid land except what is made so by the presence of alkali.

In Idaho the average annual precipitation is 17.52 inches, the maximum 37.6 and the minimum 9.3. The precipitation is very unevenly distributed. In the north-erly counties of Bonner, Kootenai, Shoshone, Latah, nearly all of Nez Perce and part of Idaho, it runs from 20 to 30 inches. South of these counties, it is, generally speaking, 15 inches and less, save in the counties of Washington and Boise in the central western area. In the south-eastern and southwestern counties, it runs from 9 to 15 inches.

In Utah the average annual precipitation is 12.66 inches, the maximum 23.1 and the minimum 4.1. The north central portion has a precipitation of 15 to more than 20 inches; east and west from this area, also in the south central portion, it is, generally speaking, from 15 to 10 inches. The east and west third have each ap-proximately less than 10-inches. A very considerable portion of Utah is arid.

In Nevada the average annual precipitation is 9.2 inches, the maximum 26.1 and the minimum 4.3. Only in a very small area in the extreme western portion of

the state does the rainfall exceed 15 inches. In a much larger area in the central part of the same it runs from 8 to 12 inches. In practically all the other portions of the state it is less than 10 inches. In not less than half the entire area the conditions would seem to indicate aridity in the absence of irrigating waters. This state has the lowest average precipitation of all the states in the Union.

In **Arizona** the average annual precipitation is 12.15 inches, the maximum 24.9 and the minimum 3.1, viz., at Yuma. In portions of say five counties in the central part of the state, the rainfall is 15 inches and upwards. In the southwestern part of the state it is 5 inches and less. In nearly all the other portions it is from 5 to 15 inches. Arizona has a large area of arid land.

In **California** the average annual precipitation is 21 inches, the maximum 88.8 and the minimum 1.1, viz., at Ogilby, in Imperial county. If a line were run straight across the state so as to cut off north from it about two-fifths of the same, with the exception of a very small portion in the extreme northeastern corner, that portion would represent in nearly all instances an exceedingly heavy rainfall. Nearly half of the remaining area lying along the Pacific has a rainfall of 10 to 20 inches, and the other portion from 10 inches down to virtually no rainfall. A very considerable portion of southern California is arid.

In **Oregon** the average annual precipitation is 42.8 inches, the maximum 117.0 and the minimum 8.6. West of the Cascades the precipitation is very heavy. In the northeastern counties, it is 15 inches and upwards. In all other portions it is below 15 inches, and in nearly all parts more than 10.

In **Washington** the average annual precipitation is 36.15 inches, the maximum 127 and the minimum 6.5. Westward from a line running down through the center

of the state, the precipitation is more than 20 inches and also in a narrow strip covering all the eastern border. In some of the south central counties it is less than 10 inches and in other parts of the state from 10 to 20 inches.

In southern Alberta, southern Saskatchewan and southwestern Manitoba, the precipitation is not far different from the same in the states of Dakota and Montana, which border on them, that is, it runs from about 12 to 18 inches. One or two degrees north from the boundary it increases, and the increase is virtually as the latitude rises. Evidence of such increase is seen in the increase of tree growth.

The season of precipitation.—The season at which the precipitation falls greatly influences the character of the production. When the bulk of the rain falls in the winter, autumn-sown crops can be grown with the best success, since they get virtually the full benefit of the precipitation, and they mature before the driest portion of the year. When it falls in the spring months, spring cereals may be more successfully grown. When it falls in the summer months, the problem becomes more complicated.

In the Great Plains area the bulk of the precipitation comes in the growing season; that is, in the months of April, May, June and July. This so far is greatly in favor of the growing crops, but the loss from evaporation is greater than when much of the rain comes in the winter. In some areas nearly half the precipitation comes in June and July. In New Mexico and the dry portions of Oklahoma and Texas, the heaviest precipitation occurs in July and August.

In the Inter-mountain states the precipitation is also the heaviest in the spring months, but it is more evenly distributed throughout the year, especially in the western portions of the same. This so far is favorable to the production of both winter and spring crops.

In the Columbia river basin the rain comes chiefly in the first five months of the year, and the three closing months of the same. During the intervening months the precipitation is very low or entirely absent, which is so far favorable to the harvesting of the crop.

In the states of the Great Basin, the larger portion of the precipitation falls in November, December, January, February, March and April. These areas therefore are mainly adapted to the growing of winter cereals, and fruits. The months of July, August and September are practically rainless.

In the Colorado and the Rio Grande river basins nearly all the precipitation comes in the months of July, August and September. The precipitation is very light during the first half of the year. The seasonal rainfall in the dry areas of the several states included as arid and semi-arid is in outline as follows: In North Dakota, Nebraska, Kansas and also the greater portion of Montana, the larger portion of the rain falls in April, May, June, July and August. The heaviest precipitation by far occurs in June and July. In Oklahoma and Texas, the precipitation comes chiefly in the spring and summer months, being greatest in midsummer. In New Mexico the bulk of the rain falls in July, August and September. In Colorado and Wyoming, the bulk of the precipitation comes in the spring and summer months, much the larger amount falling in the spring months. In Idaho, Utah, Nevada, California, Oregon and Washington, the precipitation occurs chiefly in the late autumn and winter months, and to some extent in the spring months. In Arizona the rainfall is very light in the winter months, almost entirely absent in the spring months, quite heavy in July and August and light during the rest of the year. In the dry areas of Canada, much the largest precipitation comes in April, May, June and July.

Other weather condition in dry areas.—In addition to the amount of the precipitation and the time at which it falls, other weather conditions that merit attention include: (1) the manner of the precipitation; (2) the nature of the temperature, and (3) the character of the winds.

The value of the precipitation is largely dependent on the way in which it falls. It renders far greater service to agriculture when it falls gently and for a prolonged period than when it comes as a downpour. Falling thus, much of it is lost to the soil. Rain is said to be torrential when it falls at the rate of an inch or more per hour. When it falls thus the larger portion of it may be lost even on summer-fallowed land. To lessen such loss, the ground is left more or less rough, and it is supplied with vegetable matter, as for instance the straw of headed grain plowed in. When rain falls in the winter and early spring, it is seldom torrential. When it falls in the summer, it is more likely to be so. The Great Basin is more subject to this form of precipitation than the other areas of the dry country.

More of the precipitation comes as snow in northern areas and on high elevations, the highest precipitation falling on the elevations. Even on the northern areas of the Great Plains country the snowfall is not heavy. The benefit which it brings to the soil is largely dependent on the degree of the frost and on how the snow is removed. Little frost in the soil and slow melting may result in saving to the soil nearly all the resultant moisture. When conditions the opposite are present, the greater portion may be lost.

The worst form in which the precipitation can come is in the form of hail. The Great Plains area is most subject to these visitations. In some instances hail storms are very destructive.

The temperature in the arid and semi-arid regions is seldom very extreme. Except in southwestern Manitoba, Southern Saskatchewan and the western Dakotas, and on very high elevations, the winter weather is not severe. Even in much of the Great Plains country live stock, especially horses and cattle, can graze much of the winter. West from the Rocky Mountains, frost enters the ground only for a short distance and not for a prolonged period, and in southern areas the ground does not freeze. Only in the south and southwest is the summer heat subtropical, and even in these areas the nights are cool, as they are everywhere in the dry area.

Other peculiarities of climate include the following: (1) an atmosphere that is dry, rarified, pure, and very wholesome, as shown in the healthfulness of live stock and the comparative freedom from pulmonary disease in the human family; (2) sunshine during more than 60 per cent. of the time between sunrise and sunset; (3) little or no liability to sunstroke; (4) almost entire exemption from prolonged periods of dreary, drizzling rain.

The frequency and the constancy with which wind currents blow, especially in the level stretches of the Great Plains area, is one of the unpleasant features of farm life in those areas, but even in these the stiff wind currents are largely confined to the winter and spring. They are but little present in other portions of the dry area. The summers are usually pleasant in the greater portion of the dry area and the autumns are simply delightful.

Other peculiarities of the winds include: (1) blizzard conditions, though infrequent in the eastern part of the Great Plains country; (2) winds warm enough in the same area to injure the crops more or less, though less so now than formerly, since so much of the ground is being clothed with growing plants; (3) the almost complete absence of cyclones and tornadoes.

CHAPTER IV

SOILS IN DRY AREAS

The discussion of soils in dry areas will be essentially popular in kind. The attempt will not be made to classify these soils on what may be termed a strictly scientific basis. They will be discussed on the basis of the popular conception of their leading characteristics. Hillgard suggests the following classifications: (1) soils very sandy; (2) ordinary sandy soils; (3) sandy loams; (4) clay soils, and (5) heavy clay soils. The first of these has from 0.5 to 3 per cent. of clay; the second 3.0 to 10.0; the third 10 to 15 and the fourth 15 to 35. The present discussion will regard them as: (1) clay; (2) sandy; (3) silt; (4) volcanic ash; (5) gumbo, and (6) alkali. It will be preceded by the consideration of some of the characteristics peculiar to western soils and subsoils and followed by the discussion of natural production as an index of soils.

Some characteristics of western soils.—The soils in dry areas frequently differ from those in humid areas: (1) in color; (2) in their mineral constituents; (3) in the supply of organic matter, and (4) in their moisture-holding power. In other respects they may be similar to the latter, as in their physical constituents.

The average soil of the Mississippi valley is dark in its color. This is essentially the outcome of the large amount of organic matter which it contains in one or the other of its forms. One who is familiar only with such soils, looks suspiciously on those of the semi-arid west. He is much prone to conclude that they are lacking in fertility and that they are also difficult to till. These conclusions are far from correct. These soils, which are usually brown in color, with variations, of course, that are lighter and darker, are much richer in the essential

elements of plant food, especially those that are mineral in character, than the soils of humid areas, and in many instances it is easier to maintain them in proper condition as to tilth after they have been broken. The sparse character of the vegetation that frequently grows on them in a state of nature still further enhances the contempt which many persons from humid regions cherish for the soils of the semi-arid country when they first see them.

Soils in dry areas are much richer in soluble salts, alkalies and mineral plant food than the soils of humid areas. They have all the minerals contained in the rocks from which they come, and of soluble salts there may be even an accumulation. They have not been washed out as in humid areas. The soluble silica and alumina which indicate the availability of these soils are about $2\frac{1}{2}$ times greater in the former and about 4 times greater in the latter than in the soils of humid climates. Soda and magnesia, which up to a certain limit stimulate plant growth, are also plentiful. Where the accumulation of these is excessive, vegetation partly or wholly disappears. Phosphate, potash and lime are also more abundant in dry than in humid soils. It has been claimed that the phosphate is from 1 to 2 times greater on the average, that potash is more than 3 times greater, and that lime is frequently from 10 to 12 times greater. It is fortunate that so much lime is present in semi-arid soils. Among the benefits resulting from its presence are the following: (1) It aids in the quick conversion of organic matter into humus, and this in many instances represents the main portion of the nitrogen content of the soil. (2) In so doing it encourages the presence and action of bacterial life, which is an important factor in maintaining and developing soil fertility. (3) It aids in liberating and rendering more available the phosphoric acid and potash in the soil through the chemical changes which it brings about. (4) It tends to prevent acidity in soils

where much organic matter is buried in the same, a condition that is often seriously detrimental to plant growth in humid climates. In the semi-arid belt the amount of lime present is relatively very large before it proves injurious. In many humid climates the application of lime may in many instances be necessary in order to insure good returns. It is seldom necessary to add lime thus to semi-arid soils. Western soils are comparatively low in humus. For the reasons, see p. 413.

Because of this it is a matter of prime importance that the humus supply in these shall be increased if maximum production is to be obtained from them. For some of the ways in which this may be brought about see p. 420. The moisture-holding power of much of the soil in the semi-arid country is very marked. This follows from the fact: (1) that while it is sufficiently porous it is not unduly loose, a condition arising from the character of the soil grains which compose it; (2) that it is possessed of sufficient firmness, without that undue consolidation which is a barrier to the penetration of moisture; (3) that it is close grained, but not run together and so adhesive that it cannot be readily penetrated by the roots of plants. This moisture-holding power is increased by proper cultivation (see chapter VIII) and increasing the supply of humus in the soil.

The following are among the essential characteristics of a good dry land soil: (1) It must be easy of tillage. Such will be its condition when the sand and clay constituents are properly blended. Western soils have usually enough sand in them to make them easy of tillage when they are sufficiently moist. They also excel in flocculation, that is the looseness or fineness of the particles. (2) It must be easily penetrated by moisture when subjected to the processes of tillage. Many soils that are so firm as to resist the easy penetration of water when not yet broken are easily penetrated

by the same when tilled, a result of the structure of the soil grains as neither too coarse nor too fine. Some soils are so fine that through impaction they resist the easy penetration of water. Such are clays of fine texture. Other soils may be so open that they lose moisture by leaching almost as fast as it comes to them. Such are coarse sands, but these are not very prevalent. (3) It must be able to retain moisture. This will follow when the soil grains are neither too large nor too small, too adhesive nor too much filled with air spaces. This condition is best found in sandy loam soils well supplied with humus. The deeper that the soil possessed of these properties is, the more moisture will it contain. Such a soil and subsoil will readily store a goodly supply of moisture for further use, and it will also furnish ample feeding ground for the roots of plants. (4) It should not have in excess those elements that lead to a gumbo or an alkali condition (see p. 73). Such soils are very hard to till owing to the difficulty of keeping them in a proper mechanical condition. (5) They should not be so light and fine as to lift with the wind. Such a condition would add greatly to the difficulty of cultivating and cropping such soils in dry areas. (6) They should not wash readily when rainfall is abundant. This is one of the weak characteristics of many western soils. The particles are so light and so little adhesive that they are easily held in solution and hence are easily carried away. This is often true of soils that are productive. This tendency may be lessened in various ways, but more especially by adding humus to the soil. (7) It should be rich in plant food not only in the tillable portion but in the subsoil. This characteristic is usually present in a marked degree, not only in western soils but also in the subsoils that underlie them.

Characteristics of subsoil.—In dry areas the physical constituents of soil and subsoil are frequently much

alike. The same is true of their chemical constituents. The surface soils have more humus in them and more of the mineral plant food is in an available form. But the difference in these respects is oftentimes not very marked. That it so is very fortunate, as deep storage is thus made for moisture and much opportunity is given for that soil moisture movement which carries plant food in solution up to the surface soil. It also furnishes deep feeding ground for the roots of plants.

Should the subsoil be dense clay, the downward movement of water would be hindered. Should it be hard-pan it would be more effectively hindered. Should it be coarse sand or gravel, the upward movement would be entirely cut off, or virtually so. But when the subsoil is much like the surface soil, none of these evils follow. The most objectionable subsoils in dry areas include the following: (1) soils that are underlaid with hard-pan that is not distant from the surface; (2) those that have gravel seams not far below the surface or that are underlaid with sand coarse in character, and with but little clay interspersed between the soil grains; (3) subsoils that are so compact that they are not easy of penetration by air or by the roots of plants, and (4) subsoils that are saturated frequently with seepage water that rises to the surface.

A hard-pan condition is usually brought about by the action of lime, which is so abundant in the soil of semi-arid areas, and water. Water carries down the lime in solution as far as it goes, but, owing to the light precipitation and the dry and hard character of the subsoil, it does not go very far, and it goes down to about the same distance from year to year. When the lowest limit of water penetration is reached, it combines with other soil ingredients and forms a layer of calcareous material so dense and hard that it cannot be penetrated easily by the roots of plants. Even where but little lime is pres-

ent, clayey particles are worked down, so as to aid in forming so firm an under-soil that the roots of plants may not easily penetrate it. Such a condition of the subsoil may frequently be removed by tillage that is deep and judiciously given. Such tillage facilitates the downward movement of water to an extent that tends to break up the hard-pan even at distances far below the surface soil.

When a gravel seam has been deposited not far distant from the surface, it facilitates the downward movement of water in the soil and cuts off the upward movement of the same, on the principle known as capillarity. In dry areas such a condition is greatly harmful to vegetation. If the gravel seam is of great depth, the harmful influence referred to is intensified, and if the subsoil consists almost entirely of coarse sand grains, similarly adverse influences will follow. It may be impossible in some instances to obtain satisfactory production from soils thus underlaid, but should the sand or gravel be interspersed with clay particles, these harmful results will be reduced proportionately to the extent to which the clay particles are present.

In some instances fine clay particles are carried down from the surface and left to mingle with the substances composing the subsoils so as to form a mass that is not easily penetrated by the roots of plants. Opening up the surface soil so as to admit more readily the descent of water will usually help this condition, and it may be still further aided by the decay of deep rooted plants, as those of alfalfa, which to a greater or lesser extent may have penetrated these soils.

In some instances, especially in the soils adjacent to higher lands, seepage waters come down from the former and to such an extent as to rise to the surface at certain seasons of the year. These may exclude the air from both soil and subsoil to such an extent as to

prevent growth in the higher forms of vegetation and in some instances any form of the same. In soils thus saturated, oxygen, so essential to germination and vigorous growth, is in a great measure excluded. In the absence of this element of the air, microscopic organisms cannot carry on their beneficent work, the decay of plant food is proportionally retarded and the formation of nitrates is proportionately hindered. Moreover, when the seepage waters contain alkali substances, these conditions are intensified, and oftentimes to the extent of excluding all kinds of vegetation. Such a condition cannot be remedied until drainage has been effected that will promptly carry away the ingredients that are harmful.

Clay loam soils.—These may be defined as soils that contain approximately from 15 to 20 per cent. of clay. They differ from clay soils in the less percentage of the clay which they possess, and from sandy loams in having a lower percentage of sand. They have also less clay than soils that are classed simply as loams. They are relatively high in their percentage of humus.

It would seem correct to say that clay loam soils prevail to a greater extent on the grass-covered bench lands than any other class of soils. This means that they are the principal soils found on the benches of the Plains country. The soils that grow sage brush are also frequently of this type. They are also found interspersed to a considerable extent in the Inter-mountain region, and to some extent in the Great Basin.

The superiority of clay loam soils lies first in the ease with which they may be tilled, second in their moisture-holding power, and third in their richness in the elements of plant food. It would not be correct to say that they are the easiest tilled soils in semi-arid areas, but they are relatively easy of tillage, because of the happy blending of the clay and sand particles, more

especially when they are properly supplied with humus. The moisture-holding power of course increases with the humus supply, other things being equal. The richness which these soils usually possess gives them great wearing power. It is also retentive of gases and soluble plant foods.

Heavy compact clays are undesirable. They are slow to absorb water and quick to lose it by evaporation, because of the readiness with which they impact and form openings in the surface which allow moisture to escape. Stiff clays are composed of the finest particles of the soil, in some instances five hundred times finer than sand grains. They are so fine that they do not settle readily when held in solution. If these soils are tilled when wet they become so adhesive as to be almost unworkable on drying. Such a condition will preclude successful production in dry weather. But the mission of clay particles when mixed with coarser soil particles is most beneficent, since it increases their richness and also their moisture-holding power.

Sandy loam soils.—In dry areas sandy loam soils are such as are composed of sand particles intermingled with clay to the extent of 10 to 15 per cent. of clay. The clay content in them is from two to three times as much as the clay content in sandy soils. In some areas sandy soils have come from sand-bearing rocks which, when decomposed, are not capable of furnishing clay, hence the low fertility of these. But this is not usually true of sandy soils in dry areas, as in arid regions experience has shown that these soils are as productive as other good soils when sufficiently supplied with water. This holds good even with arid soils that are desert in the absence of irrigating waters. The sand and silt particles in these are capable on further reduction of yielding clay. The clay particles are greatly helpful in lessening the spaces between the soil grains. Many of

these particles may adhere to one grain, and in so far as they do they lessen the tendency to leaching.

Sandy loam soils and also sandy soils cover much of the surface of the semi-arid areas. In the eastern portion of this area these are usually sectional, and in some instances the silt particles in them are so light that they lift more or less with the wind. In the Inter-mountain region these areas are more pronounced. In some parts of the valley of the Columbia they cover wide areas, and the same is more or less true of the Big Basin country. In many instances sandy soils maintain but little growth while yet untilled, hence oftentimes they have a barren aspect.

In dry areas sandy loam soils are among the best, whether viewed from the standpoint of production or from that of tillage. These soils encrust and compact less readily than other soils and they do not lose water so readily by evaporation. They may be tilled at almost any season of the year not locked with frost. They warm more quickly in the spring, and are therefore more favorable to early growth. Their value, however, is much influenced by the degree of the clay which they possess. When too lacking in clay or silt particles, they become leachy.

Silt soils.—Silt soils are composed of soil grains that have been deposited mainly through the action of water. The particles of which they are composed are usually small and fine, much smaller and finer than the average sand particles and larger than the particles of clay soils. They are of varying degrees of fineness, dependent on the extent of the reduction of the sand particles which compose them. In some instances they are possessed of much uniformity in texture, and this may extend to a great depth. In other instances they are intermixed with gravel more or less coarse and they are not infrequently underlaid with a subsoil of coarse gravel.

which may come up near to the surface. In yet other instances these soils are so impregnated with fine clay particles that they lose much of their silty character and assume more the character of a clay soil. If alkali is present these soils may assume a gumbo character. True silt soils are relatively rich in the elements of plant food and are very easily tilled, but they frequently lose moisture easily by leaching, and they are much liable to wash.

Silty soils, sometimes called alluvial soils, are found to a much greater extent in the valleys that line the streams than elsewhere. These valleys in western areas are usually relatively large, hence the area embraced as silt is quite considerable. These soils are also found in areas of considerable size that were at one time the beds of ancient lakes.

The relative value of silt soils depends largely on their composition. True silt soils that are also deep and uniform in their composition are usually very rich. This may also be true of soils that are less uniform in composition and texture. As a rule they are also easily tilled. But they, in very many instances, allow water to pass down through them so easily that crops grown on them in dry areas in the absence of irrigating waters are much liable to be injured by drought. The author has found it much more difficult to grow good crops on these soils in dry years than on the average bench land soil. When these soils were underlaid by gravel, even some considerable distance below the surface, the loss of moisture was increased. When the gravel came up quite close to the surface good crops could not be obtained, even in seasons that were reasonably moist, in the absence of irrigation. When the gravels were mixed with silt, the results were much less harmful, just as the gravel subsoils on bench lands that come up near the surface are much less harmful when they are mixed with a goodly sprinkling of clay. The summer temperature

is also considerably higher in those river basins than on the benches and the rainfall is usually somewhat less. These conditions add to the difficulty of getting good crops from such soils in the absence of irrigation.

Volcanic ash soils.—Volcanic ash soils, as the name implies, are composed of very fine particles resembling ashes in their fineness and in the ease with which they may be dissolved and carried away by the action of the water. They owe their existence to the action of volcanoes in eruption in primeval centuries. The particles which compose them are very fine, finer than the particles found in silt soils. These, more than any other soils found in the west, are flocculated in character, which means that the exceedingly fine particles which compose them are gathered together into little flocks, as it were, through the action of lime, which tends to bind them together. Were it not for this binding process, plants would be unable to live in the soil. Organic matter also helps these soils by keeping asunder the particles of the same.

These soils cover considerable areas of the far western states, especially of the Inter-mountain regions. They are found not only in the valleys, but also on the higher elevations. In many instances they are found without intermixture and of much depth. In other instances they are more or less mixed with the substances which tend much to modify their character.

Volcanic ash soils are exceedingly high in the elements of plant food, especially in the mineral elements of the same. They have great wearing power, and as a result under fair treatment will grow many successive crops without showing any indications of a waning fertility. They are also easily tilled. They do not bake readily in the sense in which hard clay soils bake, but they do incrust on the surface more or less after rain, as nearly all soils do that are low in organic matter.

This is the great lack of volcanic ash soils, and it furnishes one explanation of the ease with which they are gullied and carried away by the action of water. The adaptation of these soils to a great variety of production when sufficiently supplied with water is simply marvelous.

Gumbo soils.—Gumbo soils are soils that are possessed of enough of the elements of alkali (see p. 73) to make them adhesive, and yet these elements are not sufficiently adhesive to make tillage impracticable, although it may be and is usually difficult. These soils may contain much clay. They usually do, but they may also contain some sand. They are so adhesive that when dry it is exceedingly difficult to plow them. They turn up in great chunks which it is impossible to pulverize until they are softened by rain, which acts on them much as it does on unslaked lime. If worked when wet they adhere to the implements of tillage to such an extent as to make tillage virtually impracticable. In order to till them, advantage must be taken of those periods when moisture is present in that degree which makes tillage practicable, and when it is not present in that degree which will result in the baking of the land after it has been worked. This narrows very considerably the season of the year during which gumbo lands may be successfully tilled. The highways in areas where gumbo soils prevail are almost impassable in time of wet weather. Owing to the adhesive character of these soils when wet it is almost impossible to drive a vehicle along the highway because of the accumulation of plastic soil which adheres to the wheels.

Gumbo soils are not generally present in extensive areas in the dry west. They are more commonly met with in river basins and in depressions on the higher lands, oftentimes they are found in spots of more or less size in areas where the soil is easy of tillage. That they

are found to a greater extent in river basins than in other areas is fortunate, since it makes it possible to run irrigating waters over them in many instances in a way that will render great service in their tillage. But on other land such aid is, of course, impossible.

Gumbo soils are rich. They are generally speaking unusually rich, hence their power to wear is unusually good. If brought into a proper mechanical condition, they produce enormous crops when the conditions are all favorable. But frequently the conditions are not favorable. The moisture in the spring may retard tillage at the right season. The lack of moisture in the autumn may render tillage impossible. It may also hinder the sprouting of grain sown at that season. Under nearly all circumstances the fine pulverization of the land is difficult.

Experience in handling these lands has shown that when they are judiciously worked and cropped they become more tractable, so to speak. Especially is this true when coarse farmyard manure is buried in these soils or when green crops grown on them have been plowed under. When the necessity is imperative for working these soils, the aim should be to grow on them alfalfa as far as this may be practicable. In moist seasons this crop succeeds well on them, but in dry seasons it will, of course, grow less well. The roots of the alfalfa tend much to improve the physical condition of these soils when they are broken up.

Alkali soils.—Alkali soils are soils in which the solution of certain soluble salts is so strong that plants that may germinate on them cannot take up the moisture in the soil, insomuch that though they should germinate they soon perish through lack of moisture. It is of two kinds, known as white and black alkali respectively. White alkali is largely due to an accumulation of common salt, glauber salt and epsom salt. These give

it the white color which characterizes it. It is a mixture of the sulphates and chlorides of soda and magnesia. The most harmful effect from the presence of white alkali is that it retards or entirely prevents germination in the seeds. Some crops, however, will stand as much as one-tenth of one per cent. of white alkali.

Black alkali is due to the presence of carbonate of soda along with the aforementioned salts. It dissolves the vegetable matter in the soil and gives it its dark color. It tends to consolidate the soil in proportion as it is present. In some instances, because of the previous nature of the soil, the black appearance may not come to the surface and yet there may be much carbonate of soda in the subsoil. When it is present in any considerable quantity, the soils which contain it are practically untillable during the dry portions of the year. One-tenth of one per cent. of black alkali will prevent the growth of useful plants. Nevertheless in small amounts the alkalies are quite helpful in promoting vegetation. Plants will be much stimulated in their growth because of their presence. It is when they are present in excess that they become injurious. They are more injurious in seasons which have fairly good spring rains followed by a shortage in the summer rainfall. The salts are thus brought into the root zone by the excessive evaporation which follows, and the plants then fail because of drought. Unwise or excessive irrigation brings the alkali to the surface, and to the extent in some instances of rendering land unfruitful which previously may have produced good crops. Alkali is most liable to accumulate where the land is depressed and where the drainage is not good. In humid areas the excess of these salts is washed out from time to time, so that in these their presence is not usually harmful. Both classes of alkali tend to destroy the soil texture. They destroy its granular condition, causing it to become impervious to water.

They lead to a plasticity of condition when it is wet, and they cause it to become cloddy when dry.

Fortunately alkali soils do not usually cover large areas. More frequently they occur in spots and especially where water collects in low ground at certain seasons of the year. In some instances, however, considerable bodies of land occur that are more or less impregnated with alkali. Such soils are very undesirable for tillage.

Because of the difficulty found in tilling these soils their value is very low for agricultural uses at the present time, whatever the future may reveal. Because of this such lands should not be chosen for agricultural uses until more is known as to how they may be handled. They are usually exceedingly rich. The great obstacles to their tillage are, first, the difficulty found in handling them, and, second, the burning of the seed or crop that may be sown on them.

The removal of alkali when present in excess is seldom an easy proposition and in some instances it is not practicable. The first step in removing it is to supply thorough and complete drainage either through the agency of open or of tile drains. In some instances black alkali in solution will not enter the latter. In such instances it should be changed to white. This is done by adding considerable quantities of gypsum; that is, of sulphate of lime, which becomes carbonate of lime. When thus changed, the alkali may be washed down and out in the drainage water which is thus carried off in the drains. The second step is to work into the soil from 10 to 20 tons per acre of strawy horse manure in the summer or early fall, in areas where much of the precipitation comes in the winter, or in the spring when it comes subsequently to that time. It tends to prevent evaporation from coming to the surface, makes the soil more open and porous, and correspondingly reduces the

tendency to puddling and baking. It also aids in supplying the young plants with plant food when the alkali soil alone would not do so. The third step is to grow such plants as will aid in removing the alkali and will at the same time give a profitable return. Sugar beets will absorb more of the salts probably than any other crop, but it may not be easy to secure a stand of the young plants. Among the small grains oats have the highest adaptation for such soils. Sweet clover may also be used in removing alkali from these soils.

Production as an index of soils.—If a soil is to produce well in dry areas it must be possessed of certain physical and chemical characteristics. The former include: (1) much depth of soil and subsoil; (2) much uniformity in the character of the soil grains in both soil and subsoil; (3) much power to absorb and hold moisture, and (4) that blending of sand and clay elements which favors easy tillage. The latter include: (1) the large inherent storage of the elements of plant food; (2) the elements of plant food held in proper balance, and (3) the absence in excess of such elements as may lead to what is termed an alkali condition of the soil. In the absence of physical examination much may be determined by the character of the vegetation found growing on the soil. Such vegetation includes: (1) the growth of sage brush in one or the other of its forms; (2) greasewood and rabbit brush in varying degrees of vigor and plentifullness; (3) sparse vegetation, and (4) the presence of various grasses.

Sage brush is essentially a product of semi-arid soils in dry areas. It is of several types which cannot be dwelt upon in a work of this nature. It would seem correct to say, however, that the character of the sage brush is a measure of the fertility of semi-arid soils. Where the brush is abundant and of large growth, the ability of the soil to produce well under proper condi-

tions of tillage need not be questioned. This means that where sage brush is plentiful and of vigorous growth, the ability of the soil to produce abundantly need not be questioned under correct methods of tillage. The soil constituents and the precipitation that will produce large and abundant sage brush will also produce large crops of grain under proper conditions of tillage.

Plants popularly known as "greasewood" and "rabbit brush" grow on certain western soils. These indicate that alkali salts are present in that degree that will interfere with abundant production. Such soils may be tilled with a certain degree of success, but not with that degree of success that is to be looked for from the tillage of soils that are covered with an abundant growth of sage brush of relatively large size in the shrubs.

In other areas, especially those that are very sandy in texture, the vegetation may be very sparse. The sage brush that may be growing on these is dwarfish and the plants are relatively distant. Such growth does not necessarily indicate any absence of the essential elements of fertility in the soil, but rather the absence of moisture. In those areas the production of grass is sparse in its character, and good crops cannot usually be grown in the absence of irrigation.

The grasses which nature produces on the bench lands of the west are one of the surest indications of the possible production that may be looked for from the judicious tillage of the lands that produce those grasses. Where the native grasses form a sod that is reasonably dense on the untilled prairie, the presence of a sufficient rainfall for the production of good crops in a normal season need not be questioned. Where, however, the production of these grasses is sparse and limited, a light rainfall relatively is to be looked for. The precise character of the grasses will vary with the soils and the amount of the precipitation, but it may be safely assumed

that a free growth of grasses cannot be maintained in the absence of at least a reasonable amount of precipitation, regardless of the character of the soil. It may be taken for granted, therefore, that where the growth of native grasses is normally good, grains may be grown there with at least fair success under proper methods of tillage.

CHAPTER V

SOIL MOISTURE AND DRY FARMING

In the farming of dry areas the question of soil moisture is all-important. To farm such areas intelligently and successfully the farmer should have information regarding: (1) the amount and character of the precipitation; (2) the rate of the evaporation; (3) the methods by which water may be retained in the soil until it is needed, and (4) the plants that may be grown with the most complete success under the conditions that prevail.

When judging of rainfall and the use that is to be made of the same, the farmer should have information not only in regard to the amount of the annual precipitation, but also with reference: (1) to the period covered by the records; (2) the season or seasons when it falls, and (3) the manner in which it falls. The longer the period during which the records have been kept, the more reliable are they. It is never safe to base the nature of the farming to be followed on the record of precipitation for one or two seasons, the records vary so much in different years. In dry areas the rainfall of one year is sometimes less than one-half of normal, and in other years it is greatly in excess of the same. The season at which the rain falls has a greatly important influence, not only in determining the crops that shall be grown, but also the precise character of the tillage that should be adopted. These differ very materially when the bulk of the precipitation falls in the winter in the one case and in the summer in the other. The manner of the precipitation has also an important influence on the methods that should be adopted in order to utilize it to the best advantage.

While the degree of evaporation is probably less important than the amount of the precipitation, it is nevertheless greatly important. In areas far southward in the dry belt, the precipitation called for to produce plant growth is very considerably more than what is called for to effect the same in areas of the same altitude but located far to the northward (see p. 95).

The methods by which water may be retained in the soil until it is needed involve consideration of the handling of the soil in all its phases, including: (1) the breaking up of the same; (2) the subsequent plowing; (3) the various processes of tillage, including packing, discing, harrowing and rolling; (4) subsoiling, and (5) succession in the crops that are to be grown.

The plants that may be grown with the greatest success is in itself an important study. The species of plants not only differ very much in their adaptation to dry areas, but this is also true of varieties of the same species. To attempt to grow those lacking in adaptation would not be wise. The value of correct information along these lines cannot easily be overestimated (see chapter X).

Water in semi-arid soils.—Water occurs in all soils: (1) as free water; (2) capillary water; (3) hygroscopic water, and (4) the water that runs away and is lost to the soil. In semi-arid areas the free water and the water that runs away is much less abundant than in humid areas. The distinctions thus given are not sharply drawn, as will be apparent from what is said below.

Free water, sometimes called gravitational water, is that which fills the pore spaces between the soil grains and moves down through the soil by gravity. When present in excess it excludes the air so as to hinder healthy plant growth and in many instances to confine it to growth that is not of much value. Passing down into the subsoil, it may reach a point where further descent

ceases, and where ascent may begin, when it becomes capillary water, which is very frequently the case in semi-arid soils. In humid areas it frequently passes down until it reaches ground water below, when it may move laterally through the soil until it reaches some outlet, as for instance, through springs. When the water table is not too near nor too distant from the surface and when the supply is constant, it renders great service to plants by supplying them with water carried to the roots through capillary action. Water occurs thus not infrequently in the basins of semi-arid countries, more especially where mountains occur. When thus found it comes from higher levels. In its downward movement it finds a stratum of subsoil that is usually sufficiently porous to admit of free movement laterally. Such movement of water in the soil is spoken of as seepage. The presence of such water at proper levels will frequently maintain good crops in areas where they will completely fail when not supplied from such a source.

When the air spaces between the soil grains are completely filled, the maximum of gravitational water is present. The capacity of dry farm soils thus to hold this water will, of course, vary, but on the average it is from say 35 to 40 per cent. of the dry weight of the soil. In humid soils such water moves downward after every heavy rain, until it reaches the water table, that is, providing it is not too distant, when it flows out into streams. In dry areas the water table in the ordinary sense of the term is seldom present. In such areas it goes down as far as the force of gravity can take it, which is, of course, dependent upon the supply. It is thus stored in the subsoil as capillary water until drawn upon by plants in process of growth, in areas that are properly cultivated. The great importance of such water to the dry farmer cannot easily be overestimated, hence it should be his aim to increase this supply to the

greatest extent practicable. This, of course, can only be accomplished by keeping the soil sufficiently open to admit of the downward passage of all the water that falls, and by not cropping so frequently as to completely exhaust the supply.

Capillary water is the thin film that surrounds and adheres to each soil grain. It is the outcome of the attraction between soil grains and water which is always present. Because of the almost infinite number of the soil grains, an average soil may hold a large amount of capillary water. As the fineness of the soil grains increases, it is manifest that the capacity of the soil to hold capillary water will increase. Thus it is that the capacity of clay loams to hold capillary water is much greater than that of sandy loams. King is authority for the statement that the largest amount of water that can be held in clay loams varies from 22.67 to 18.16 per cent., in sandy loams from 17.65 to 10.67 per cent., and in humus soils from 44.72 to 21.29 per cent.

The movement of capillary water in the soil is upward when it moves. It climbs thus on the principle that oil climbs up through the pore spaces of a lamp wick when the lamp is lighted. The supply of oil that renews the flame is thus maintained until the oil is consumed, when the flame must cease. Capillary water is thus drawn upon as the supply above becomes exhausted. It may be drawn up in two ways: first, to supply water removed from the surface by evaporation, and, second, to renew the supply called for by plants in process of growth. If evaporation should virtually cease, as it does frequently in winter in the absence of plant growth, the movement of capillary water would practically cease for the time being. The movement of water in the soil may be thus summarized: (1) It enters the soil in the form of rain or melted snow. (2) It moves downward in the soil as gravitational water until it is converted

into capillary water or until it reaches the water table below. (3) The distance that it goes down as gravitational water before it is converted into capillary water will depend mainly on the dryness of the soil and on the copious character or otherwise of the precipitation. (4) The rapidity of the downward movement will be accelerated by increase in the degree of the soil saturation. (5) It is being continually drawn upon by the influences of evaporation and to supply the needs of growing plants. (6) These drafts lead to that upward movement of the water known as capillary movement. (7) When the supply of capillary water is too small to meet the needs of the plants they languish proportionally in their growth. To maintain such supply is one of the most important questions that can engage the attention of the dry land farmer.

Hygroscopic water is water that is held within the soil grains. The proportion of the hygroscopic water in the soil varies in soils and in localities. In some very dry areas this percentage has been placed at less than 2 per cent.

Whether such water aids to any extent in promoting plant growth is a disputed question. It may aid in keeping the soil cooler than it would otherwise be in warm areas. It may also exercise some influence in bringing plant food into solution, but there is not enough of it present in the soil to make it a carrying agent.

The run off waters are those that flow away: (1) in quick melting of the winter snows; (2) from the downpour of torrential rains, and (3) from the continuance of prolonged rainfall. Especially in areas where "Chinook" winds prevail, the snow melts so rapidly that much of it runs away before it can sink into the soil. In much of the semi-arid country rain frequently falls in showers that are dashing in character. In some localities these assume the character of a downpour. Occa-

sionally cloudbursts occur, and when they do the rain falls in sheets. When it falls thus much of the water is lost to the soil, much of the soil is also removed to lower levels and the gullying of the land becomes more pronounced. The aim should be, of course, to prevent such loss as far as this may be found practicable (see p. 128). The loss from the third source mentioned is seldom serious, as prolonged and heavy rains seldom occur in dry areas.

Functions of water in soils.—These include: (1) dissolving plant food in the soil; (2) carrying the food dissolved to the plant, and (3) maintaining proper growth in the plant. These functions can only be found at their best in soils of proper texture, well supplied with the elements of plant food, free from matter hurtful to plant growth and in proper condition as to tilth; water must also be present in sufficient quantities in the soil and subsoil.

Plants take their food from the soil through the roots. These cannot appropriate the food unless it is held in solution. The water which surrounds the soil grains in the form of a film dissolves the food so that the plants can feed upon it. When the plant food is thus liberated in excess of the needs of the plants or at a season when plants are not growing, it is carried down in solution in the gravity water. Should this gravity water reach the water table below, it is much liable to be carried away in the drainage water. Should it be absorbed in the lower soil along with the capillary water, it may be again carried to the area where the roots of plants feed in the upward movement of the capillary water, and it may also be reinforced by plant food liberated in the lower levels that have been reached by moisture.

The food solutions are carried to the plants through the root hairs which ramify through the pore spaces of

the soil, hence the great benefit of plant growth by maintaining as far as this may be possible a suitable degree of tilth in soils. The rootlets cannot readily penetrate compact soils. The food thus absorbed is carried up from cell to cell in the plants to the leaves, where it is elaborated into food suitable for the plants. It is then distributed to those portions of the plants that are in need of it to enable them to make further growth.

It is evident, therefore, that if plants are to be maintained in vigorous growth, the food thus carried in solution must be present in sufficient supply. The growth made will be restricted, other things being equal, in proportion as the necessary food is lacking. If not supplied in sufficient degree to continue growth, the cells become impaired and the leaves wilt. When this happens, growth subsequently in many instances cannot be secured, and if secured it is never so vigorous again. Any period of stagnation in the growth of the plant hinders future development. In order to sustain good growth the food in the soil must first be held in solution by the capillary water in the same, hence the transcendent importance of a sufficiency of this element in dry areas.

How soil moisture may be lost.—It may be lost: (1) by evaporation at the surface; (2) by transpiration through plant growth, and (3) by leaching out through the subsoil. These influences may operate singly at different times, or they may all operate at one and the same time. The first is operative chiefly in the season of mild and warm weather and the second only during the growing period. The third may be operative at any time, but under some conditions in dry areas it is not operative at all at any time. The greatest loss, however, in much of the dry area, especially where the soil has not been tilled, occurs in the run off water that does not enter the soil at all.

Evaporation at the surface means the loss of moisture from the soil as it climbs up through the pore spaces in the same to the surface, where it becomes vaporized as it becomes incorporated with the air. To prevent loss from this source is of the utmost importance to the farmer in dry areas, hence the extent to which this question is dwelt upon below. Under the most favorable conditions the amount of moisture in the soil is less than could be utilized to the best advantage. If this should be lost or any large portion of it, the farmer is undone for that season. In dry farming the handling of the soil in a way that will cause the precipitation falling upon the soil to enter the same to the greatest extent possible is fundamental, and of no less importance are measures that will tend to prevent the escape of moisture to the greatest extent possible until it has been utilized in growing plants.

Loss of moisture by transpiration means the passing of moisture into the air through the leaves of the plant which has been taken from the soil by the roots. This process is continuous while growth lasts. It is a loss that cannot be lessened very much by those who till the soil. But the harm that may follow to succeeding crops may be minimized and in many instances entirely prevented by wisely regulating the rotation followed.

Loss of moisture by leaching is of course the loss of water that has passed down through the soil into the subsoil, whence it moves on and out as drainage water into streams. It seldom occurs in dry areas, because of the small quantity that enters the soil. In humid areas the water that passes down through the soil carries with it in solution much plant food that has been taken out of the soil. The richer the soil and the more abundant the precipitation the greater is the loss from this source. This explains, in part at least, why soils in areas of much rainfall frequently call for much fertilization,

while crops are being grown upon them. The farmer in dry areas is usually spared loss from this source.

In some instances, nevertheless, soils may be excessively wet, as when, for instance, seepage waters flow into depressions from a subterranean source. If these are possessed of much clay, they usually become hard when the water evaporates sufficiently to admit of tilling them. When plowed they turn up cloddy, and much labor is involved in pulverizing them. If plowed when wet they bake. Moreover, they are much liable to contain substances that are injurious to vegetation, as an excess of salts. These soils are undesirable, as has been already shown (see p. 73).

Loss of moisture by evaporation.—The chief influences that lead to the loss of soil moisture by evaporation are: (1) sunshine; (2) dry and warm air, and (3) wind. The sun shining down on moist soil turns the moisture near the surface into vapor, which rises and mingles with the air. The rapidity of the process is proportionate to the heat of the sunshine and the degree of moisture in the soil. The influence of sunshine as a factor in removing moisture by evaporation is readily seen by comparing the quick drying of the surface soil after rain when exposed to bright sunshine with the slow drying of soil in a similar condition on a cloudy day. Sunshine is the most powerful factor in thus removing moisture. In dry areas such removal should be specially guarded against, because of the great abundance of the sunshine.

Air penetrates the soil to a greater or lesser depth, according to its density or porosity. It more readily penetrates between the soil grains in a newly cultivated soil. As it passes between these, more or less of the moisture which adheres to the soil grains becomes incorporated with the air thus diffused in the soil, and escapes with it into the atmosphere as a result of constant move-

ment of air. The degree of the soil moisture thus removed is increased with increase in the dryness and warmth of the air. Warm air will hold several times more vapor than cold air. As the air is usually more dry in dry areas than in humid ones, the loss from this source will be much more in the former, and, because of the increased heat of summer, it will be much greater at that season than in winter.

Wind is a strong factor in removing moisture from soils, especially moisture on or near the surface. The influence of wind in thus taking up moisture may be clearly seen in the rapidity with which water is removed from the highway by strong wind blowing, after rain. Winds are usually more prevalent in dry than in humid areas, because of the comparatively treeless condition of the former, hence the relative loss of the moisture from this source is greater. These influences frequently act in conjunction, and when they do the loss of moisture from the soil will be very rapid in the absence of measures to prevent it.

The extent to which soil moisture is lost through evaporation will be proportionate: (1) to the extent to which the agencies of air and wind are operative in removing it; (2) to the extent to which other influences are present that facilitate such loss, and (3) to the extent to which soil conditions are absent that would tend to lessen and prevent the same.

From what has been said, it will be apparent that evaporation will be much greater in southern than in northern areas of the dry belt. In the former the sunshine is hotter, and the humidity of the air is less. The winds may not be any stronger but they are warmer. The annual average evaporation of surface water in dry areas is usually several times greater than the annual precipitation. In the Panhandle of Texas, the annual evaporation has been placed at about 54 inches, where-

as along the Canadian boundary in North Dakota and Montana it is not more than half that amount. It is even more imperative, therefore, that measures shall be taken promptly and persistently to prevent the escape of soil moisture in areas far south than in those far north.

Prominent among the other influences that aid the escape of soil moisture in the absence of preventive measures are showers, especially those that fall frequently and in small quantities. Water climbs upward in the soil by capillary attraction. The more thin the film of water that surrounds the soil grains the more slowly does it move upward. Should the soil be dry, the upward movement ceases. Should rain fall and moisten the soil down to where soil moisture is still present, the upward movement begins again. Water moves up to the surface and unchecked mingles with the air. If this movement is not checked by stirring the surface soil, much moisture will soon escape. Such stirring of the soil is much more liable to be neglected after light than after heavy rains, hence the hazard that light showers will bring to dry farming in this way.

Subsurface packing of the soil may also facilitate the escape of soil moisture from below, since it facilitates the ascent of the same by making it possible for it to climb more readily toward the surface than would be possible in the absence of such packing. Any influence that will facilitate the ascent of soil moisture will facilitate the escape of the same in the absence of hindering influences.

Weeds also pump water out of the soil in the process of growth, hence the loss of moisture from this source will be proportionate to the extent to which weeds are allowed to grow. The same is true of useful plants in their growth, but with the former there is no compensation as with the latter.

The measures that may be adopted to prevent or at least to lessen the escape of soil moisture include the following: (1) The maintenance of a dust mulch on land that is being fallowed; (2) the stirring or cultivating of the soil that has been sown or planted, and (3) the artificial shading of the soil.

A dust or soil mulch is a dry layer of earth covering the surface of the soil. It is formed by pulverizing the surface after the land has been plowed. It may also be formed by discing stubble land in the autumn or spring, and by stirring fall-plowed land in the early spring, that has settled upon itself. The implement chiefly used in making it is the spike-tooth harrow, but on cloddy soils the aid of the roller or the planker may be called in. On hard surfaces the disc should precede the harrow. The process is frequently spoken of as summer tillage. The depth of the mulch is from 2 to 3 inches. The fineness of the same is dependent to some extent on the character of the soil. On some soils, especially those that are granular, it does not readily become too fine. On others, as fine clays, the excessive use of the harrow may make the soil so fine that it is not readily penetrated by rain. In clay soils covered with a dust mulch, the loss by evaporation is greater than in those covered by a mulch of coarse particles, as coarse sand, for the reason that water climbs more readily in fine than in coarse soil particles.

Rain is the chief agent in destroying the efficiency of the dust mulch. It does so: (1) by tending to restore the pore connections between the dust mulch and the soil below, and (2) by the numerous cracks which follow in many soils from the rapid drying of a more or less impacted surface. It is greatly important that the soil mulch shall be renewed after rains, and especially after heavy rain in many of the soils of the west. The aim should be to make such renewal at the most pro-

pitious time, that is, when the soil has dried enough to prevent it from sticking to the harrow, but not enough to cause it to crumble into particles too fine. Of course in practise this cannot always be done when very large areas are to be harrowed.

The chief use of the mulch is to prevent the loss of soil moisture. This loss is far greater in the upper layer of the soil than in those layers that are lower, hence the great importance of maintaining the soil mulch on summer tilled lands. But it may also serve to aid in the increase of the moisture content of the soil, and in putting the soil in a condition that will favor the active working of the bacteria that inhabit the same. The first result follows from the added moisture through rain, which, because of the tillage, finds easy penetration into the soil. The amount of such accumulation will be proportionate to the amount of precipitation, and to the effectiveness of the measures for preventing its escape. All the moisture that enters the soil cannot be saved, but a very large proportion of it can, as much in some instances as 50 per cent. The second follows from the moisture thus maintained in the soil and the aeration given.

In some soils and under some conditions, the drying of the surface soil is so rapid and complete that this in itself forms a mulch, so to speak, through which moisture cannot pass up from below. This explains why moist soil may sometimes be found under soil that is quite dry on the surface. Such a condition may also be brought about where the temperature is high, the sunshine abundant and the relative humidity low.

The results that follow the judicious cultivation of growing crops are virtually the same in kind as those that follow the maintenance of the soil mulch on land that is fallow. The cultivation is given with the harrow when applied to cereals and with both the harrow

and cultivator when applied to such crops as corn and potatoes. The cultivation also seeks the destruction of weeds, which will sap moisture from the soil more completely when they are allowed to grow numerously than any other agency. So valuable and so effective are these methods of maintaining soil moisture that in dry areas they are practised on crops by growing them in rows though not usually grown thus, as alfalfa for instance, in order to make such cultivation possible. When applied to small grains, however, the yields have not been found sufficient to justify the practise.

Shading the soil and thus protecting it from evaporation may be incidental or it may be designedly done. It is incidental when it is the result of crop growth, as when it is furnished by the cereals when too advanced in growth to admit of harrowing them longer, by corn and other cultivated crops when the plants have attained a considerable size, and by the high-cut stubbles of mature grain that has been harvested. It is done through design when the soil or the crop is strewn with straw, manure or some other substance. Such a method of preventing the escape of moisture has been found effective in a considerable degree when applied to orchard and other trees, and even to grass lands. The reduction of evaporation by a broad-leaved crop, as corn, when well grown, is very considerable.

Loss of soil moisture by transpiration.—Soil moisture may be lost, as previously intimated, in three ways, viz.: (1) by leaching; (2) by evaporation, and (3) by transpiration. The loss by leaching, as has been shown, seldom occurs in dry areas. The loss by evaporation, oftentimes serious, has just been discussed. The loss by transpiration through the leaves of plants is several times greater than the loss that usually occurs by evaporation.

Plants in the process of growth take up water from the soil by means of minute root hairs at the extremities of the rootlets. The water thus taken into the plant contains more or less of certain elements of plant food taken from the soil. It passes from cell to cell or up through tubes within the plant until it reaches the leaves, whence it passes off into the air. Through the medium of water, therefore, the elements concerned in promoting growth are distributed to all parts of the plant. As the water passes off into the air, there is a demand for more water, to sustain the processes of growth, hence the demand upon the water supply in the soil continues until growth is completed.

Many things are yet to be learned about the transpiration of water through plants. It would seem safe to say, however, that it is influenced by the following conditions: It is increased: (1) by increased temperature; (2) by decreased humidity; (3) by increase in the velocity of the wind; (4) by increase in the sunlight; (5) by increasing age in the plant up to the blossoming stage, and (6) by increase in the strength and the diffusion of the root system. It is very evident, therefore, that transpiration from plants is more rapid, other things being equal, in dry than in humid climates. It is decreased: (1) by increase in the soil water of the food elements which the plants require to properly sustain them, and (2) by adaptation in the plants to the requirements of growth under dry conditions. This last consideration is one of great moment, viewed from the standpoint of the future of dry farming.

The farmer can do but little directly to reduce transpiration in the crops. The greater the supply of plant food maintained in the soil, and the more available its condition, the less will be the relative amount of water taken from the soil. This emphasizes the wisdom on the part of the dry land farmer in maintaining a liberal

supply of plant food in the soil in a readily available form. This in dry areas may be accomplished meanwhile by that high-class cultivation which will insure the abundant liberation of fertility.

While not very much can be done to regulate the amount of water transpired by individual plants, the farmer can do much to regulate the amount of water taken from the soil in the aggregate, by regulating crop growth, and he can increase the amount of water available for transpiration. He may influence the amount of water that shall be taken from the soil: First, by deciding as to the crops that he will grow, some of which take more and some less moisture from the soil. Second, he may regulate the thickness or the thinness of the stand of the plants in a given crop. Third, when he finds that a crop that has been sown inopportune is not going to prove remunerative, he should at once remove or bury it, and thus stop the drain on soil moisture to no purpose that is being made by the plants that compose the crop. The amount of water available for transpiration may, of course, be increased by that cultivation which will encourage the entrance of water into the soil and which will retard its escape when it has so entered. Experiment has shown that the amount of water called for to produce a pound of dry matter in various soils is much greater in those that are not well cultivated than in those which are. Experiments conducted in Utah have proved that the summer-fallow materially reduces the amount of water called for by plants as compared with land that has been continuously cropped.

As cultivation extends in dry areas and as it becomes more carefully conducted, the store of moisture in the soil will increase; as the crop area increases, transpiration through the growing of crops will also increase. To such an extent will this increase prevail, that it should exercise a material influence by increasing the humidity

in the air, and this in turn should tend to lessen the injury done by the hot winds that sometimes prevail in dry areas. This increase in transpiration has led to the hope that it will result in an increase in the precipitation, but the evidence based on the results does not sustain this view. The influence emanating from this increased transpiration does not appear to be enough to affect the precipitation, at least to any very appreciable extent.

Other influences that affect evaporation.—Among the influences that affect evaporation in addition to those that have been dwelt upon are: (1) the influence resulting from latitude; (2) the influence resulting from altitude, and (3) that resulting from the store of humus in the soil. In the discussion of this question these influences cannot be ignored, because of the important bearing which they exercise upon evaporation.

Latitude influences evaporation because of the influence which it exerts upon temperature. Evaporation increases with increase in the temperature. This explains why evaporation is greatest when the summer heat is greatest, other things being equal, and why it is least in cool and cold weather. The loss of soil moisture, therefore, in northern latitudes, will be proportionately increased, other things being equal, with increase in the temperature which follows as the result of the lower latitude of the locality.

The influence of altitude is probably no less potent than that of latitude. With increase in the altitude comes decrease in the temperature, and with decrease in the temperature comes a lessened transpiration. Elevation alone may result in protecting a crop from the baneful influences of a temperature that will wither the same in lower altitudes, notwithstanding that these may be in the same latitude. Thus it is that betimes a crop will be withered in a low valley by hot winds which do not harm the same on a high altitude in proximity there-

to, the latitude being the same. Because of the influence thus exerted by latitude and altitude on evaporation, it has been claimed by high authority that 15 inches of annual precipitation in Dakota or Montana will be as helpful in sustaining vegetation as 20 inches in southwestern Nebraska and northwestern Kansas.

The influence of humus in the soil is very potent on the transpiration that will result, not only because it lessens transpiration, but because it increases the moisture supply available for transpiration. A soil well stored with humus will sustain plant growth without languishing in a time of drought for a much longer period than a soil not thus prepared to resist the influences of drought. But the best methods of storing the soil with humus in dry areas have but imperfectly been worked out. The crops that are best fitted to increase the humus supply and the best methods of growing them are as yet but imperfectly understood (see p. 420).

The importance of subsoil moisture.—The chief function of water in the subsoil in dry areas is to furnish a supply to the growing crops, when the supply from the surface soil is insufficient to meet the needs of the same. This is done by entering the root hairs that penetrate between the subsoil particles, and by furnishing additional water drawn from lower depths through capillary movement. Winter wheat and winter rye are frequently brought safely to maturity through water from this source. Crops of spring grain may grow vigorously for a time and then fail because of the shortage of water in the soil near the surface, whereas such failure would not have occurred had a sufficiency of moisture been present in the subsoil. But the fact should never be forgotten that the upward movement of subsoil moisture will carry it into the air when not taken up by growing plants, or when such escape is not prevented by the presence of a dust mulch on the surface.

Such water serves the further purpose of facilitating the passage of water downward to lower levels where it enters the soil. Water penetrates a moist soil more quickly than a dry one, hence the maintenance of a supply of water in the subsoil tends to deepen the area of such reserve supply. Experiment has shown that in well managed soils in dry areas the moisture in the soil in the spring is considerably more than it was in the autumn, but this result did not follow when the surface soil was hard. Subsoil moisture is an important regulator of crop growth, hence the great wisdom of trying to increase the supply of the same. Injury from water carried up from lower depths occurs only when substances hurtful to plant life, as alkali, are present in the subsoil water.

To get water down into the subsoil is one of the first considerations that should engage the attention of the farmer, and to increase the storage of the same should be an object of constant solicitude. The following are chief among the methods by which it may be accomplished: (1) by opening up the soil deeply when breaking it; (2) by keeping it fallow the first season; (3) by maintaining the surface soil in that condition which will admit of easy access of water when it falls; (4) by growing alfalfa in the rotation every few years; (5) by not cropping too freely with small grains; (6) by preventing water from running away over the surface.

Opening up the soil deeply at the first is one of the most effective methods of getting water down into the subsoil. Usually this is not easily done and it is costly. The more deeply the soil is stirred when breaking it or by subsoiling, the more deeply will water penetrate in the average season. But if the farmer crops the land the first season, the crop takes from it in its growth moisture that would otherwise have gone down into the subsoil. Those who can afford it, therefore, should allow

breaking to lie fallow the first season, whether the land is plowed in the autumn or in the spring. The surface soil is kept in condition for the easy access of water when it is subjected to the summer-fallowing process, or when a cultivated crop is grown upon it. The use of the disc on stubble land after harvest aids materially in the storage of water in the soil. When land is being fallowed or a cultivated crop is being grown upon it, the forming of a crust a few inches below the surface should be guarded against. If present it should be broken up by deep cultivation. When alfalfa comes frequently in the rotation the spaces occupied by the decayed roots form ready channels for the easy descent of water into the subsoil. If the farmer persists in growing small grains on the land year after year where the precipitation is light, the soil moisture will be drawn upon to such an extent that none will be left to enter the subsoil. The run off waters may be partially held until they enter the soil, but loss from this source may not be wholly prevented in all instances. Loss from this source only occurs when moisture accumulates within short periods of time, as when rain comes in downpours or snows melt suddenly. The plowing, discing and harrowing of sloping land along the slope will lessen the loss. Keeping surfaces from baking will do the same. Stubbles also are helpful. It is not possible under any conditions to save all the water that enters the soil, but much of it may be saved. When the subsoil is moistened to low depths, the roots will feed deeply save where there is an excess of water in the lower soil.

In humid areas the question is not usually how to retain subsoil moisture, but how to get rid of the excess. In dry areas the former will always be a burning question. The subsoil moisture, like the soil moisture, is drawn upon from two sources. One is the needs of the crops that are grown. The other is the influences con-

cerned in evaporation. Draughts from the first source can only be partially prevented while grain crops occupy the soil. But it may be regulated by regulating the number of the crops to be grown and also the kind of the crops. Those from the second source (see p. 165) may be greatly lessened but not entirely prevented by the maintenance of the soil mulch even as persistently as this may be practicable. Under no circumstances can it be maintained so continuously as to entirely prevent loss from evaporation. Even on the carefully managed summer-fallow there will be loss. When rain falls, water is taken from and near the surface before the mulch can be renewed by using the harrow. Small showers and frequent, aid in such escape. Vapor comes up from below in hot weather and cracks are formed through which moisture escapes. There are periods when a dust mulch cannot be maintained, as when grain crops are in the advanced stages of growth. When the land is plowed in the autumn some moisture is lost from a damp surface, and the same is true in the early spring. From all these causes moisture will escape, hence in many soils it has been thought that not more than half the precipitation that falls is retained. But it is very evident that the loss of moisture will decrease as the dust mulch is maintained. The more, therefore, that the processes of cultivation are followed that will admit of maintenance of the dust mulch, the less will be the loss of moisture from the soil and subsoil.

The utilization of subsoil moisture.—The stored water in the soil and subsoil is much more valuable than an equal amount of rain water falling during the period of crop growth. It contains nitrates formed the previous season. These are not washed out as in humid regions. It also increases the supply of potash and phosphoric acid in the soil. It is in a considerable degree secure from evaporation, and it enables the roots to penetrate

more deeply than would otherwise be possible. But beneficial as subsoil moisture is to growing crops, there are limitations as to the extent to which it should be drawn upon. The idea has prevailed that the large yields in the Canadian west are the outcome of moisture liberated gradually in the subsoil by the melting of the frost of winter as summer advances. It would be claiming too much to say that no advantage results to the crop from this source, but it is correct to say that the chief advantage to the crop comes from moisture that has been stored in the soil and subsoil the previous summer, and as the outcome of the nitrates which the subsoil moisture contained.

Under some conditions, from 50 to 90 per cent. of the precipitation that falls may be stored in the soil and subsoil. The larger percentage, of course, goes to the surface soil. Much of the water stored in the surface is drawn upon by the crop in the early stages of growth. The question naturally arises, how much of the moisture stored in the subsoil should be drawn upon in the growing of crops and how much should be left because of the influence which it exerts on the accumulation of subsoil moisture. The larger the quantity of water in the soil in the autumn, the more quickly will the winter and spring precipitation go down, and the greater will be the store of the accumulation. It is very evident, therefore, that it would be unwise to follow a system of tillage that would at any time exhaust the soil of its supply of subsoil moisture. Experiment has shown that when moisture is maintained in the subsoil, the tendency is to increase in such moisture. More especially is this true in areas where much of the precipitation falls in the winter. Subsoil moisture is sometimes drawn upon to no good purpose.

Moisture from the subsoil is drawn upon to no good purpose when the supply is insufficient to properly ma-

ture a crop. This result is almost certain to follow when grain crops are grown every year in the semi-arid country. The amount of moisture in the soil and also in the subsoil are not enough to properly mature a grain crop in a dry year, and the outcome is that the crop fails. The moisture that has been used in growing it is therefore lost. Under such conditions subsoil moisture is drawn upon to no good purpose.

A reserve of moisture in the subsoil is so important that its presence or absence may make the difference between success and failure in the growing of crops. In areas with an average rainfall of less than 15 inches, experiment has shown that enough of reserve moisture cannot be maintained in the soil to produce good crops when small grains are grown upon the soil every year. In a dry year they may promise well for a time, but before they reach full maturity they fail. Experiments conducted by the Montana experiment station extending over a period of five years have shown that more grain can be obtained in a series of years by alternate cropping and alternate summer-fallowing of the land than by growing on it annual crops of small grains. Such a process of tillage maintains a reserve of moisture in the soil and this reserve carries a crop through safely in a time of drought that but for its presence might absolutely fail.

In order to maintain this reserve of soil moisture, therefore, the bare-fallow must be occasionally introduced where such introduction is practicable. It may not be practicable in all instances, as where, for instance, soils are so light as to drift with the wind. In lieu of the summer-fallow a cultivated crop may answer the purpose, but not quite so well, as the cultivated crop makes drafts upon the soil moisture in the process of its growth. The timeliness of the cultivation and the depth of the same to effect these ends is greatly significant.

Experiments conducted in Utah have tended to emphasize the great importance of stirring the soil at the earliest moment practicable in order to conserve soil moisture after rainfall. Nearly one-half the entire loss from the unstirred surface soil of fallow land was lost during the first three days subsequent to the rainfall. The depth to which the soil should be cultivated in order to conserve the moisture is still an unsettled question. Of course it is influenced by soils. For the retention of soil moisture only, it will probably be found that deep cultivation is to be preferred to shallow, but when a cultivated crop is being grown, cultivation should not be practised deep enough to seriously interfere with the growth of the plants. The objections to the summer fallow are: (1) the loss of a crop for a single season; (2) the depletion of organic matter in the soil, and (3) the blowing of the soil in certain areas. The first objection may be obviated by growing a cultivated crop, which, in addition to furnishing the crop, will serve almost the same purposes as the summer-fallow. In both instances, however, the depletion of the organic matter is about the same, but in the case of the cultivated crop some benefit has resulted to the crop grown. It has been stated that the blowing of soil may be prevented entirely by stirring it at the opportune time after rain, so that it may form granules rather than soil particles. This is only partially true.

CHAPTER VI

PLANT GROWTH IN DRY AREAS

In some respects plant growth in dry areas is, of course, the same as in humid areas. The laws that govern the processes of growth are the same the world over, but the results may be widely different from the operation of those laws, because of modifications in their application. These modifications are the outcome of changed conditions. The leading characteristics of plant growth peculiar to dry areas will be discussed in this chapter.

Some features peculiar to such growth.—These include the following: (1) It is more sparse than in humid areas. (2) It is more or less dwarfish. (3) It tends to abundant fruitage. (4) It is made chiefly in the early season. (5) It is less certain than in humid areas.

The evidences of sparseness of growth in dry areas are more or less present in all portions. The grass plants are less numerous relatively on a given area. Even the sage brush shrubs grow at some distance from one another. A dense covering of grass such as results from the growth of blue grass in moist situations is seldom or never met with, nor is the land covered by a thick growth of bushes save in proximity to streams, or that are in some way supplied with ground water. So invariably is such sparse growth present that the degree of the same furnishes a fairly reliable index of the amount of the precipitation. The soil also, of course, has some influence on the density or sparseness of the growth. Such growth is a wise provision of nature to proportion growth to the number of plants so that each may have enough moisture to enable it to reproduce itself. It is on the same principle that production which is the outcome of cultivation is more satisfactory when the plants

grow more or less thinly than when they are too numerous. Should the plants be too few to result in maximum production, nature in part at least makes up for the lack by the abundant stooling of the plants. This stooling, so marked in dry areas under proper conditions of growth, is caused in part at least by the strength of the root system developed in such areas.

Grain and forage plants in dry areas are dwarfish in their habits of growth. This peculiarity is characteristic of all dry areas, and, other things being equal, it is present increasingly as the moisture decreases. Grains in the dry areas are usually much shorter than the same in humid areas. The same is true of corn and other forage plants. Even fruit trees do not attain to a near approach in size to the same varieties in humid areas. The scarcity of moisture is doubtless in part and probably chiefly responsible for this result, as enough moisture is not present to promote rapid growth during the season for the same. The lack of rainfall that is usually present after midsummer makes the growing seasons very short and tends much to hasten maturity.

The fruitage in plants is very abundant. This characteristic pervades all plant life. It is seen not only in the relatively large yields obtained from dwarfish fields of grain, but it is also seen in the enormous fruitage that characterizes growth in all kinds of fruit-bearing trees, the large as well as the small. It is the outcome in part of the abundant food materials in the soil for the production of seed and fruit rather than of wood, stem and leaf growth, and in part of the absence of exuberance in the growth of these. Marked exuberance in the growth of wood in the tree, or of stem and leaves in the plants, draws the energies of the plant, so to speak, away from the production of fruit or seed. It would also seem to be a law of nature that the harder the struggle

for existence the more are the energies of the plants centered in producing the elements that relate to reproduction.

The growth of plants in dry areas is nearly all made early in the season. This is more especially true of areas in which the precipitation, or much of it, falls during the period of early growth. The grasses of the prairie as a rule cease to make appreciable growth after July, whereas the grasses in humid areas usually make much growth in the autumn, and in many instances continue to grow on until the closing in of winter. The partial and oftentimes complete cessation of growth after mid-summer is the outcome of the lack of moisture in the soil, and this is further accentuated by the lack of moisture in the air. This it is that makes it so important that land on which winter crops are to be sown shall have the moisture conserved by proper cultivation during the summer previously. In some limited areas, as in the upper Flathead valley for instance, enough moisture falls in the autumn to result in a more or less free autumn growth.

That production in dry areas will be less certain than in humid areas, at least in some of its phases, cannot be gainsaid. This results from variation in the annual precipitation and in the time of the same. It does not follow that the actual variations in the precipitation will be greater in dry than in humid areas, but they will be felt more. In dry areas the precipitation is seldom or never beyond the best needs of the crops in a normal season, while in humid areas an excess of moisture is not infrequent. The crop in dry areas will take harm usually in proportion as the shortage from the normal increases, whereas an equal decrease in the rainfall in humid areas may do but little harm. From what has been said the necessity for the proper conservation of

moisture in dry areas will always be present in order to guard against the contingency of crop failure.

The functions of water in the soil.—Chief among the functions of water in the soil are the following: (1) to improve its physical condition; (2) to act upon it chemically, and (3) to carry food to plants. Each of these functions is greatly important.

In the absence of water, soils cannot be tilled as a rule without greatly increased labor. This explains why breaking the soil in dry areas is usually more or less laborious. Such unbroken soil is too lacking in moisture during much of the year to plow easily. It is so firm that heavy rains usually run away over the surface to a very considerable extent. This explains why the wide-awake farmer is so careful to push plowing rapidly at those seasons when the ground has in it the largest amount of moisture. The service rendered by water in facilitating pulverization as the outcome of tillage is no less important. Deep plowing on stiff soils in the absence of moisture is virtually prohibitory and pulverization is even more difficult.

All the ways in which water acts upon the soil chemically cannot be discussed here, but it may be said that it is a principal agent in promoting the decay of vegetable matter in the soil, the acids from which aid in the liberation of plant food. In the absence of moisture buried vegetable substances in the soil will not decay, and until the decaying process begins it cannot act upon the soil chemically. Water also dissolves plant food in the soil, changing it from the insoluble into the soluble form, so that the plants may take it up readily. Until such transformation takes place sufficiently, plants may starve in the soil in the presence of an abundant supply of unreduced food. In humid areas water is frequently present in excess. When it is, two evils may follow. One is the dissolving of plant food too rapidly

in the soil and carrying it down out of the reach of plant roots and into the drainage water before it can be taken up by the plants. The other is, excluding the air when the soil becomes saturated. In such a condition the transformations referred to practically cease. Saturation also stays the process of tillage. In dry areas such excess of water is seldom, and in a great majority of instances never, present. Thus far, therefore, soils in dry areas have a great advantage over soils in humid areas.

In the early part of the season, it aids in warming the soil, which in turn favors germination and early growth. These results follow the greater degree of warmth in the water that falls at that season than is possessed by the soil. When the soil becomes unduly warm, as in summer, water falling on it from the clouds cools it, and such cooling at that season promotes growth. It is only when moisture, heat and air are present in the soil that the bacteria in the same can fulfill the ends for which they exist. Should any one of these be absent beyond a certain degree, their activity ceases.

Water is also the medium through which food is carried to plants. This food is dissolved through the action of water, and is held in solution by the same. While in this condition it is taken up by the minute hairs which are attached to the rootlets of plants, and is thence conveyed through the plants for their support and upbuilding. The importance, therefore, of a sufficient supply of water in the soil to accomplish this end will be apparent, from whatever source it may be obtained.

Reducing the loss of water.—Since water in the soil is so precious in dry areas, the importance of practical measures that may be adopted for its maintenance cannot be easily over-estimated. In various ways its loss may be reduced. Prominent among these are the following: (1) by storing it deeply in the soil; (2) by surface cul-

tivation; (3) by keeping down weed growth, and (4) by shading the soil, as in the process of mulching. In humid areas these preventive measures call for but little consideration.

Where the precipitation is not more than 15 inches in a year, the unbroken soil is usually so firm and dense that rains seldom penetrate it to the depth of more than a few feet, usually not more than 2 to 4, and much of the water that falls does not enter the soil at all, but runs away over its surface. When the dense soil is broken up and especially by deep plowing supplemented by subsoiling, the water that falls, or much of it, goes down. If the land is summer-fallowed the first season, it goes down usually to the depth of 2 to 3 feet. The more frequently that the land is summer-fallowed and also cultivated, as through the growing of a cultivated crop, the more deeply will the water that falls from the skies go down into the subsoil. It penetrates but slowly into the dry ground below, but within a very limited term of years it will work down in the subsoil to the depth of, say, 6 to 10 feet. As moisture works down into the subsoil, the more quickly will that which falls work downward, hence the more will be the proportion of that which falls that will work down into the subsoil, on the supposition that the surface soil is properly tilled.

The advantages of storing moisture in the subsoil, as far as this may be practicable, include: (1) the fact that moisture is much less readily lost from the subsoil than from the ordinary tillable areas of the same, and (2) that because of this the subsoil may furnish a reserve of moisture at a critical time when it may be impossible to obtain a supply from any other source. Experiments in Utah have shown that in 7 days the first foot of soil that contained 23.22 per cent. lost 13.30 pounds of the same, while another soil, that contained but 16.64 per cent., lost only 8.48 pounds. The total water in these two soils to

the depth of 8 feet was at the outset 17.57 and 16.55 per cent., which shows very conclusively that the larger the proportion of the water in the surface soil, the greater relatively will be the loss, and vice versa, the treatment of the soils being the same in both instances. When the surface soil is kept in proper condition, the loss of moisture from the subsoil is very little, save through transpiration in growing plants.

The most potent agency in preventing the escape of moisture from the soil which it has entered is surface cultivation. The influence of cultivation, mainly through the maintenance of the dust mulch is discussed elsewhere (see p. 165). The same is also true of the maintenance of humus in the soil, which also is discussed more fully in another chapter (see p. 413). Of course no system of cultivation can be adopted that will entirely prevent the loss of moisture or even the loss of more than half of it on the average, during the year, but beyond all question a system of cultivation may be followed that will safely hold a large share of the moisture that would be lost to the soil in the absence of such cultivation.

Reference is made elsewhere to the loss of moisture to the soil through the growth of weeds (see p. 386). This loss cannot be entirely prevented but it may certainly be very greatly reduced. Ordinarily, it is possible to prevent such loss in the summer-fallow and also in crops that are cultivated. But it is not possible to prevent it entirely in cultivated crops, although by a judicious system of tillage it may be kept so low that it may not be a serious loss. In humid areas, loss of moisture from this source is much less serious than in dry areas, but in either case the aim should be to prevent it.

In semi-arid as in humid areas the shading of the soil, as already intimated, may under some conditions tend materially to reduce the amount of evaporation. The shade may be natural or artificial. Natural shade is

that which is furnished by crops while they are growing or by vegetable matter in its decay on the soil which produced it. Sorghum in its growth, and especially in the later stages of the same, furnishes a good illustration of the former, and leaves from trees of the latter. The shade thus furnished by sorghum in a considerable degree compensates for the loss of moisture by transpiration through the corn leaves. Such protection should be considered when determining the crops that should be grown. Straw from grain that is headed may furnish considerable shade, and even the stubble from grain that has been harvested may have an appreciable influence in reducing the loss of moisture that falls upon them. Artificial shade is that which comes from mulching, as by top dressing crops with straw in the early stages of growth; by top dressing, especially pastures, with manure, or by using various waste vegetable matters in covering the soil above the roots of trees. Such measures, each in its place, may render substantial service in reducing the loss of moisture through evaporation.

The seasonal use of moisture.—What may be termed the seasonal use of moisture considers adaptation in plants: (1) to winter rainfall; (2) to spring or early summer rainfall, and (3) to rainfall conditions that are variable. Close attention to such adaptation has an important bearing upon production in dry areas.

When the precipitation occurs mainly in the winter, it is important that such crops shall be grown as will profit most by such winter rainfall. These crops include wheat, winter rye, winter oats, winter vetch, winter barley, and to a less extent winter speltz. The crops which are carried through the late autumn, winter and spring months, are thus enabled to utilize the moisture that falls in the seasons named, as spring sown crops could not utilize the same. Fortunately, these winter crops are chiefly grown in climates, the severity of which does not preclude

all growth in the winter season. If such crops were not grown in these areas, much of the winter precipitation would be lost to crops sown in the spring, hence the wisdom, as it were, of giving crops sown in the autumn what may be termed the right of way under these conditions.

When the precipitation is confined mainly to the spring months then spring crops should as a rule be chiefly sown. There will be difficulty in germinating autumn crops under the conditions named, and when these do not germinate in the autumn, the results are usually more or less uncertain. While, therefore, it would not be wise under such conditions to try to force the growth of autumn crops, certain spring crops may succeed unusually well.

In yet other conditions, the rainfall is variable and more or less fitful. This means that while the bulk of the precipitation falls mainly in the season for ordinary growth, in some instances it does not fall freely at such a time, but may fall later. Under these conditions certain crops would fail outright during the dry period, while others would simply cease to grow for a time, and would again resume and complete growth when the rains come again. Where these conditions are frequent, the growth of such crops should be encouraged. Among these are certain sorghums, and buffalo and some other grasses. They feed not far distant from the surface, and are, therefore, easily accessible to the moisture when it comes.

At certain times, moisture in the soil, the outcome of precipitation, is more dependable than at other times, though in few instances in dry areas is it absolutely dependable. The aim should be to grow plants that will make the bulk of their growth during the most dependable season for moisture. Thus, when the rain usually ceases to fall for a time after July, as in Montana, early ripening oats are a safer crop than oats that are late

ripening, and in some parts of Colorado where considerable rain falls late rather than early, late potatoes are a surer crop than those that mature early.

Root development.—Prominent among the functions of roots are: (1) supplying plants with water; (2) furnishing them with the elements of growth, and (3) mooring them to the soil. Water is supplied to the plants almost entirely through the roots.

These penetrate the soil variously, and at the tips of the rootlets are numerous minute hairs which are in a sense immersed in the water films that surround the soil germs, and they are active in absorbing it for the needs of the plant. The elements of growth that are held in solution by the soil water enter the plant with the water. Those elements indispensable to growth are nitrogen, phosphoric acid, potash, lime, magnesia and iron. Various other elements are helpful to growth, but not so indispensable as those that have been named. The way in which plants are moored to the soil by the roots needs no illustration.

It has been frequently noticed that there is a close relation between the character of the root development and that of the top growth, hence in the dry areas it is specially important that good root growth is secured, that the plants may better endure severe conditions should they come. The root growth sought should be active, deep and strong.

The more active that the growth of the roots is, the more quickly will they be distributed through the soil. The water which they will take up will be proportionate to the extent to which they ramify the soil. As water is taken up by the rootlets, it is drawn upon from all directions to take the place of what has been removed. Growth in the plants will be proportionate as the supply of soil water is timely and generous, and this will be proportionate to the activity of the root growth, which in turn is de-

dependent on the favorable conditions for growth viewed from the standpoint: (1) of the sufficiency of the water supply; (2) of the abundance of the plant food, and (3) of the favorable character of the mechanical soil conditions that favor root penetration. Such activity in root growth is specially important in the early stages of growth.

Relatively deep rooting is specially important in plants in dry areas. Such rooting enables them to secure increased moisture and also increased plant food. The moisture supply near the surface is usually greater in humid than in dry areas, hence the greater tendency in root growth in the latter to go down much more deeply than in the former. Corn roots in these have been known to ramify the soil in all directions to the depth of 7 or 8 feet, and the roots of small cereals have been traced in the subsoil to the depth of 10 feet. These are of course extreme instances. They also find more easily digestible plant food than is usually found in the subsoils of humid areas. The generally favorable physical character of the subsoils of western areas for root penetration after they have been moistened by water favors deep growth in the roots, and this brings to the plants greater immunity from the hazard that would otherwise come to them in time of drought. Where plants are irrigated they establish a root system near the surface, as there they may find ample water to supply their needs.

Strong root growth is also important, owing to the closeness of the relation that obtains between development in the roots and growth above ground. Especially is this relation important with reference to the production of seed. It has been claimed, and it would seem properly so, that there is some relation between strong root development and the abundant stoebling that comes to the small cereals in dry areas. No measures, therefore, should be overlooked, when preparing the soil for seed,

that are calculated to facilitate quick and strong root growth in the plants.

The superior quality of dry farm crops.—It may be truthfully said of dry farm crops that: (1) they are richer in dry matter than other crops; (2) are possessed of relatively more nutrition; (3) have a high proportion of grain to the straw, and (4) they are usually higher in palatability. It would be a mistake, therefore, to measure the feeding value of dry farm crops as compared with crops grown in humid areas on the basis of weight or production.

Other things being equal, the food value of plants increases in the relative proportion of the dry matter which they contain. Widtsoe states that hay grown in humid regions has 12 to 20 per cent. of water, and in arid regions from 5 to 12 per cent. The average water content in wheat as given by Wiley is 10.62 per cent. In some parts of the dry area it is not more than 8 to 9 per cent. The less plentiful the water supply during growth, the higher will be the percentage of the dry matter in the plants produced.

The food nutrients in plants grown in dry areas are considerably more relatively than in the same plants grown in humid areas. More particularly is this true of the nitrogen content. Experiments conducted in Holland found that in a soil that contained 30 per cent. of water throughout the growing season, the protein percentage in oats grown in the same was but 5.6 per cent., while the protein percentage in oats grown in a soil that contained but 10 per cent. of water during the same period was 10.6 per cent. Hard spring wheat grown in Utah has about 4 per cent. more protein than the same variety grown in the middle west. The reasons for such increase in the protein content in dry areas rest mainly on general climatic conditions, including a more or less limited water supply. Protein is most abundant in plants

when young, and in plants that mature relatively quickly, which they usually do in dry areas.

The higher proportion of the grain to the straw in dry farm crops than in crops grown in humid areas is probably owing to the abundance of the food materials stored in the root system. This also would seem to account for the larger relative proportion of leaf growth found in the former. In normally healthy and sufficiently large straw, the yields of grain will usually decrease with increase in straw development above the requirements named.

Crops grown in dry areas are usually more palatable than those grown in humid areas. This applies more especially to fodders. It arises in part from the smaller stem growth in plants and the larger relative leaf production, and in part from the brighter curing of the same in the almost total absence of dew and rain in the harvest season. It is legitimate, therefore, to claim that the average feeding value of crops grown in dry areas is considerably above that of the same grown in humid areas.

Weeds grown in dry areas.—Weed growth should be far less prevalent in dry than in humid areas, since the absence of abundant rainfall is so far unfavorable to the growth of weeds. This fact in itself places the farmer on a vantage ground that should enable him to maintain cleanliness in his farm and crops far more easily than the same can be done by the farmer in humid areas. But what are the facts? With but few exceptions the farms become polluted with weed life in its various forms before they have been tilled many years. This fact proclaims to the world the lack of effort on the part of pioneer farmers to maintain cleanliness in their lands.

In newly settled countries weeds are usually introduced in the seeds brought in for sowing, howsoever they may be propagated subsequently. They may come in

the seeds of almost any kind of cereal that may be introduced, but to a greater extent they come in flax seed than in the seed of any other kind of grain. This is owing to the greater difficulty in removing foul seeds from flax than from other cereals. That it is so is so far unfortunate, for in semi-arid areas flax is more commonly sown as the first crop than any other cereal. In this way the land becomes polluted with weed seeds in many instances at the very outset. That it is so is peculiarly unfortunate. The homesteader begins his work on new and clean soil. With the exercise of proper vigilance it could be kept clean at least from many forms of pernicious weed life for many years to come.

The weed seeds that are most liable to come in the seeds of grain are wild mustard, wild oats and penny cress, but of course almost any kind of weed may be introduced in this way. Wild mustard and the wild oat are the most baneful among weeds that come to the dry farm. Foul seeds are also frequently introduced with alfalfa seed. Of these dodder is the most dangerous.

After weeds have been introduced, they are distributed by various methods. These include the following: (1) through the purchase and changing of seed; (2) through the medium of threshing machines; (3) in the droppings of cattle, and (4) by the agency of birds. But the most potent agency by far in the distribution of weeds after they have been introduced, especially in the Plains region, is wind. The extent to which this agency may scatter the seeds of some kinds of weeds is in a sense without limit. The seeds of the Russian thistle, tumbling mustard and other weeds of the tumbling order, may be thus carried to distances that are in a sense incredible, nor is there any way of guarding against such introduction. Certain styles of wire fencing are in some sense a safeguard but not in all instances, as the weeds may pile up to such an extent that they form an inclined

plane over which those that come later roll, and speed on their way to farther distribution. Fortunately nearly all this class of weeds is short lived or at least comparatively so, and they are more easily destroyed than some other forms of weed life. Wild oats and mustard and other seeds are frequently carried by the winds from one farm to another that happens to lie adjacent to it on the leeward side. Fortunately water is not an important agent in carrying weed seeds in dry areas as it frequently is in humid areas and also wherever irrigation is practised.

Certain forms of weed life are more difficult of eradication in dry than in humid areas. This is especially true of weeds the seeds of which have much oil, as for instance wild mustard and penny cress. The small amount of moisture relatively that is in the soil tends to prolong vitality in the seeds. Because of this, weeds will grow after longer periods of burial in such soils than if buried in soils more humid. Of course as long as seeds retain vitality they remain ready to grow when subjected to favorable conditions for growth.

It should be easier nevertheless to maintain cleanliness in farms in dry than in humid areas, owing to the character of the rotation. The farmer in dry areas is compelled to give much attention to summer-fallowing the land, or to growing cultivated crops, or to both, in order to secure the requisite amount of moisture. If this work is faithfully and intelligently performed, and proper attention is given to the cleaning of the seed used, it should be quite practicable to keep farms practically free from noxious weeds. Nowhere else where farming is conducted, should the farms be so free from weeds as in dry areas.

Grain plants volunteering.—The tendency in cereals to volunteer is ever present in dry areas. Volunteer grain means grain that grows from seed that has shat-

tered previous to or during the process of harvesting. If grain, in some varieties at least, is not cut promptly when ripe, a certain proportion of the kernels may shatter through the swaying of the winds. The plump filling of the grain in dry areas favors shattering. The volunteering of grain in dry areas may give the farmers more trouble and labor than the noxious weeds.

The season for such volunteering is of course the season of the harvesting of the crop. In addition to the shattering of the seed, heads are scattered during the harvesting process. The weather subsequently is so dry that these, in many instances, do not germinate in the autumn. They are buried in the soil by the disc or plow, and the next season they germinate and grow up amid the crop that follows, providing such a crop is sown the following year. If the crop is of a different species, there is admixing in the same, as for instance wheat and oats. If of the same species but differing in variety, the varieties become badly mixed. If of the same variety, the volunteer plants growing up amid the plants from the seed sown so increases the number of the plants as to frequently reduce the yields. To such an extent does grain thus volunteer in some instances that a fair return in grain is sometimes reaped without sowing any seed, and even without stirring the ground with any implement. Such crops are more frequent in the case of winter wheat and winter rye than in that of a spring cereal.

The evils that arise from this source will be readily apparent. It greatly increases the tendency in grains to mix, and therefore increases correspondingly the difficulty of maintaining purity in grain. The loss resulting may not be serious in grains that are to be fed to live stock, at least in some instances. But it may not be so with grains that are to be marketed. Suppose, for instance, that winter rye or some soft variety of wheat

grows numerously in a crop of hard winter wheat, the price paid will be lowered in proportion to the extent to which such admixture is present. The difficulty found in obtaining pure seed in dry areas is largely the outcome of such volunteering of grains.

The volunteering of grains may be greatly lessened: (1) by early and prompt cutting of the crop; (2) by careful handling of the same when cut, and (3) by the gleaning of sheep and swine amid the stubbles. The early and prompt cutting of the grain will prevent shattering in the same to a very considerable extent, but it will not in all instances entirely prevent it, providing the grain is allowed to become sufficiently mature before it is cut. Owing to the shortness of the grain crops in some instances, the loss of heads is greater in the harvesting process than it would be in the case of grains that were of greater length. This loss is considerably increased if the sheaves are handled in a careless manner. Sheep or swine may subsequently gather many heads, but they cannot gather them all, hence even under the most favorable conditions there will be some loss from the shattering and falling of heads in the harvesting process.

The remedies for the volunteering of grain or rather for the harmful influences that may result, are the following: (1) summer-fallowing the land with sufficient frequency; (2) growing a cultivated crop with sufficient frequency, and (3) modifying the rotation. The frequency of the summer-fallowing will depend in a considerable degree: (1) on the amount of the precipitation; (2) on the rotation, and (3) on whether the crops are grown for feeding or for being marketed. The greater the precipitation, the less the necessity for the summer-fallow in order to prevent volunteering, for the more that the rainfall is, especially in the autumn, the more will the grain sprout at that season, and when thus sprouted it may be destroyed by subsequent cul-

tivation. But the summer-fallow even will not be effective in destroying volunteer grain, because of its deep rooting, unless some implement is used with sufficient frequency that will cut off the plants below the surface of the ground. The reasons that relate to the frequency with which the land should be summer-fallowed to destroy such grain will apply equally to the growing of cultivated crops. But when growing the latter, some hand work may be necessary to complete the work. The less frequently that the same varieties are grown in succession, the less will be the tendency to admixing in the grains. The harm from volunteering may be much lessened by observing such practise in the absence of the summer-fallow and also of the cultivated crop, when alfalfa is one of the crops that is introduced into the rotation. When the summer-fallow or the cultivated crop or the two in conjunction, that is in alternation, are brought between each two grain crops, the harm from grains volunteering may be entirely prevented.

CHAPTER VII

PLOWING IN DRY AREAS

In the cultivation of soils in the semi-arid regions the plow in one or the other of its forms will always have a foremost place. But that place will always be less important relatively than in humid areas. In the latter the plow is almost invariably used when preparing the land for a crop. In the former the disc is very frequently used instead of the plow after the land has once been broken with the plow.

Prominent among the objects sought from plowing are: (1) breaking up the land to admit moisture and air; (2) making a seed bed in which to plant the crop; (3) cleaning the land. Other benefits follow, though not so important, perhaps, as the former. Prominent among these is bringing the land into that condition which makes it possible to prevent the escape of moisture by the nature of the cultivation given to it subsequently on and near the surface.

Much of the untilled area in the dry region is covered with a shrubby growth consisting mainly of what is termed sage brush. This is so named doubtless from the sage-like odor which escapes from the bushes and the sage-like taste of the stems and leaves. Millions and millions of acres of land in the western states are covered by those shrubs. They grow from the height of a few inches to several feet, as many as five or six in some instances. They usually grow at a little distance from one another and some native grasses may grow between the plants. The abundant presence of these plants is looked upon as an indication of a fertile soil, and a tall and vigorous growth in the same as an indication of rainfall more copious than the average.

It will be at once apparent that this growth and other forms that mingle with it, as "rabbit brush" and "grease-wood," will prove an obstacle in the way of the plow in proportion as it is abundant and strong. In some instances it is grubbed out with the mattock. This method is usually followed by the small farmer whose available horse labor may not be equal to the task of drawing a plow through the brush. Where the brush is not over strong and the power is sufficient, strong plows are used in breaking the land and uprooting the brush in the one operation. The shrubs thus loosened are thrown into heaps and burned.

Various devices have been tried with more or less success to clean the land from brush before it is plowed. One of these consists of two railroad rails fastened together with strong chains. The rails are drawn by hitching at both ends, so that the whole length of the rail is drawn against the brushes so as to break them off or pull them out. In some instances but one rail is used and preferably bent forward at the ends. If used straight it is necessary to attach a small platform behind it and weighted to keep the rail from tipping. It is necessary in some instances to drive the rails over the land several times, and it may be further necessary to do some hand grubbing to complete the work. Other devices have been used for pulling out the shrubs, especially when they are of large size. Success with these thus far has only been partial. Where larger trees, as the mesquite, juniper and cedar grow, grubbing is necessary.

On other areas, more especially in the Plains country, the soil is more or less covered with grass of different degrees of density. The power called for in breaking up this land increases with the density of the sod, other things being equal. But where the sod is dense the rainfall is more copious than where the opposite

conditions exist. Because of this it may take more power in some instances to break up a sod with less of density than would suffice for sod of greater density. On yet other areas the land may be so encumbered with stones lying on and near the surface that it is necessary to remove these before any attempt is made to plow the land. Such land may have a forbidding look to the land seeker, but it frequently happens that the obstructions referred to lie only on or near the surface and that when once removed the soil may make excellent farming land.

The ultimate object of plowing is to put the soil in proper condition for growing a crop. While the objects sought from plowing are virtually the same in kind in semi-arid and humid regions, they differ much in degree. In the former the breaking up of the soil that it will more readily admit moisture is much more important relatively than in the latter. In the former a carefully prepared seed bed is more important than in the latter, and in the latter the plow renders greater service in destroying weeds because of their relatively greater prevalence.

The unbroken soil of the prairie is dry, and because it is dry it is usually hard to break with the plow. It would probably be correct to say that the larger portion of the soil of the semi-arid country has not been wet down to a greater depth than 3 to 4 feet at any time before it was broken with the plow, and into much of it water has never penetrated thus deeply. This dry condition is the outcome of a light precipitation, but to an even greater extent it results from the relatively small proportion that enters the soil of that which does fall. When the soil is broken with the plow, the water that falls may enter it readily, and the more deeply that the land is thus loosened, at least to a certain limit, the more moisture does it absorb and the more deeply does it penetrate the soil. This explains why the sub-

soil in semi-arid areas that are properly cultivated is much more moist than it was before the land had been broken.

But breaking up the land admits the air as well as the moisture. This of course aids in preparing the soil for becoming a suitable home for the roots of plants. When air penetrates a moist soil, it aids in bringing about mechanical and chemical changes that prepare food for plants. These processes come practically to a standstill when the soil is virtually destitute of moisture, or when it has an excess of the same. In semi-arid regions excessive aeration is to be carefully guarded against. It is excessive when it aids in the removal of moisture that is needed from the top soil. To prevent this as far as it may be possible, the soil is usually compressed or firmed soon after it has been plowed.

On land that has never been plowed, it would not be easy to form a seed bed. It could of course be done with the disc, but to make it thus would involve much labor, and it would not be satisfactory when made. The plow alone does not form a seed bed, but it puts the land in a condition so that the work can be completed with the aid of other implements. A good seed bed in dry areas should be: (1) fine and mellow on the top two or three inches of soil and firm but not hard below; (2) as free as possible from weed seeds and the presence of perennial weed growth, and (3) moist enough to germinate the seeds of crops that are planted on the soil. To insure these ends the plowing must be done at a certain time and in a certain way, but after the land has been plowed the roller, the harrow and sometimes the disc must usually be more or less used.

After ground has been broken with the plow, the seed bed is frequently prepared by the aid of the disc and harrow only. This plan is generally followed after cultivated crops, and for the reason chiefly that moisture

may thus be conserved to a greater extent than if the land were plowed.

In humid areas there is usually a very considerable aftergrowth of weeds and other plants amid the stubbles of fields that have grown grain. This does not usually follow to anything like the same extent in dry areas, but even in the latter weed growth is frequently more or less troublesome. The plow, better than any other implement, buries weeds that are thus in process of growth, and prevents them from further seeding. For this reason among others it is frequently the aim to plow the land as soon as practicable after the previous grain crop has been removed.

The time for plowing.—Plowing may be done at any season in humid climates where the frost does not hinder the work. It is not so in arid or semi-arid areas. In some of these the ground cannot be plowed at certain seasons without great labor and the expenditure of much power, because of the overdryness of the soil. In such areas the chief of the seasons for plowing are: (1) the spring; (2) the summer, and (3) the autumn.

In the semi-arid country spring plowing is very commonly practised more or less on almost every farm. The advantages from spring plowing are: (1) The work is then more easily done than in the autumn as a rule because of the greater moisture content in the soil. (2) Where snow falls in wind-swept areas more moisture enters the soil on stubble land when the snow melts, as the stubbles have aided in holding the snow. (3) The homesteader may grow some crops the year that he locates, although no land had been plowed the previous year.

The disadvantages from spring plowing are: (1) The crop cannot be planted in time, or at least much of it cannot. (2) The soil has not had time to settle upon itself before it is sown, hence the lower section of the

seed bed is not firm enough to grow the crop planted on it in best form, should a dry season follow. (3) The seed bed is less warm for early sown crops, hence early growth in these will be less vigorous than on autumn plowed land. (4) No time has been given between the plowing and the sowing for the unlocking of inert plant food through weathering influences. In dry areas crops will suffer much more as a rule on spring than on autumn plowed land, should the rainfall be less than normal. Among the crops that will be the least harmed under these conditions when sown or planted on spring plowed land, are flax, corn and potatoes. Where rain falls chiefly in the late autumn and winter months, the aim should be to grow winter rather than spring crops. If the latter are grown, the only hope of success comes from planting them early.

When land is plowed in the summer it is for fallow rather than for growing a crop that season. The best time for such plowing is dependent to a considerable degree on the time of the greatest precipitation. When rain falls chiefly in the late autumn and winter, the time for plowing fallow land should begin as early as such plowing is practicable, even in the autumn and winter months, that it may open the soil for the easier penetration of moisture into it when it falls. The plowing of such fallow land should not take place later than early spring, as subsequently much of the moisture would have escaped from it and more would not fall to take the place of what had been lost. Where the bulk of the precipitation falls during the growing period, as in much of the Plains country, the best time to plow fallow land as a rule is in the months of May and June, as then it usually has the largest amount of moisture in it. The plowing is then more easily done than at any other time. Much of the moisture then in the soil may be retained by judicious management, and it may thus be made to aid the

crop that follows. When the plowing of fallow land is deferred until much of the moisture has left the soil, the effect upon the crop that follows will be proportionately adverse. In the Plains country, land for fallow, or, as it is frequently called, summer tillage, may be plowed in the spring, but there is seldom opportunity for such plowing, as then it is that the crops must be planted. When land can be broken in May and June, a strong argument is found in favor of such breaking in the fact that sod broken at a season when the grasses are succulent rots much more quickly than if broken when the vegetation is dry and dead.

The advantages from plowing in the autumn include the following: (1) When the work is done at that season the crops may be sown quite early in the spring, which gives them the benefit of all the moisture that falls subsequently. (2) The turning up of the soil exposes it to all the benefit that comes from weathering influences, as sun, air, rain and frost. The soil is thus mellowed on the surface, which makes easy the forming of a good seed bed. The liberated fertility is thus made easily accessible to the young plants. (3) The soil has time to settle on itself, thus giving the necessary firmness to the lower section of the seed bed. (4) Opportunity is thus furnished for the entrance into the soil of the precipitation that falls on it in the interval between plowing and sowing the crop. (5) When ground is thus plowed in the fall the opportunity is furnished to harrow or disc it as soon as this may be done in the spring without injury to the land, a process that will quite effectively prevent the loss of moisture.

The disadvantages of fall plowing include: (1) The difficulty that is frequently found in doing the work because of the lack of moisture in the soil. This applies more to breaking than to stubble land, but it applies to all land previously broken and plowed shallow. To plow

such land to the proper depth calls for the use of much power, which means that it is relatively expensive. (2) Land thus plowed does not hold the snow as stubble land does, hence the moisture that melted snow brings to stubble land when not too much frost-locked does not come to plowed land to the same extent. On the other hand, should the precipitation come in the form of rain with but little frost in the soil, it will penetrate the plowed soil much more readily than unplowed soil. (3) Should stubble land be cloddy when it is plowed in the autumn, and but little precipitation fall during the winter, the lower section of the seed bed would be in a very poor condition for promoting growth because of its lack of density.

From what has been said it will be apparent that the balance of argument favors summer and autumn plowing. The practise of the best farmers recognizes this fact, and it is coming to be more and more recognized as time goes on. The plowing of wet soils has not been discussed, and for the reason chiefly that in the arid and semi-arid areas the soil is seldom too wet to plow. This does not apply to all soils, as those affected by seepage water, or to soils known as "adobe" or "gumbo." The former should be drained before they are tilled. The latter must not be plowed when unduly wet, or it will be impossible to pulverize them subsequently. On the other land, if left until unduly dry it is virtually impossible to overtake the work.

The depth to plow.—Testimony is practically a unit that lands should be plowed deeply in dry areas. The arguments in favor of deep plowing include the following: (1) It increases the storage capacity of the soil to receive water that falls upon it and in proportion to the depth of the plowing. Should a soil be broken to the depth of only 3 inches and should a heavy rain fall on the same, the soil would only absorb the rain quickly to the depth

to which it had been plowed. The excess of the rain above what the 3 inches of soil will absorb must run away over the surface, and in doing so it will carry away the finer and more valuable portions of the soil in proportion as such excess of precipitation is present. Buffum has affirmed that soils which will hold 20 per cent. of moisture will not store more than 7-10 inches of rain when plowed 3 inches deep, nor more than 1.4 inches when plowed 6 inches deep, but when plowed 9 inches they will store more than 2 inches of rain. Water thus caught will sink down slowly into the lower soil and will thus tend to equalize its movements and distribution. (2) It improves the tilth and the producing powers of soils. These results follow from the pulverizing influences brought about by the deep stirring of the land and from the increase in aeration, warmth, and in the activity of bacterial agents in the soil. (3) It enlarges the feeding ground for the roots of plants, because of the greater ease with which their roots may find food in a soil thus broken and stirred. (4) Lifting with the winds may to some extent be reduced because of the more pronounced character of the depressions between the furrows. - But too much must not be made of this advantage, as it is frequently necessary to obliterate such furrows soon after plowing by the use of implements of tillage.

The depth to plow will vary with the soil. It should seldom be less than 6 inches or more than 10 inches. When plowing deeply, the timeliness for this and the cost of the same should not be lost sight of. It may cost less in one instance to plow soil 7 to 8 inches than to plow it 4 inches in another instance, because of a difference in the moisture content in the soil. Deep plowing is never more opportunely done than in connection with the plowing of fallow land, providing the latter is plowed at that season when it has the largest amount of mois-

ture in it. The work can then be done with a minimum expenditure of power, and there is time for weathering influences to become operative before the planting of the crop that follows. The aim should be also to plow the land more deeply when preparing it for certain crops than when preparing it for other crops. Deep plowing is specially beneficial to alfalfa, corn, root crops and trees. As a rule gradual deepening of the plowing is preferable to sudden deepening, as it gives greater opportunity for weathering influences to operate on the raw soil. It is also more important relatively that land shall be plowed deeply in the fall than in the spring, as the soil has more time to settle firmly below than if spring plowed.

While in dry areas the aim should be to plow deeply on average soil, there are some exceptions to the method which plows deeply. These apply only to certain soils and soil conditions. Land should not be plowed deeply (1) where the soil is shallow or poor below, or where the elements of fertility are largely in an unavailable form; especially should this be avoided where too much lime or gypsum lies near the surface. The gradual deepening of a soil possessed of a reasonable amount of fertility, though largely in the inert form, will greatly improve it in time. (2) Where the conditions present render the work over-costly and difficult. These conditions are such as relate to soils hard and dry, to the use of plows not suited to such work, and to the lack of strength in the teams that do the work. Were it not for the extra cost, it would be better to plow deeply even when soils are dry and hard, especially in the autumn, but there is a limit to the cost of plowing, beyond which it may be unwise to go. Furthermore, when dry land is plowed deeply, even in the autumn, there may be seasons in which the dry soil thus loosened may not wet down far enough to become sufficiently impacted for the

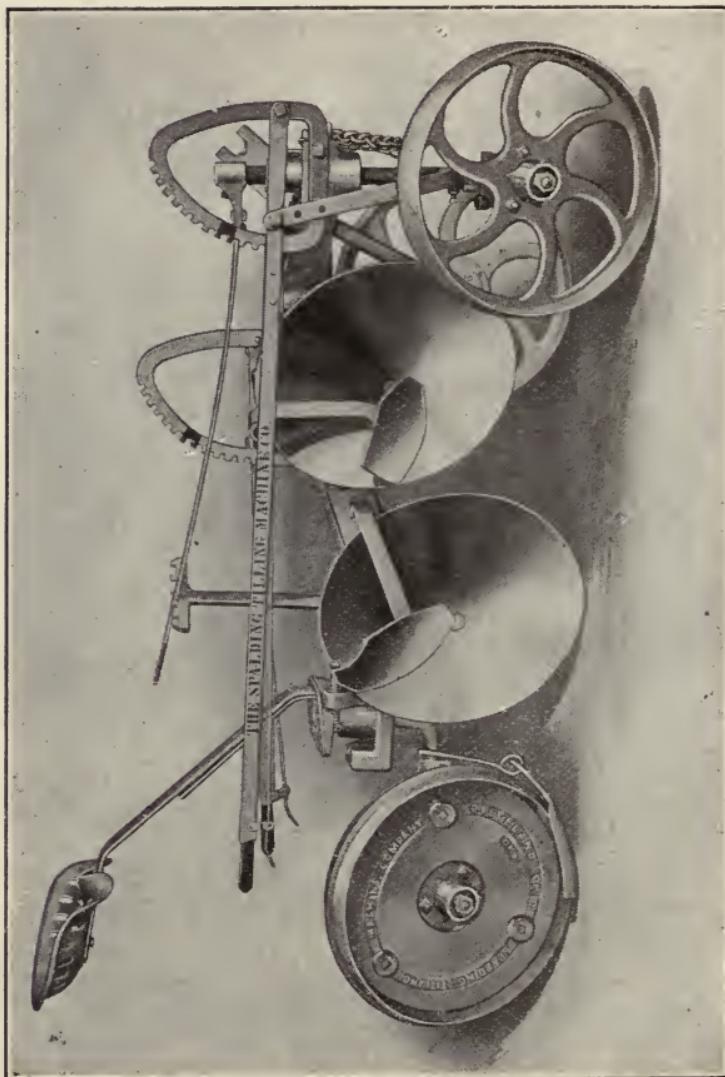
proper growing of the next crop. But deep plowing is to be preferred in the autumn when it can be done, as, should rain come, many western soils can take up 40 per cent. of moisture. One-third of that amount rightly used will grow a good crop. (3) Where plowing is done in the late spring and a crop is to be grown on it that season, as the crop will start readily in the top soil thus loosened and the roots find firm soil below.

The depth of the plowing in dry areas should not be uniform, that is it should be deeper for some purposes than others. If land is plowed uniformly at the same depth from season to season the soil at the bottom of the furrow becomes hardened by the smoothing and compressing action of the sole of the plow and the tramping of the horses. This condition is unfavorable to capillary action. When land is broken deeply, as it should generally be broken, it will be better in some instances to plow say two inches shallower the next time, so that the buried sod may have longer time to decay before it is again exposed to drying atmospheric influences. The plan of plowing sod land shallow and then backsetting it later in the season by plowing it more deeply, has found favor in many of the provinces of Canada and in some portions of the northwestern states.

The kind of plow to use.—Plows as adapted to work in dry areas may be divided into three classes. These are: (1) the mold-board plow; (2) the disc plow, and (3) the deep tilling machine. Of the first two there are several modifications.

The mold-board plow cuts the furrow slice and turns it over. Owing to the shape of the mold-board, it packs the furrow slice more or less, thus causing it to lie more or less smoothly against the furrow previously turned. A plow with a long mold-board is best for some kinds of breaking. One with a short mold-board and possessed of abrupt curvative aids to some extent in

breaking up and pulverizing the land which it turns. For hard clays and some other soils the steel mold-board is probably better than the chilled. It should have in-



THE SPALDING DEEP TILLING MACHINE.
Courtesy Gale Manufacturing Co., Albion, Michigan.

terchangeable lays or shares, which must be sharpened occasionally if the work is to be efficiently done. On very hard soils cast shares may be cheaper. These, of

course, cannot be sharpened. Because of the extensive areas that are cultivated in dry regions, the sulky, that is, the riding plow, is most commonly used. The mold-board plow will do better work than the disc where the conditions are favorable for using it, but the disc plow has also an important place.

The disc plow consists of one or more large discs set at an angle that will turn over the furrow slice, but less perfectly than the mold-board plow. It has been found preferable to the mold-board plow under the following conditions: (1) In heavy clay soils that are hard to plow and that are more or less liable to become sticky. (2) In plowing land baked so hard with the sun that it is difficult to keep the mold-board plow in the soil. (3) In the first plowing of sage brush land when the brush is strong. (4) In plowing stony land which could not be plowed with the mold-board plow without much difficulty. The disc plow is frequently used when plowing stubble land and old land generally. It is lighter of draught than the mold-board plow. It does not bury grass or weeds so completely as the latter. The deep tilling machine is a plow with two discs. The one in front cuts down to a certain depth and turns the soil. The one in the rear cuts down more deeply and turns the soil from a lower stratum, inverting it, in part at least, above the furrow slice first inverted. Among the advantages of this plow are the following: (1) It is light of draught relatively in proportion to the depth to which it will plow. (2) It may be used in plowing ground when it is so dry that it could not be plowed with the moldboard plow. (3) It makes it possible to plow the soil to any reasonable depth. (4) It aids materially in pulverizing the soil which it plows. This plow will probably render most excellent service in much of the dry area, but its introduction is too recent

to justify the statement as to the relative importance of the place that it will occupy among the plows used.

There is a place also for the lister plow in dry areas. It is a plow which throws the soil out both ways. It is used chiefly in connection with planting corn. It opens furrows only where the corn is to be planted. The seed is drilled in the bottom of the furrow, either by a drill attachment to the lister, or by a separate drill. Corn planted thus deeply will stand drought better than when planted in the ordinary way, but planting it thus, is in some instances attended with some hazard (see p. 279).

Power to use in plowing.—The three kinds of power used in plowing at the present time are: (1) farm animals, especially horses and mules; (2) steam power, and (3) gasoline power. Electricity generated by mountain streams may yet become a source of power in conducting some of the operations of the farm.

After the land has been broken, and even when breaking it, horses and mules will be used to a far greater extent in the future, as in the past, by the average farmer, than any other source of power. The more diversified the character of the farming, the greater will be the necessity for using such power, for reasons that will be manifest. The new settler may find it very expensive to use this class of power until he can grow the food called for to maintain the animals that do the work. Ox labor will usually be found cheaper than the labor of horses or mules when breaking land, a fact that has apparently been almost entirely overlooked during recent years.

Steam traction engines are frequently used in breaking land, especially when areas large and long are to be broken. Where all the conditions are favorable, as when coal and water do not have to be drawn too far, the steam engine may prove satisfactory when breaking land, but subsequently the great weight of the engine makes it

costly to propel it over the loose soil. In some instances the compaction resulting from the great weight of the wheels may do harm. In some countries of Europe the engines are stationary and are placed at each end of the field. Plows, harrows and seeders are drawn over the land by the aid of cables. The comparative merits of these and of traction engines has not yet been proved in America.



BREAKING WITH STEAM POWER, STARK COUNTY, NORTH DAKOTA.

Courtesy Northern Pacific Railway Co.

Engines propelled by gasoline and kerosene power will probably be used to a greater extent on the dry farm than those propelled by steam, especially after the land has been broken. But these also in some instances compress the land overmuch, through the weight of their ponderous wheels. Yet again in other instances, such compression may be beneficial, as when moisture

is unduly lacking. Where such power is used the reasonably small engine is to be preferred on the average farm. It is not so unwieldy as the more ponderous engine, and can therefore be used under a greater variety of conditions.

When steam or gasoline power is used in plowing, the aim should be to smooth the land by rolling or in some other way compressing it, and to form on it a dust mulch with the aid of a harrow, the plowing, smoothing and harrowing being completed in the one operation. The plan which turns over large areas of land in the early summer and leaves them thus all season without further working is to be condemned in unmeasured terms.

Although the use of steam and especially gasoline power is rapidly extending in the semi-arid regions, and especially in the breaking up of the prairie, the exact place that these will occupy in the future in the farming of these areas cannot now be forecasted. The behavior of those engines in the future cannot be gauged by their behavior in the past, as many of those who have manned them have not been sufficiently skilled to get from them all the work that they are capable of doing. For a similar reason the breakages have been overfrequent and costly. While there is certainly a place for the use of such power on the farm, that place has not as yet been definitely determined. That ground may be plowed and pulverized and the crop sown on it by the aid of such power cannot be questioned. The relative cost, however, as compared with horse labor, is yet an open question.

Good plowing in dry areas.—It is important that plowing shall be well done under all conditions, because of the important bearing that such plowing has on the retention of soil moisture. When land is plowed shallow, the furrow slice being imperfectly turned, and there are many skips in the plowing, it will be at once apparent that a good seed bed cannot be made on such land. In

the absence of a good seed bed, crop production is doubly hazardous in a dry country.

Good plowing may be defined as follows: (1) a straight and evenly turned furrow of uniform depth; (2) a furrow so turned that it will lie well over against the furrow previously turned, so that air spaces underneath will be excluded to the greatest extent possible; (3) plowing in which skips are entirely absent and in which the cut and cover method has no place; (4) plowing which completely buries all rubbish and grass and in which the furrow slice is crushed more or less; (5) plowing of such depth as is best suited to the conditions under which the work is done and to the needs of the crop which is to follow.

If good work is to be done, careful attention must be given to the condition of the land and of the plows. Good work cannot be done on land plowed overwet or overdry. Some soils, especially those known as gumbo, will become so hard if they are plowed when overwet that they cannot be pulverized properly when preparing a seed bed, even though much labor should be expended on the same. When lands are cloddy, it is scarcely possible to do good work when plowing them. It is also greatly important that the plows shall be kept in first-class condition. They should be kept free from rust by housing and proper oiling when they are not in use, and by keeping the shares sharp and in shape when they are being used. Usually it will result in better work when the furrow slice is cut rather less than the full width that the plow can cut.

Subsoil plowing in dry areas.—In the true sense of the term subsoil plowing means a loosening or breaking up of the soil to a greater or lesser distance below the depth to which land is ordinarily plowed. The land so loosened is not brought any nearer to the surface. The term has been improperly applied to the process which

brings up soil from below the sole of the furrow made by the first plowing and places it on top of the furrow slice first made. It is simply deep plowing, the additional depth being gained by running the plow twice in the same place, the second plowing being deeper than the first. Where the elements in the subsoil are very similar in kind and condition to those in the top soil, the practise is to be commended, but where the food elements in the lower soil are in a raw and undigested condition, the practise is to be strongly condemned, as it will certainly be followed by a lessened production. The inert plant food thus brought to the surface cannot be taken up by plants until it has been made available by what are termed weathering influences.

There are different kinds of subsoil plows. One of these simply tears through the lower soil much after the fashion of a curved harrow tooth. It consists of a steel bar attached to and running below the plow that turns the top furrow. In other instances it consists of a wedge-like shoe attached to the lower part of the steel bar, which is drawn forward through the lower soil. In many instances the subsoiler is not attached to the ordinary plow, but more commonly it runs in the furrow made by the former.

The objects sought in subsoiling are: (1) to deepen the area which the roots of plants may readily penetrate in search of food; (2) to increase the capacity of soils for receiving and storing water more readily than comes in the form of precipitation; (3) to facilitate the liberation of plant food in the lower soil by allowing air and water the more readily to penetrate it. It will be readily apparent, therefore, that the benefits resulting from subsoiling will be largely dependent on the character of the soil and especially the subsoil, also the character of the crops as deep or shallow rooted. Subsoiling is not helpful in very open subsoils, as in these it would only tend

to promote excessive leaching. It will not avail in un-drained soils until they are drained, if they hold an excessive amount of water for any considerable period. The necessity for subsoiling in dry areas and the benefits to be derived from it have called forth opinions that are more or less conflicting. Many authorities look upon it as a necessity in nearly all the semi-arid region. They lose sight, apparently, of the cost of subsoiling. In much of the semi-arid region the limited rainfall does not call for a great depth of stirred soil to take in all that falls. When once thus absorbed, the water can usually go downward with sufficient readiness in the average western soils. If the connection between the upper and lower soils is too much disturbed, the upward movement of moisture will be hindered until the disturbed soil has time to settle again.

As a rule, the most effective subsoiling mechanical in character is that which stirs the soil more and more deeply by a gradual process, rather than by stirring it to a very considerable depth at once. Usually the necessity for going more deeply than 12 to 18 inches would not seem necessary for ordinary cropping. For alfalfa and also for field roots, it may sometimes prove helpful to go more deeply.

When alfalfa comes to be generally grown in dry areas, subsoiling mechanically would seem to be unnecessary. It would be difficult to conceive of subsoiling more complete than that furnished by the roots of a good stand of alfalfa in their decay. They burrow deeply in the subsoil during the process of growth. In their decay they leave it honeycombed with avenues leading downward. Moisture can readily go down in these and form a reserve for later growth. The process does not cost the grower anything.

The frequency of the plowing.—The frequency with which land should be plowed will depend to some extent

on the way in which the land is worked, to some extent on the season, and to some extent on the annual precipitation. The aim of the farmer in humid areas is to multiply the number of plowings to the greatest extent practicable. The aim of the farmer in dry areas should rather be to plow as seldom as will answer the needs of the system of cropping followed. The more frequently that the former plows the more effectively does he destroy weeds and the more perfect is the tilth secured. The more frequently that the latter plows his land, the more difficult is it for him to retain moisture in it.

When land is first broken the aim should be not to turn up the buried sod again, until it has reached a somewhat advanced stage of decay. The sod will rot more quickly down in the bottom of the furrow than when exposed to the dry air. This may be accomplished in two ways. By one method the land, if plowed for the second crop, will be plowed less deeply than for the first crop, providing the same is practicable. By the second it is prepared by discing fall or spring or both seasons. A seed bed thus prepared is much more free from sods than one made amid upturned and imperfectly decayed sods.

When plowing land for fallow, the aim should be to plow but once during the season. The care of the fallow should be done with other implements than the plow. Every additional plowing given to the land adds to the difficulty of firming it sufficiently to prevent the undue escape of moisture. A second plowing is allowable should the weeds prevail to such an extent that other implements of tillage may not be able to cope with them effectively. It is also necessary when a green crop is grown to be buried in conjunction with the fallowing process, to add plant food and humus to the soil.

There are certain times also when discing will be preferable to plowing, but so much depends upon con-

ditions that it is not easily possible to lay down definite rules that will serve as safe guides to the farmer. Usually land may be prepared for a crop by discing with less labor than by plowing, and in some instances such preparation will be followed by better results.

Where the precipitation is light and the soil is heavy, the practise is not only allowable, but it may be commendable to grow the second grain crop after careful summer-fallowing by discing rather than by plowing; such preparation involves less labor and it will in most instances hold more moisture. The second crop will not, of course, equal the first, but more grain will result from such a system of cropping than from summer-fallowing and cropping alternate years.

When the first plowing has been done in the spring and it has been shallow, and is followed by a dry season, it may be better to disc than to plow, whether viewed from the standpoint of the saving of labor or from that of the conservation of moisture. But should the ground possess a fair amount of moisture at the time for plowing, then plowing, and more deeply than the first plowing, will be preferable.

When land is so dry that it cannot be plowed to a sufficient depth in the autumn, and when if plowed it may be cloddy, then discing is preferable to plowing, and the following spring a second discing may be in order.

After a cultivated crop, it is seldom that the plow should be used in making a seed bed in preference to the disc, lest there should be undue loss of moisture, and because of the seed bed less clean that would follow. Lands that are quite light are also frequently better prepared with the disc than the plow. When thus prepared, the intermingling stubbles aid somewhat in hindering the blowing.

In some instances it is better neither to plow nor disc for a crop, as for instance when the soil is very much liable to lift with the wind, or when winter wheat follows a grain crop under climatic conditions where protection is necessary. In the first instance discing would add to the lifting of the soil, and in the second it would render less perfect the winter protection. The grain in both instances would be planted by the simple process of drilling. But in neither instance should grain be thus planted on weedy land.

CHAPTER VIII

CULTIVATION IN DRY AREAS -

Cultivation in the broad sense includes all the various processes of tillage. In the discussion that follows it will include virtually all of these processes as applicable to dry areas except plowing, which was discussed in chapter VII. These include subsurface packing, discing, cultivating by implements other than the disc, harrowing, including the use of the weeder, rolling, planking and drilling. The discussion will also include the maintenance of the dust mulch, cultivation suitable for growing crops and clean tillage in the bare-fallow.

Subsurface packer and its use.—The subsurface packer as ordinarily constructed consists of a series of wedge shaped wheels, which revolve on a common axle. They are usually about 18 inches in diameter and are placed about 6 inches apart. They thus press the loose soil downward and to some extent laterally when in use. The primary object sought is the firming of the land that has been newly plowed toward the bottom of the furrow slice and leaving it loose and friable at the surface. The pressure of the soil below so compacts it that moisture from the firmer subsoil may ascend into the less firm soil in the lower part of the furrow slice. In other words it re-establishes the capillary connection broken by plowing the land. The moisture which thus ascends is largely prevented from escaping by using the harrow after the packer. This implement also aids materially in crushing lumps in cloddy soils.

The subsurface packer may be used with advantage:

- (1) On spring plowed lands that are loose and lacking in moisture-holding power.
- (2) On lands that contain more or less trash, the bulk of which in plowing is placed between the furrow slice and the unbroken soil below,

and which in dry areas, because of its slow decay, prevents the soil moisture that is below from properly ascending. (3) On land that is dry and cloddy at the time of plowing, whether plowed fall or spring. The aim should be to avoid plowing land when in that condition in dry areas. When it must be plowed, the disc should usually precede the plow as, when it does, the proportion of fine earth is increased that falls at the bottom of the furrow slice, which so far is favorable to moisture retention.

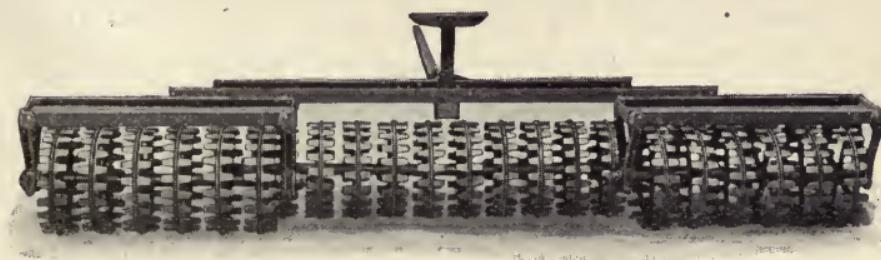
The packer usually follows the plow the same day that the land is plowed, and in some instances at the end of each half day, to prevent rapid escape of moisture. The harrow should at once follow the packer. In many instances, the packer should be weighted in order to firm the land sufficiently. More commonly, stones are used for such weighting.

The subsurface packer should not be used: (1) On soil that is sufficiently moist when it is plowed, unless in the case of land that is normally deficient in moisture-holding power. (2) On fall plowed land which, under normal conditions, will become sufficiently firmed below by the time that the season has arrived for sowing in the spring. Much of the bench land in dry areas is of this class. Especially is this true of such of them as contain much lime, gypsum, granite and more or less sand. To use the packer on such land is liable to do serious harm, as it may put the lower soil in a condition which prevents the easy penetration of the roots of the plants through it. To keep such soils sufficiently loose is more important than to firm them. (3) On lands that are naturally overtenacious, as stiff clays and gumbo soils.

The claim that soil should be packed with the subsoil packer to prevent precipitation from going too far down in the subsoil is not tenable save in soils that are

overleachy. It is harmful in its tendencies, since in time of heavy rainfall the loss from "run off" water would be increased. From what has been said it will also be apparent that while there is an important place for subsoil packing on certain soils, the claim sometimes made that the packer should in all instances follow the plow cannot be defended.

The packers most commonly in use are not of very much value. They are too diminutive for effective work, and the wheels are of cast iron, which clog in damp soil and which wear quickly. Among the best are the Dunham soil packers and pulverizers combined. The Dunham rigid frame packer and pulverizer is 8 feet long



THREE SECTION DUNHAM PACKER AND PULVERIZER.
15 Feet Long.

Courtesy Deere & Webber Co., Minneapolis, Minn.

and has 12 sections. The Dunham flexible packer and pulverizer is of two sizes, viz., 10 and 12 feet long, with 14 and 18 sections respectively. A third Dunham packer and pulverizer is 15 feet long and has three divisions. The two last mentioned implements can adjust themselves to uneven land.

The disc and its use.—The disc, though commonly classed as a harrow in common with certain other implements, will not be so considered in the present discussion. The same may also be said of the cutaway harrow, the spring tooth harrow and the alfalfa har-

row. Clearly these are cultivators and they will be so considered. They are all used for digging up the soil and to some extent for pulverizing it, while a harrow simply pulverizes, with the additional function of covering the seed. A true harrow has spike teeth and they are dragged through the soil by a cutting and sliding rather than a revolving friction. The disc is more commonly used for loosening up the surface soil, hence it is a cultivator rather than a harrow. It consists of a series of wheels from 12 to 20 inches in diameter, which are attached to an axle and revolve with the same when in use. Those most in favor are in two sections. The wheels have a sharp cutting edge, are to some extent concave on the outer side, and they are generally used at more or less of an angle to enable them to stir the soil effectively. In each of the sections the discs face outwards and this leaves a deep depression in the center between the two sections. In order to leave the land level and to do thorough work, what is termed double discing is usually practised. Double discing means drawing the disc over the land in one direction and lapping the implement to half its width on the disced land on the next trip.

The value of the disc consists: (1) In stirring the surface soil more effectively and to a greater depth than this can be done by the ordinary harrow, and at a much less expenditure of power than would be involved in overturning the soil with the gang-plow. The friction in the revolving wheels is much less than the same would be in the dragging plowshare. (2) In loosening surfaces too much impacted to be readily loosened with the ordinary harrow. (3) In making a deeper seed bed on overturned sod lands than can be made by the harrow alone. (4) In destroying weeds that are too firmly rooted to be destroyed by the harrow. (5) In covering seed, and in cultivating crops at least to a limited extent.

One great advantage of the two-section disc cultivator arises from the fairly regular depth to which the disc will cut regardless of the unevenness of the surface. A double-action disc is now in common use which will double disc the ground at one operation. The first section breaks the soil and the second reworks and firms it, and as the gangs are outthrow and inthrow the land is left in a good condition. The size of the wheels or discs is ordinarily from 12 to 20 inches, and the width of the land stirred is from 6 to 10 feet. Usually discs 14 to 16 inches in diameter do more effective work than those that are narrower, but they are heavier of draft.

The disc may in all instances be used: (1) In the early spring on fall-plowed land that has become more or less impacted, to aid in making a good seed bed. (2) On summer-fallowed land, in the absence of a more effective implement, to dislodge weeds which have become so firmly rooted that the ordinary harrow cannot dislodge them. (3) On summer-fallowed land to break the subsurface crust that in some instances forms beneath the dust mulch made by the harrow. (4) On cultivated land, as corn, when preparing it for the grain or alfalfa crop that is to follow. To plow such land would result in the loss of moisture and would bring up weed seeds from below, which would tend to cover the land with weed life. (5) On breaking or sod land, setting the discs so straight as not to bring up sods. The object is to press down the furrow slice and to aid in making a soil mulch.

It may be used in many instances: (1) On stubble land as soon as practicable after the grain has been removed to destroy weeds that are then growing, to encourage germination in weed seeds and in volunteer grain, to prevent the escape of subsoil moisture, to open the soil for the easy penetration of rain, and to make more easy the plowing of the land at a later period.

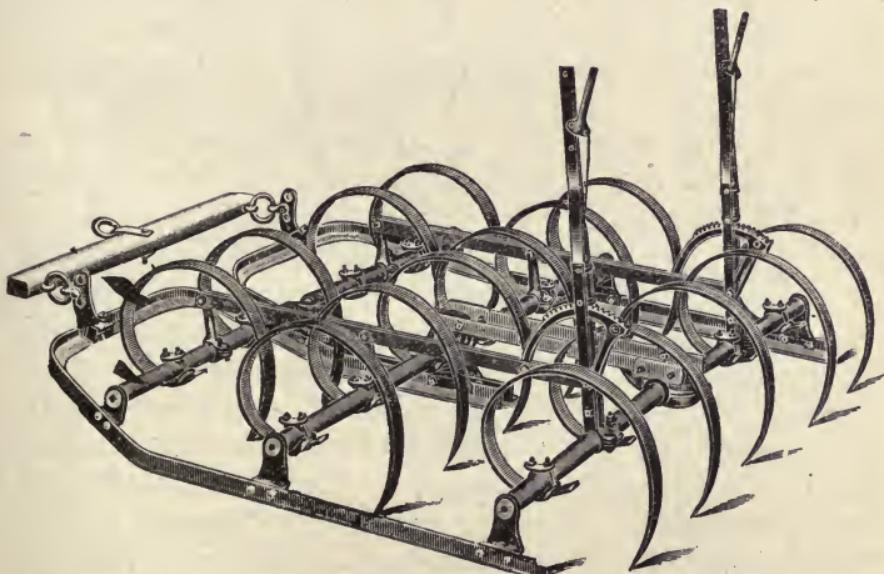
(2) On well established alfalfa crops in the early spring in the absence of other methods of stirring the soil, and in some instances after certain of the cuttings of the same, the object being to destroy weeds and to aid in maintaining moisture. (3) When preparing the land for the second crop on breaking where it has not been back-set, as such preparation gives longer time for the sods to decay before they are brought up again to the surface. (4) On summer-fallowed land where summer downpours are not infrequent. When thus used the land should be single disced lengthwise, and then crosswise, so as to make little basins for catching the water. (5) On sod land that is to be broken, especially if the work can be done in the early spring, with a view to admit more moisture and to make the land plow more easily later. (6) On stubble land in the fall or early spring, that is to be summer-fallowed, to encourage the sprouting of weeds and the deeper penetration of moisture. (7) On autumn-sown grain in the spring when the soil has become so impacted that the harrow teeth cannot loosen it sufficiently, in order to admit air and moisture.

The disc should not be used as a rule: (1) On land that is so loose that it does not require discing to make it more friable. To use it thus would be labor lost. (2) In preparing land for a crop for successive years on the same land, or even in a single instance, when plowing gives promise of better results. The disc works too near the surface to make it effective in doing work that is usually done with the plow. (3) On stubble land in which winter wheat is to be drilled where the danger is present that the wheat may be killed by the severity of the weather.

The cutaway disc cultivator, a modified disc, frequently called the cutaway disc harrow, may render substantial service under some conditions on the dry farm, especially in fields where trash and sods abound.

The blades give a chopping blow and, therefore, cut more deeply in hard ground than the round disc, but they do not pulverize it so well. The cutaway disc is something of a mean between the disc and the spading disc, which is virtually a form of disc that does not clog. It can be used on rough corn ground, for instance, several days earlier than the ordinary disc.

Cultivators other than the disc.—The various cultivators in use are very many and for each there would



THE MINNESOTA CHIEF SPRING TOOTH HARROW.

Courtesy Deere & Webber Co., Minneapolis, Minn.

seem to be a place where it will do better work than can be done by other cultivators. In dry areas, however, the number of these that are highly adapted to the needs of the farmer is somewhat limited. Prominent among these are: the spring tooth cultivator, frequently called the spring tooth harrow; the clod crusher; the Climax cultivator; the alfalfa cultivator; the alfalfa renovator, sometimes called the alfalfa harrow; the

surface cultivator, and the spike tooth cultivator. There is also a garden cultivator, of which that known as the Planet Jr. is one of the best.

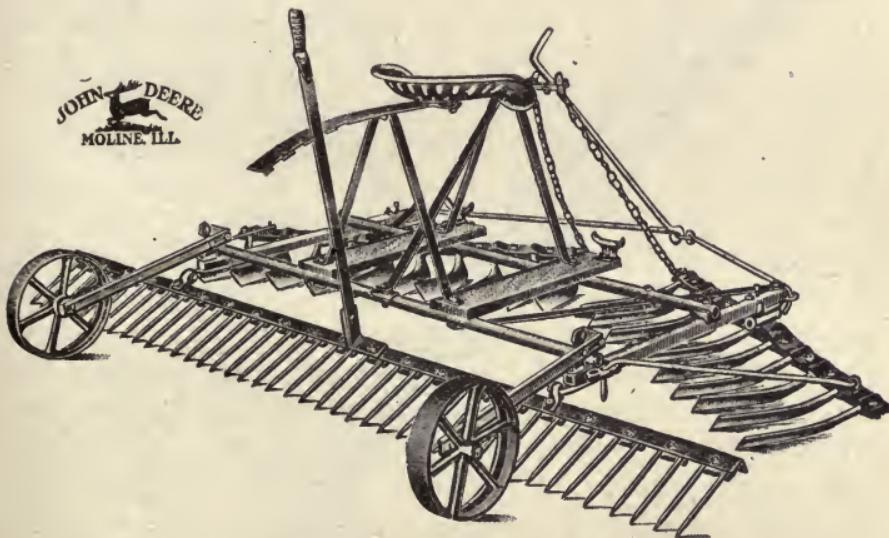
The spring tooth cultivators are of several types. Prominent among these are the Old Reliable, with wood frames, and the Minnesota Chief (see p. 149.) The latter has a steel frame and it is of such construction that it acts also as a runner, that is, it has runners on the two sides which tend to lighten the draft. The depth to which the teeth cut can be adjusted. When they meet an impediment in the soil, as the name implies, they are so flexible that they spring over it without breaking.

The clod crusher is virtually an improvement on the Acme harrow, which has been used so effectively on wide areas in the humid country, and which may also do effective work under dry conditions in certain areas. The knives of this very useful implement are curved and the slant given them is adjustable. They cut into the soil for some distance and fine it by crushing the lumps. They slice off ridges and hummocks, and destroy weeds unless they are strongly rooted. The rake teeth at the rear still further fine, smooth and level the ground. The rear gauge wheels make it possible to regulate the cutting depth of the knives. It does most effective work while the clods are not yet hard and dry.

The Climax cultivator is a wheel cultivator with two or three sets of V-shaped teeth or shares of different widths. These are attached to iron or steel bars which project downward from a strong frame. The shares cut below the surface of the ground and are adjustable as to the depth of the cutting. The different widths are intended to make it possible to cut over the whole surface or a part of it or to dig into the soil rather than cut through it. This implement, considerably used in some

places to cut off such weeds as the Canada thistle below the surface, is somewhat heavy of draft.

The alfalfa cultivator (see p. 317), as the name implies, is specially designed to cultivate alfalfa fields. The round curved and sharp pointed teeth are designed to dig into the soil with a view to loosening it for some distance below the surface. The depth to which they penetrate the soil can be adjusted, and it is wholly independent of the weight of the machine. A seeder at-



THE DEERE CLOD CRUSHER, LEVELLER AND SMOOTHER.

Courtesy Deere & Webber Co., Minneapolis, Minn.

tachment for sowing alfalfa seed may be secured along with the cultivator, which makes it easily practicable to add to the stand of the plants.

The alfalfa renovator or harrow (see p. 311) is a modification of the ordinary disc, in that it has strong steel spikes projecting from the discs. The Deere alfalfa harrow is of two sizes, 6 and 7 feet long respectively, and it has stationary scrapers to aid in keeping the implement free from clogging with trash when in use.

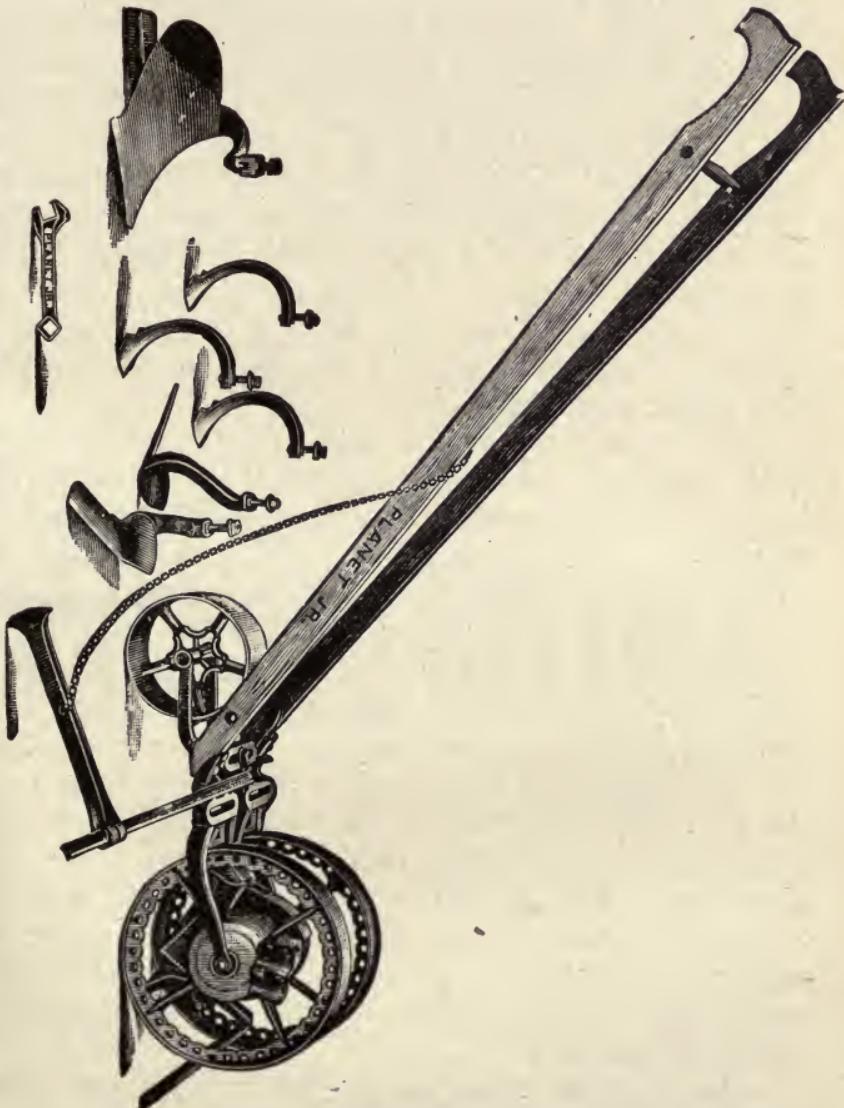
The surface cultivator (see p. 278) is chiefly used for cultivating corn, but may be used in cultivating various other plants. As the name implies, it works the soil near the surface and it is furnished with knives rather than shovels, which cut off and thus displace weeds. Shovel rigs may also be used upon it and surface attachments for smoothing the soil. The large wheels with their broad tires make it easy of draft, and the high arch between the wheels makes it possible to cultivate corn without breaking it when 3 to 4 feet high. It is drawn by two horses as a rule, and cultivates one row at a time, but there is also a two-row cultivator which is drawn by three horses.

The spike tooth cultivator (see p. 200) has steel teeth slightly curving forward. It has a gauge wheel for regulating the depth. It is drawn by one horse and is intended to stir the soil deeply should this be desired. It is not so valuable as the surface cultivator for destroying weeds. Various other cultivators are in use, some with discs, some with shovels, some with knives, and some with a combination of these, but the surface cultivator and the spike tooth cultivator, judiciously used, will usually suffice for the cultivation of corn and various other crops. But where corn is listed, other cultivators, more commonly of the disc pattern, are called for.

The Planet Jr. is a very useful cultivator. It may be worked by hand or by the aid of a horse. It is furnished with knives and shovels and is intended for use in gardens and on small areas generally.

The spring tooth cultivator is used chiefly for loosening up land that has been plowed and has again become impacted. It has special adaptation for use in ground where obstructions to cultivation are present, as in the form of roots or stones, and for land that is too moist to work well with the ordinary disc. The clod crusher

has adaptation for land that is still cloddy after grain has been sown on it, and also for summer-fallows when weeds are just beginning to sprout numerously on them.



PLANET JR. COMBINED DRILL SEEDER, WHEEL HOE CULTIVATOR AND PLOW.
Courtesy S. L. Allen & Co., Philadelphia.

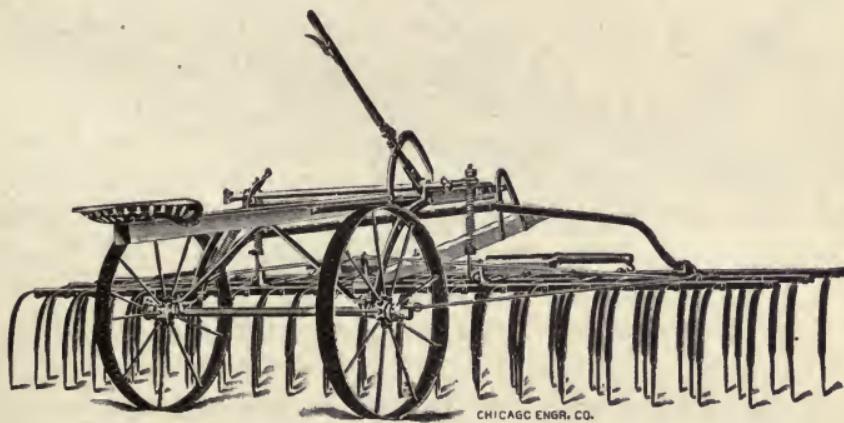
The Climax cultivator is useful in cutting off perennial weeds below the surface of the ground, as, for instance, the sow thistle and the Canada thistle, especially on land

that is being summer-fallowed. The alfalfa cultivator has special adaptation for loosening alfalfa soils to a greater depth than would be easily practicable with the ordinary disc. Owing to the peculiar shape of the teeth they do but little harm to the plants. The alfalfa renovator stirs the soil more fully than the alfalfa cultivator, but not to so great a depth. It also will break up the hard crust that forms beneath the surface in some soils. The surface cultivator has special adaptation for freeing the land from weeds in cultivated crops where it is not desirable or necessary to cultivate deeply. The spike tooth cultivator is specially helpful in breaking up the undercrust that in so many instances forms in cultivated land under the dust mulch.

The spring tooth cultivator should not be used on land where the disc will accomplish the work more effectively. The Climax cultivator should not be used ordinarily on summer-fallow land when it can be kept clean with the disc and harrow. The alfalfa cultivator should not be used on alfalfa fields at any time when the soil is unduly moist or when it will tend too much to stimulate growth on the approach of winter. The surface cultivator should not be used on corn or other crops to destroy weeds that have become so deeply rooted as to call for some kind of shovel teeth to dislodge them unless indeed such teeth can be used on the same, nor should it be used when its further use would break down the corn plants to any considerable extent. The spike tooth cultivator should not be depended on alone to clean weedy land. This it cannot do without involving an undue amount of labor.

Harrows and their uses.—While there are several styles of harrows in ordinary use, it would seem correct to say that only three of these are specially suited to the needs of dry areas. These are: (1) the adjustable spike tooth steel lever harrow, (2) the weeder, and (3) the

sixty-penny spike tooth wooden harrow. The first of these is made of steel and in sections (see p. 157). The sections are coupled insomuch that when it is so desired they may be made to cover 24 feet at one stroke of the harrow. When thus used they are drawn by 4 to 6 horses. More commonly, however, they consist of but two sections and are drawn by two horses. The teeth are adjustable, insomuch that the harrow may be used with the teeth pointed forward or backward at any angle that may be desired or they may be used erectly. The



THE JANESVILLE HALLOCK 12-FOOT RIDING WEEDEER.

Courtesy Janesville Machine Co., Janesville, Wis.

angle at which the teeth are adjusted influences the depth to which the teeth drag and also the extent to which they dislodge volunteer grain or weeds.

The weeder consists of a series of long, rigid steel teeth attached to a bar which is stationary. The implement is conveyed on wheels and the depth to which the teeth penetrate the soil is adjustable. The use of this implement is confined mainly to the destruction of newly sprouted weeds in grain crops or in cultivated crops in the early stages of their growth.

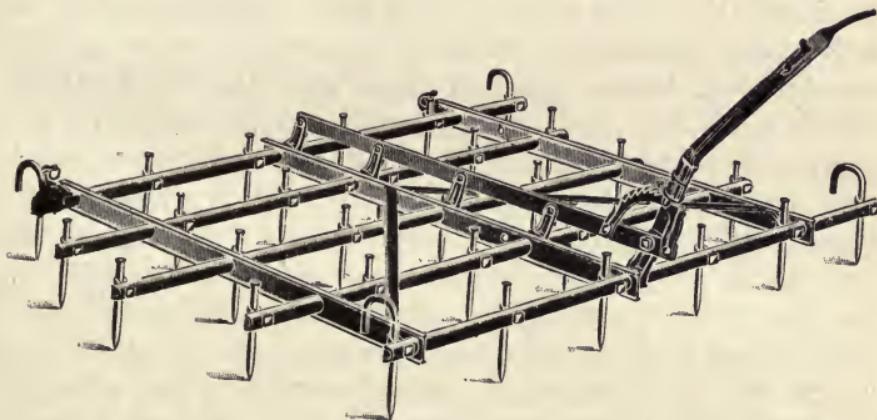
The sixty-penny spike tooth wooden harrow has a frame made of 2 by 4 inch scantling and the frame is of some light wood, as pine. The teeth are the sixty-penny spikes driven through the scantlings in openings prepared by brace and bit, to the desired distance. This harrow is of home construction and may be of any width desired. It is intended for use on very soft, fine surfaces where the steel harrow would sink too deeply in the soil. (See p. 168.)

While the objects sought from the use of the harrow are various, the following are prominent among these: (1) The pulverization of the soil so that germinating plants will be furnished with conditions that favor rapid growth. (2) To cover the seed that may have been broadcasted, as when sown by hand. (3) To destroy weeds in the early stages of their growth. When firmly rooted they cannot be dislodged by the harrow. (4) To aid in conserving soil moisture. In dry areas no implement will equal the harrow in efficiency for such a use.

The steel harrow is used: (1) To pulverize the seed bed on land that has been plowed. It is greatly important that this shall be done as soon as possible after the land has been plowed or disced, to prevent the escape of moisture, and also after rain, should the same be practicable. (2) On summer-fallow land to firm and maintain a dust mulch throughout the season, and especially after any considerable rain, and to destroy weeds as they begin to grow. The dust mulch is to hinder as far as may be the escape of moisture. (3) To cover the seeds of grain that may have been broadcasted, as when hand sown, and to furnish additional covering for drill-sown grain on land not in good condition of preparation. (4) On several cultivated crops, especially corn and potatoes, before they appear above ground, and subsequent to their appearance until they are several inches high. The number of these harrowings is dependent on

the conditions present, but usually it is not less than four. (5) On nearly all kinds of small grain, after the blades begin to show and until the plants are ready to shoot, to keep the soil from encrusting, to destroy weeds and to prevent moisture from escaping from below. The number of the harrowings given to a grain crop may run from 1 to 5. In some instances harrowing may not be called for, owing to peculiarities of season and soil.

The steel harrow is sometimes used, but not in all instances: (1) On fall-plowed land to aid in its pul-



ONE SECTION OF THE AJAX STEEL LEVER HARROW.

Courtesy Deere & Webber Co., Minneapolis, Minn.

verization. (2) On several of the small grains between the season of sowing and the appearance of the plants, the object being to destroy weeds and to prevent encrustations. (3) On winter grain autumn and spring, to hold moisture and to loosen and aerate the land.

The harrow should not be used: (1) On cloddy land until the clods are first crushed with roller or planker, as on such land it will not do effective work. (2) On breaking or overturned sod until the sods have been pressed down with disc, roller or planker, lest many of the sods should be left with the grass on the

top side. (3) On grain from, say, 1 to 3 inches high, save when a crust forms, lest much of the grain should be buried. (4) On grain crops when wet with dew or rain, as then the grain will be more or less injured with the soil that will adhere to the blades, and the weeds present will not be destroyed. The harrow cannot do effective work in killing weeds when the soil or the grain is unduly wet.

The weeder is used on soils that are so loose as to interfere with the use of the steel harrow, which sinks so deeply into them as to drag the cross-bars more or less along the surface of the ground. The teeth of the weeder may be so adjusted as to regulate the depth to which they will cut. This implement is intended for use mainly, if not, indeed, wholly, on crops that are growing. It may be used on plants too high for being harrowed with ordinary spike tooth harrows. On large areas four-horse gang weeders are the most satisfactory.

The sixty-penny spike tooth wooden harrow is intended to stir the surface of the soil in grain crops where it is very loose. Its value lies in a considerable degree in the small cost of construction, as it may be made by the farmer himself. The end which it serves may be served as well, if not, indeed, better, by the weeder. Neither the weeder nor the sixty-penny spike tooth wooden harrow has any important mission where the soils are stiff or cloddy, or where they are much inclined to encrust.

Rollers and their uses.—Rollers are of various types. These embrace: (1) The old-fashioned log roller made from the trunk of a tree and in some instances containing two and even three sections. (2) The steel land roller (see p. 160), usually made in three sections and with closed head, which prevents earth from accumulating inside of the drum. These are from 8 to 10 feet long. (3) The corrugated steel roller, also sometimes made in sections. This roller has somewhat wedge shaped pro-

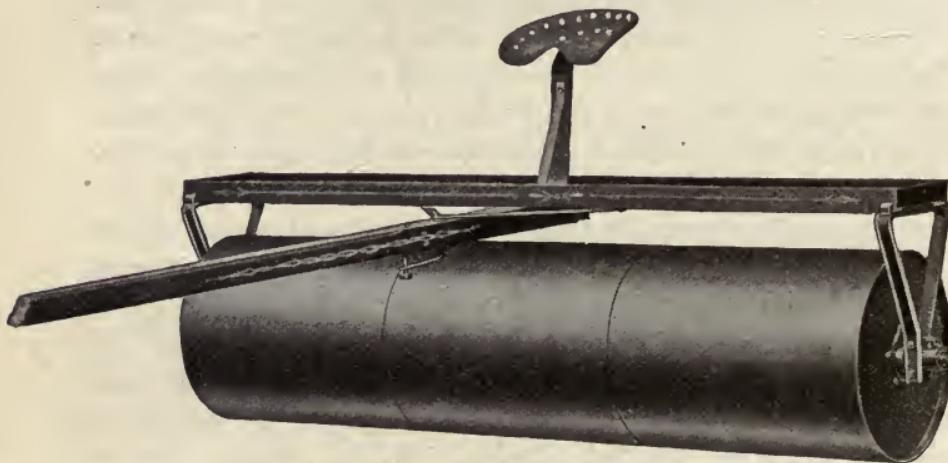
tuberances on the rim of the drum, which aid in crushing lumps and in leaving the soil in a condition that will cause it to lift and encrust less readily with the wind. While each of these may have a place on the dry land farm, the place for the corrugated roller is more important than for rollers of the other types.

The mission of the roller in dry areas is virtually twofold—first, to aid in smoothing plowed land so that it may subsequently be pulverized more readily, and, second, to aid in crushing clods when these are present. Its use is much more restricted than in humid areas, and chiefly for the reason that it tends to draw moisture to the surface, much of which will escape into the air unless the disc or the harrow follows the roller. It will not effect the end served by the subsurface packer, as it firms the soil above, and to a less extent below, whereas, the subsurface packer firms it below and leaves it loose above.

Rollers should be used in dry areas: (1) To flatten down sod land newly plowed so that the disc or harrow or both may do more effective work when securing the requisite pulverization that should follow. The compression of the sod also hastens decay. In some instances the disc, in the absence of the roller, will do this work sufficiently well. (2) To crush clods when preparing cloddy land for the harrow. When clods and pulverized earth are both present, it may be necessary to follow the roller with a disc or spring tooth harrow to bring up clods from the subsurface soil and to roll a second time. When a good subsurface packer is at hand, it may suffice to crush the clods below without bringing them up, providing it may be safely and advantageously used on such soil. (3) To press the soil around newly sown grain when the grain has not been put into the same with a press drill. But when thus used the harrow should follow to prevent the too rapid escape of moisture that would otherwise occur. (4) To

break the crust that forms on grain as the result of rain at that stage of growth when the use of the harrow may bury the grain. In some instances the roller will do this work quite as effectively as the harrow.

The roller should not be used in dry areas: (1) on any land or any crop, unless followed by the harrow, lest the land should encrust if rain follows; (2) on light sandy land that will lift readily with the wind, as the wind lifts the soil much more readily from a smooth than from a rough surface; (3) on land that packs readily, unless in



THE DANDY DUNHAM STEEL LAND ROLLER.

Courtesy Deere & Webber Co., Minneapolis, Minn.

exceptional instances; (4) for the purpose of covering grass seeds that have been sown broadcast, as is sometimes done in humid areas; (5) on either fall or spring sown grain as the final operation of tillage; (6) on autumn-sown grain in the spring, save where the soil is liable to heave.

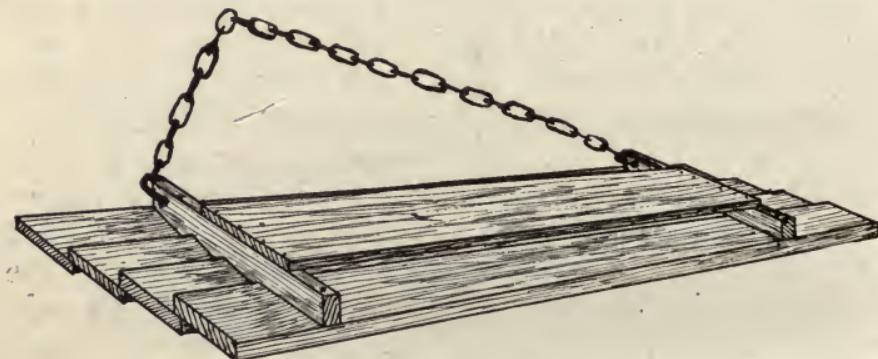
Plankers and their use.—A planker is an implement, more commonly of home construction, that is used in smoothing and levelling and in some instances also for compressing the soil. It is made of planks and is of various patterns. There is perhaps no type of

planker better adapted to the needs of the dry farm than that which consists of three or four $2\frac{1}{2}$ or 3 inch planks, 12 inches broad and say 8 to 12 feet long. It should be made of some strong wood, as fir, but soft wood, as pine, will answer, although it will wear more quickly as a result of the friction when it is drawn over the land. The construction is in outline as follows: One plank is laid on the ground or on cross-pieces for greater convenience in making it. A second plank is so placed that it will lap over the first one about 4 inches. The third and fourth, if a fourth is used, are similarly lapped. They are spiked together, or, what is better, are held together by pieces of scantling which run across the planks, the latter being somewhat notched on the high edges to receive them. Bolts are inserted from below which run through the cross-pieces. On top of these and lengthwise of the planks a sufficiently strong plank may be nailed on which the driver may stand should he so desire. It is drawn by chains attached to or toward the end front corners and meeting in the middle. If the shoulders of the planks underneath, that is, the rear edges, are faced with sheet iron, they will wear much longer than in the absence of such facing. The planker when in use may or may not be weighted with stones. (See p. 162.)

This simple device is highly useful on the dry farm. It is used: (1) for compressing and smoothing newly plowed sod land; (2) for pulverizing clods that lie numerously over the surface; (3) for leveling land that is uneven; (4) for smoothing land that is to be drilled for certain uses, and (5) for compressing land under certain conditions that has been sown or planted.

When used to compress sod land, the planker should be weighted. It is very effective for such a use. It should follow the line of the plow furrow when used on such land. It puts it in excellent shape for following

effectively with disc or harrow, or with the seed drill, when flax is to be sown. It turns clods into dust much more effectively than the roller. The planker will very effectively crush clods in such land by following it with the spring tooth harrow to bring up clods from below, and again using the planker. When levelling land that is uneven, the planker should be drawn with the shoulders underneath projecting forward so that loose earth will be drawn in front of these to fall into the low places. Should it be necessary to plank the ground a second time when levelling it, the disc should precede the second planking given. In all other instances, the shoul-



HOME MADE PLANKER.

ders should point backward. When smoothing land that is to be drilled it leaves it in a condition that makes drill or row marks easily traceable. When used on a flax crop newly sown on sod or even on other land, quick germination is promoted and the land is left in a nice, smooth condition for reaping.

The planker should not be used: (1) On land that is sufficiently friable and otherwise in good condition. To use it under such conditions would be a waste of time and energy. (2) To serve the ends sought from using the subsurface packer, as it firms the soil above but not below. (3) On soils that are liable to blow, un-

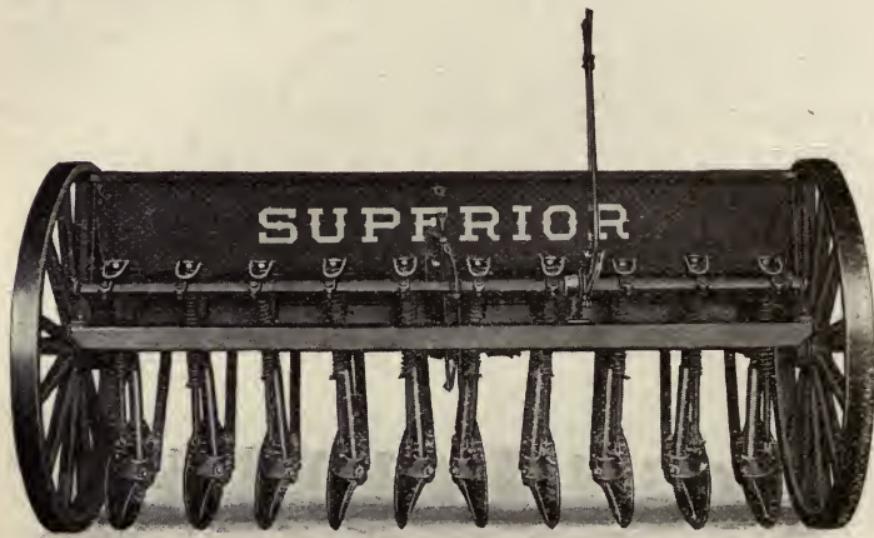
less followed by the harrow or the grain drill. (4) On land that is much strewn with stones, but where only a few are present it may serve as a means of conveying them to the borders of the field.

Seed drills and their uses.—Seed drills are of several kinds. They include the single disc drill, the double disc drill, the double disc press drill, the hoe drill, the shoe drill and several makes of broadcast seeders. For ordinary sowing in dry areas, the hoe drill and the shoe drill are but little used. It is very largely confined to the three types of disc drill first named. There is also a place of no little importance for the small disc drill, which more commonly has but five discs. There is almost no place for broadcast seeders on the dry farm, as they do not bury the seed to a uniform and in many instances to a sufficient depth. Each of the four kinds of disc drills named will fill a place better than can be filled by any of the others.

The single disc drill (see p. 164) opens a furrow in the soil for the seed which drops into it, and it is covered by the earth falling back upon it behind the disc. The double disc drill (see p. 165) makes an opening into the soil between each two discs. The seed falls into this opening, where it is deposited at a uniform depth. The disc press drill (see p. 177) has a wheel following each drill mark, which firms the earth around and over the seed. The small disc drill is for use where only one horse can work, as between corn rows.

The single disc drill has adaptation for sowing grain on land that may be too rough or too moist to use the double disc drill on it to advantage. On rough and especially on stony ground, it will open a seed furrow more readily, and it will clog less readily in overmoist ground. The double disc drill has highest adaptation for clean land. As it drops the seed at the bottom of the furrow, it is first covered by moist earth, which, under dry condi-

tions, is especially advantageous. The press drill still further aids germination, especially in loose and spongy soil, by so firming the earth that the seed is left under most favorable conditions for quick and sure germination. The small one-horse disc drill may be so used that drilling can be adjusted to spaces of different widths between the corn rows.



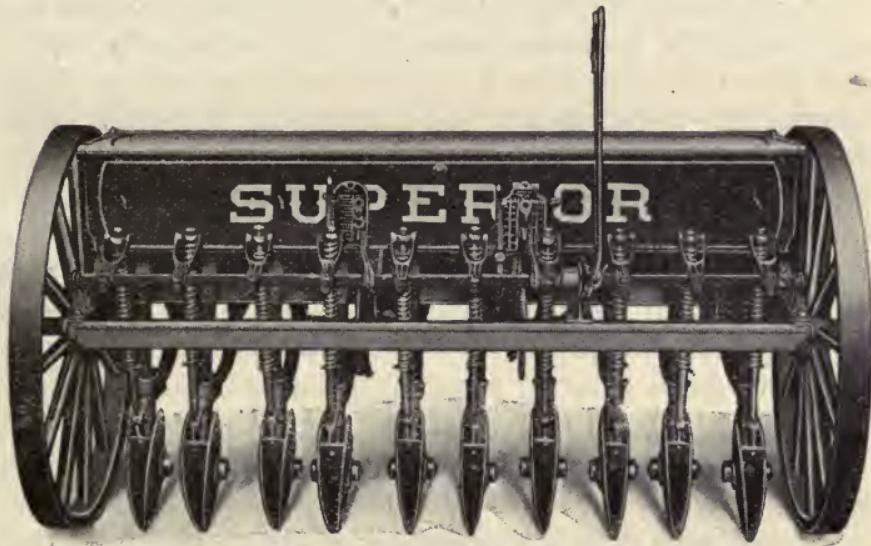
THE SINGLE DISC DRILL.

Courtesy American Seeding Machine Co., Springfield, Ohio.

The aim should be to avoid using the single disc drill where the double disc will answer the purpose better. Should it be necessary to use it on soil somewhat lacking in moisture, the roller should follow the drill and the harrow the roller. The soil will then be firmed around the seed and it will not blow. The aim should also be to avoid using the double disc drill on land over-firm, rough or stony, or when the ground is so moist as to preclude doing good work, nor should the press drill be used on soil that bakes readily, save under conditions that are exceptional.

Because of the importance of burying the seeds of grasses, clovers and alfalfa in the soil, those who invest in drills in the future should aim to have a grass seed attachment that will run the seed into the grain tubes so that it may be provided with a covering whether sown alone or along with the grain crop.

Maintaining the dust mulch in dry areas.—By the dust mulch is meant a layer of earth more or less fine and dry, covering the surface of the soil to the depth of



THE DOUBLE DISC DRILL.

Courtesy American Seeding Machine Co., Springfield, Ohio.

2 to 3 inches. It is usually composed of fine soil, but the ideal dust mulch is composed of soil that includes soil particles as fine as dust, intermingled with soil granules. Soil granules means soil in which a number of soil particles adhere so as to form small lumps of soil. When the soil is destitute of these soil granules it is much liable to lift more or less with the wind and to run together and become impacted by rainfall so that it encrusts. When composed wholly of soil granules, it does

not sufficiently prevent the escape of soil moisture, hence the combination of these forms the ideal dust mulch. Repeated harrowings in dry weather will probably result in too much fining of the particles, whereas harrowing at the opportune time after rains will result in that granular condition of the soil which, in conjunction with the fine soil particles, makes the ideal dust mulch. The name "dust mulch" is something of a misnomer. The designation "soil mulch" is more appropriate.

The mission of the dust or soil mulch is to prevent the escape of moisture from the soil below the mulch and also from the subsoil. When water climbs up from below, on the principle of capillarity, it cannot pass through a layer of dry earth. In the absence of such a layer on the surface it climbs up and goes out into the atmosphere insomuch that it is lost to the soil. When rain falls so as to saturate the dust mulch it puts the surface in that condition which facilitates the escape of moisture, on the principle that capillary water can only climb through a moist soil. When the dust mulch has become thus saturated, on drying the soil contracts, with the result that it becomes filled with numerous fissures. Through these the moisture rapidly escapes into the air. To check such loss of moisture it is necessary to harrow the land as soon as dry enough to remove the encrustation, and to fill up the cracks. When the harrowing is done at the right stage of dryness, it tends to insure that granulated condition of the soil which is so favorable to the maintenance of a dust mulch. Should such harrowing be neglected or even too long deferred, the benefit that would otherwise result from rain may be lost, as when the top soil is moistened it facilitates the climbing of the moisture to the surface.

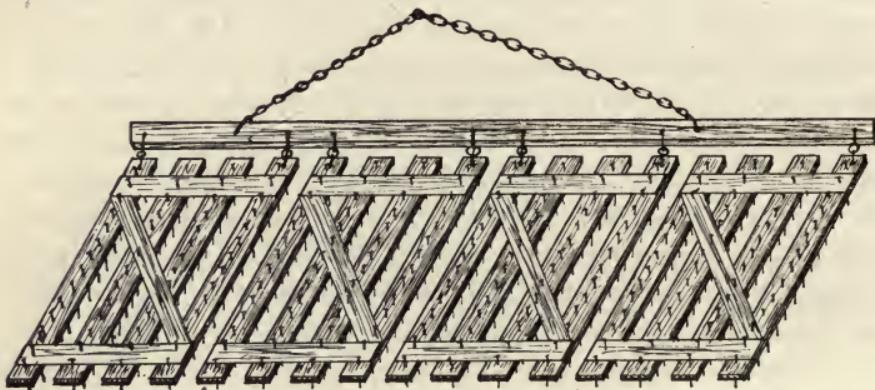
The dust or soil mulch has an exceedingly important place in all areas where the supply of moisture is less than could be desired. The less the degree of the pre-

cipitation, the greater is the necessity for the dust mulch. It has also an important place in areas with a sufficiency of rainfall for the season, were it properly distributed, but which are more or less subject to dry periods during the season of growth. Moreover it will prove very helpful in irrigated areas after each application of water to crops that are of that kind, and in that stage of growth, that will admit of some kind of surface cultivation while they are growing.

It is always in place: (1) On summer-fallow land in dry areas and during the entire season. (2) In these areas it is also more commonly in place on small-grain crops during the early stages of growth, but in seasons of unusual moisture during the growing period it may not be necessary. (3) On small-grain crops in humid areas in seasons of more than usual drought during the early stages of growth in the grain. (4) On alfalfa lands in dry areas, especially in the early part of the season. (5) On all crops properly known as cultivated crops, and during almost the entire period of growth. Of course, the dust mulch on small cereals and alfalfa land is very much less complete than on land that is fallow or that is growing a cultivated crop, but on the former it is nevertheless a dust mulch in a modified form.

On the summer-fallow the dust mulch is maintained on many soils almost entirely by the aid of the harrow. But on some soils the aid of the disc is necessary in some instances to aid in killing weeds, to break up impaction resulting from a heavy rain or to break up a crust formed beneath the soil mulch made by the harrow. Such a crust will form in some soils in the absence of rain. When it forms, it should invariably be broken up by some deeper form of cultivation, as when present it excludes aeration and therefore stays proportionately the active working of bacteria in the soil.

On cultivated crops the dust mulch is maintained, first, by the aid of the harrow, and, second, by that of some form of cultivator. On these, as on the summer-fallow, the aim should be to prevent encrustation above and below. This will involve stirring the soil after every considerable rain. The results would be better could it be stirred after every rain, but in practise this may not be practicable. In dry weather, when no cracks are present in the soil or any encrustations above or below, there would not seem to be any advantage from stirring the soil. On cereal crops, the aim should be to prevent encrustation until the leaves shade the soil.



THE SIXTY-PENNY SPIKE TOOTH WOODEN HOME MADE HARROW.

The summer-fallow in dry areas.—The summer-fallow in dry areas means land that has been plowed the previous autumn, or some time during the spring or early summer, and is then kept more or less free from weed growth subsequently by some form of cultivation, until the season has arrived for sowing on it an autumn or a spring crop. Because of the amount of surface cultivation given to the soil when thus fallow, it is frequently spoken of as summer-tilled land. The term fallow implies that the soil is idle during the period of tillage, but to this idea there is the exception that in

some instances a crop that grows quickly is sometimes produced for renovation purposes.

In humid areas, land is summer-fallowed chiefly for the purpose of reducing weed growth in the same. In dry areas it is summer-fallowed chiefly for the purpose of increasing the moisture in the soil and subsoil for the benefit of the crop that follows, but it is also handled thus to reduce weed growth. In such areas the former reason is usually the dominant one, but to this there may be some exceptions, as when the land is to be freed from the presence of volunteer grain. It will be at once apparent, therefore, that the place assigned to the summer-fallow will always be more important relatively in dry than in humid areas. In some humid areas where the cultivation is intense, there may be no place for the summer-fallow, as crops may be grown successfully from year to year and without any intermission on the same land, but that is not true of dry areas.

The frequency with which the summer-fallow should be introduced into the rotation will depend upon various conditions, as soil, subsoil, precipitation and evaporation. More commonly, however, where the rainfall is 15 inches and less, it will be found profitable to introduce the summer-fallow every second or third year (see p. 397). But where the soil lifts readily with the wind, it should not be introduced, except when they possess enough vegetable matter to bind them.

Sod land may be plowed for summer-fallow in the autumn when it is amply supplied with moisture at that season, which seldom happens, however, save in areas where much of the precipitation falls in the autumn and winter. More commonly it is in best condition in the late spring, and it should then be plowed to a depth of not less than 6 inches. It should be packed at once with some form of packer and a dust mulch formed on it and maintained to the end of the season (see p. 165).

The aim should be to avoid cropping such land the first season, in order that moisture may be stored in the sub-soil.

The best time to plow land for summer-fallow in dry areas, all things considered, is the autumn, providing the soil is possessed of enough moisture to admit of plowing it deeply. If the soil is very dry it will be better to simply disc it so that water that falls may penetrate it the more readily, leaving the deep plowing that should be given to it until the spring. When plowed in the autumn, it should be disced and harrowed in the early spring. It should then be harrowed with sufficient frequency to maintain a dust mulch throughout the season.

When the ground cannot be plowed or disced in the autumn, it may be disced in the early spring and then plowed later, that is, at a time when the soil has much moisture in it. This, in all or nearly all the Great Plains country, is usually May or June. It should usually be at once packed with disc or packer, and a dust mulch formed and maintained on it with the harrow. As a rule summer-fallow land should not be given more than one plowing in dry areas, lest too much moisture should be lost, but to this there may be some exceptions, as when the soil is much liable to pack. The advice sometimes given to plow summer-fallow land a second time and somewhat late in the season would seem to be misleading.

Cultivating crops in dry areas.—In dry areas more of the crops relatively are cultivated than in humid areas, and the cultivation given to them is in many instances more prolonged. This arises from the greater necessity which exists for keeping the land in that mechanical condition which will best guard it against vicissitude from the effects of drought. Nearly all the crops grown may be cultivated to some extent and in

some way during the process of growth. For a more complete enumeration of these, see p 269. Such cultivation embraces harrowing, discing, renovating and cultivating by various implements and in various ways. Grain crops, grass crops, forage crops and root crops all come in for more or less of cultivation. More commonly the only cultivation of grain crops is given by the harrow, that given to grass crops, as alfalfa, comes from the disc and harrow, that given to forage crops from the harrow and certain cultivators, and the same is true of root crops and tubers. The exact character of the cultivation suitable to each is given when discussing in succeeding chapters how these should be grown. The object at this time is rather to discuss the general character of the cultivation and the extent of the same.

Grains are harrowed to keep the soil open, for the easier penetration of water, to prevent it from escaping when it enters, and to aid in destroying weeds. The harrowing should seek to avoid burying the grain and tearing too much of it out. Grasses are disced usually before growth begins. The severity of the discing or renovating called for depends upon the excess, if any, in the stand of the plants, their ability to stand severe discing, and the hardness of the ground. Nearly all grasses will profit from an annual or biennial discing, as the surface is thus loosened for the better admission of air and moisture. Forage crops when too high to use the harrow on them can only be cultivated further by implements that run between the rows.

In humid areas, shallow cultivation during the entire period of the cultivation is recommended. The advice thus given is suitable, for under such conditions the crops root relatively shallow. This requires some modification in dry areas, as crops root more deeply in such soils. It would seem correct to say that the culti-

vation should be both shallow and deep. The necessity for this arises, at least on many soils, from the tendency in them to encrust below the shallow cultivation, as previously intimated. If cultivation reasonably deep is given at the first, while lateral root growth is yet limited, the time of such encrustations will be deferred. When it does occur some implement must be used to break it up, even at the risk of breaking some of the roots of the plants, as to do this may be the lesser of the two evils. The breaking of this crust under the soil mulch is a matter of much moment when growing such cultivated crops.

The extent of the cultivation will vary with the different crops and classes of crops. Grains are seldom harrowed beyond the time when there are indications of jointing, and not very frequently for so long a period. Some crops grown in rows, as alfalfa for seed, and peas, cannot be cultivated to a late stage of growth because of the recumbent character of the growth. Those of upright growth, however, should be given cultivation until and in some instances beyond the time for beginning seed formation.

CHAPTER IX

SOWING AND PLANTING IN DRY AREAS

In some respects the methods to be pursued in sowing grain and planting seeds of all kinds in dry areas are the same as in humid areas. In other respects the contrast is very marked. The rules that govern correct sowing and planting are much more exact and inflexible than those which govern the same in humid areas. This less degree of latitude in dry areas relates: (1) to the time of planting; (2) to the mode of planting; (3) to the depth to plant; (4) to the amount of seed to use, and (5) to the soil conditions at the time of planting. In humid areas, for instance, plants may be sown early or late, and more or less of a crop may be looked for, whereas in dry areas a late-sown crop may completely fail. In humid areas germination may be good from both drill and broadcast sowing, in dry areas the seed may fail to germinate from the latter when it will not so fail from the former. In humid areas plants will germinate within any reasonable distance of the surface, in dry areas they will only germinate when down far enough to reach moisture. In humid areas good results may follow in each instance from free seeding and in varying quantities, in dry areas limited quantities only will give results. In humid areas seed may be sown with the expectation that rain may come; in dry areas such expectation may prove fallacious. Sowing and planting in dry areas call for much more exactness than in humid areas.

The advantages from drill sowing.—Drill sowing is much superior to broadcast sowing in dry areas. In fact it is so much superior to broadcast sowing that it may in a sense be said that there is no place for the latter. Drill sowing has the following among other advantages:

(1) It buries the seed to a uniform depth. (2) The depth may be varied to suit the conditions. (3) The ground may be compressed above the seed. (4) There is a saving in the amount of seed.

The burial of the seed to a uniform depth in dry areas is greatly important. Under humid conditions seed will germinate almost equally well at varying depths, but in dry areas the seeds buried shallow, as some of them are in broadcast sowing, will not germinate at all in the absence of rain. Should the plants appear unevenly they will grow unevenly. The early plants will rob the late ones of moisture, which will result in dwarfing them, and the ripening of the crop will be uneven.

But more important than the planting of the seed at an even depth, is the planting of the same at a depth that will insure germination. For instance; the best depth at which to plant a certain kind of seed is, say, 2 inches. But the moisture in the soil may be half an inch or an inch lower down. With the grain drill, the seed may be put down to where the moisture is, and so germination is insured. In the absence of a drill such planting would not be possible. Its use renders it entirely practicable to plant autumn-sown seeds deeply to fit them for going through the winter in better form, and to plant spring-sown seeds moderately deep or less deeply to suit the moisture conditions that may be present.

The ability to compress the soil around seed more or less, which some drills furnish, is in many instances a great advantage. The class of drills known as press drills will accomplish this (see p. 177). The advantage from such compression is, that the circulation of air around the seed is so far reduced that the moisture needed to germinate the grain is better retained. Such compression, however, is not adapted to all soils. In some soils it would shut out the air too completely, as when they are of a heavy character and may contain an

excess of moisture. Such compression, however, is helpful to nearly all the soils of the dry areas.

There is also a saving in the amount of seed called for. This is the outcome of the more perfect germination secured in drill sowing. In humid areas the saving thus effected is fully $12\frac{1}{2}$ per cent., which means that where 8 pecks of seed are called for when sown on the broadcast plan, 7 pecks will answer the same purpose when sown by the drill. The saving thus effected in dry areas will be quite as much relatively, but it will be less absolutely, because of the less amount of seed called for in dry areas. The saving in the amount of seed called for will be at least relative, and this will mean that the saving effected in the amount of seed called for would soon pay for the cost of a drill where large areas of grain are to be sown. In moist areas the saving thus effected in seed is less than one peck per acre. In humid areas it is not less than half that amount. With so much of saving on each acre, the entire saving thus effected would soon repay the outlay incurred in purchasing a drill where the area to be sown is large.

The disadvantages of broadcasting.—One of the great disadvantages resulting from broadcasting the seed is, that in all instances when thus sown it may not be deposited deeply enough to enable it to reach moist soil. If the moisture has left the surface for some distance downward, the seed may not germinate at all until rains come, and when these come the season may be too far advanced to result in the production of a crop.

A second disadvantage is, that the seeds will be covered at a depth so uneven that germination cannot fail to be uneven, though all the conditions for good germination should be favorable. Should they prove unfavorable, the evil will be aggravated. When seed is

thus sown, it is covered by the harrow, or by the disc. The harrow will cover it unevenly. Some of the seeds will lie upon the surface. This means that in dry areas they will not sprout. Some of them may be covered so lightly that they will not sprout. Other seeds may germinate and yet root so near the surface that they cannot well resist the adverse influences of dry weather that follows, and all of them may be rooted too shallow to enable the plants to properly stand up and grow amid the vicissitude that may come to them because of the lack of rain. When the seed is covered with the disc, some of it may not be covered deeply enough. Much of it may be covered too deeply. There is a lack also of that compression which the disc drill gives that is so favorable in hastening germination. This lack of compression is equally present whether the seed will be covered by the smoothing harrow or by the disc.

When grain is sown with the drill, it is deposited so deeply that the harrow does not readily uproot the plants when the grain is being harrowed subsequent to the appearance of the plants above the surface of the ground. Such harrowing is absolutely essential to successful crop production in dry areas. When the crop is sown broadcast, the harrow will readily uproot the plants, or at least many of them, because of the shallowness of the rooting, and the more delicate the plants in the early stages of their growth, the more will they suffer from this cause. The better ability of plants that are deep-rooted to withstand severe harrowing is well illustrated in grain plants that have volunteered, as it were, from seeds of the previous crop shattered out upon the ground and buried deeply with the plow. In many cases, even the disc will fail to dislodge these.

The advantages of drill seeding over broadcast seeding are so many and so apparent, that it would be correct to say that broadcast seeding has but a limited place un-

der dry farming conditions. To say that it has no place, as some have said, is putting the matter strongly. There may be certain soil conditions at the time for sowing which would preclude the use of the drill, but would not at the same time forbid sowing on the broadcast plan. Such an occasion might arise from a soil so moist near the surface as to make it impossible to do good work with the drill. So much superior is drill sowing over broadcasting, that the aim should be to sow even such small seeds as alfalfa and grasses with some form of drill.



THE DISC PRESS DRILL.

Courtesy American Seeding Machine Co., Springfield, Ohio.

The amounts of seeds to sow.—In dry areas the amount of seed that ought to be sown is worthy of the most careful study, because of the influence which the amount of seed sown exerts upon the crop yields. It would seem correct to say that in semi-arid areas the less the amount of the precipitation the less the amount of the seed that is called for. This conclusion is based upon the influence which the moisture supply present in the soil exerts on plant development. When the number of plants growing on a certain area is in

excess of the moisture present to meet their needs in best form, their complete and perfect development is hindered. When the moisture supply is not sufficient, the plants will not grow to the usual size. The heads will be dwarfed in their development and the kernels in the heads will be deficient in number and also in size. Should the weather be excessively hot while the grain is nearing maturity, a thick stand of the plants is almost certain to result in shrunken grain and diminished yields.

The greater tendency in plants to stool under the conditions of growth in dry areas as compared with those in humid areas, furnishes a second reason why a less amount of seed should be sown. Under normal condition in humid areas, only a limited number of stems will be produced by each plant; in dry areas the number will be much larger. The relative thickness of the plants in both instances affects the stoeing. The fewer the plants of course the greater is the tendency in them to stool. The strong root system which is developed in plants relatively early in dry areas doubtless encourages abundant stoeing. In humid areas such stoeing arises in a considerable degree from a relatively small number of plants growing on the ground. Under some conditions this would lead to an excessive growth of straw, which would probably result in a diminished yield of grain. The tendency would also be present in some seasons to induce rust. These hazards are but little present in dry areas. Very large yields may frequently be obtained in the latter from a very light seeding of grain.

It would not be possible to state the amounts of seed that will best meet the conditions in all instances in dry areas. The precipitation is of varying degrees in different localities and of varying amounts in the same locality. What would be a sufficiency of seed in one locality would be an excessive amount in another. The

amount that would be enough under normal conditions would be too much under a deficiency in the precipitation. The condition of the preparation of the land also exerts an influence. The more perfect the preparation, the less is the amount of seed that is called for, as the greater relatively will be the number of the plants that will germinate under those conditions, and the more abundant will be the stooling. It is only possible, therefore, to state approximately the amount of the seed that should be used. Some species of cereals stool more than others, and the same is true of varieties within the species. These peculiarities should not be ignored. Speaking in a general way, it would seem safe to say that the usual amounts of seed sown in dry areas should be about half the amounts of the same sown in humid areas.

Much care should be exercised in determining the amounts of seed to sow. Because very large yields have been obtained from sowing very small quantities of seed under exceptional conditions, the mistake should not be made of reducing unduly the amount of the seed sown. The practise should be followed of sowing amounts a little in excess of what will best meet the needs of the conditions present, as all of the plants may not germinate, and very adverse weather conditions may destroy some of them. Should there be an excess of plants, it is best removed by the aid of the harrow, a result which is to be sought whenever such excess is present.

The time to sow autumn grain.—The aim should be to sow autumn grain early and for the following reasons: (1) That root development may have time to become strong so as to enable it the better to withstand the vicissitudes of winter, and (2) that the development of the top may become such as to aid in furnishing protection for the plants when passing through those periods of winter when a covering of snow may not be present. This will apply to all kinds of winter grain, as rye, wheat,

barley, oats and vetches; of these rye will best meet the hazard incurred from late sowing, because of the superior power which inheres within the grain itself to resist vicissitude.

The sowing of winter grains possessed of sufficient hardiness to enable them to withstand the winter conditions may best begin in the northern areas of the semi-arid belt in early August. As the latitude grows less the time for sowing is later. To sow unduly early there are the following objections: (1) The plants may under unusually moist conditions reach the jointing stage at too early a period. (2) The autumn growth may exhaust the energies of the plant to such an extent that the growth the following spring is less vigorous than it would have been had such exhaustion not occurred. (3) In the case of wheat, the hazard may also be incurred of attack by the Hessian fly.

The chief objection to late sowing lies in the hazards to which the young plants are exposed and which they cannot resist as stronger plants would. These hazards include: (1) Freezing through the intensity of the cold. (2) Destruction which may come to the plants through exposure to cold winds following quick removal of a snow covering. (3) The loss of the plants while the roots are not yet far from the surface through lack of moisture. (4) A lack of vigor in the growth that in many instances follows late sowing, even though the plants should survive the hazards incurred.

The plan which sows the grain so late in the autumn that it will appear above the ground in the spring has met with some favor. It is not to be encouraged. Should the winter weather be so dry that germination would not take place until spring, the crop would not reach the earing stage. Nor can the plants, though germination should take place before spring, withstand drought as well as earlier sown and deeper rooted plants. The

yields from the former are usually less than those from the latter.

Where the land has been properly prepared it will seldom happen that the moisture in the soil will not be sufficient to produce prompt germination. But this may occur in exceptional instances. When it does the question arises as to whether the sowing of the crop should or should not be deferred until rain falls. The safer plan will be to wait as long as it may be safe to wait without incurring hazard through undue lateness in sowing, and then to put in the seed. If rain comes the crop will probably succeed. If it does not come, the only direct loss incurred is that of the seed and the labor of sowing, as the ground will remain in good shape for receiving other seed sown in the spring.

The time to sow spring grain.—The aim should be to sow grain in the spring as early as the work can be properly done, and without incurring hazard to the plants, and for the following reasons: (1) To insure germination in the seed. (2) To give the plants all the benefits that can be obtained from a relatively long period of growth. (3) To mature them before the very hot and dry weather arrives. When the preparation of the land has been begun the previous year and under suitable conditions, it is very seldom indeed that the moisture in the soil will be too much lacking for germinating the seeds of cereals when these are sown in season. When the plants are given as long a season for growth as the conditions will admit of, they attain to a vigor of maturing that could not be reached save under very exceptional conditions by plants of the same variety that are sown late. This means that the yields will be relatively less. When sown early, growth is so far advanced that, when the season of warm weather comes, which may always be looked for in midsummer in semi-arid countries, they will

not be seriously harmed by it. Safety in this respect is further safeguarded by sowing early maturing varieties.

The aim should also be to avoid sowing grain late, for the following reasons: (1). Because of the hazard which such sowing brings to desirable germination. (2) Because of the hazard that the crop may completely fail. (3) Because of the disturbance to the rotation that follows failure. When grain is sown relatively late, much of the moisture may have gone from the top soil, hence when grain is deposited in the same it may be necessary to plant it too deeply to insure germination. In other instances the moisture may be so far gone that germination cannot be secured as in the case of flax sown on spring-plowed land and under very dry conditions. In yet other instances, the germination secured is only partial. Some of the plants germinate and grow on. Some may germinate and then perish, other seeds may not germinate at all. The outcome is a stand so imperfect that a full crop cannot be produced. Of course, where germination does not follow, the crop is not produced, but even though the plants should start in good form, they are much more liable to fail subsequently under adverse conditions than plants sown early. A late sown crop may start well in dry areas, and yet fail so completely subsequently that it will never come to fruition. When such failure results, the rotation planned may be seriously disturbed. The farmer may hesitate as to whether the crop should be left or disced over until the season is so far advanced that the larger portion of the moisture has left the soil. The crop may thus be lost, while the land is not left in the most desirable condition for receiving a crop the following season, because of the loss in moisture thus incurred.

The conditions suitable for sowing include: (1) a properly prepared seed bed, and (2) sowing that is seasonal. A properly prepared seed bed includes: (1) one

that has been prepared long enough beforehand and under such conditions as will insure enough moisture to give the crop a good start, and (2) a soil that is in proper mechanical condition. It may not be possible in all instances to secure either when the plowing is not done until after the opening of spring. Nor may it be possible under such conditions to bring it into a proper mechanical condition; that is, a condition of correct friability. Friability, that is a fine condition as to pulverization, is influenced by the amount of moisture present or absent as well as by the natural texture of the soil. An overwet condition of the soil is to be avoided when sowing as well as a condition overdry. Of the two evils it would be the greater.

Sowing that is seasonable may be defined as sowing that is not so early or so late as to incur hazard to the kind of crop sown. Such hazard may come from cold and frost at the opening of spring or from lack of moisture late in the season or it may come from trying to grow the plant under conditions not suited to its needs. The hazard from cold and frost in early sowing is greatly influenced by species and variety. After the opening of spring, hazard from the influences named would seldom affect spring wheat, for instance, adversely, howsoever early it might be sown, whereas oats sown thus early may be seriously injured. The order for sowing spring sown cereals is about as follows: Spring wheat, speltz and spring rye may be first sown and about equally early; peas and barley may follow closely, especially when the barley is of the hulless variety; oats may follow in close succession and after oats flax. Young plants that cannot endure freezing should be kept beneath the surface until the hazard from frost is practically past. Such are potatoes and the more tender of the garden vegetables. Other plants, as rutabagas, should not be sown usually as early as they will grow, lest the quality should be af-

fected adversely. But the aim should be to sow all crops as soon as possible after the proper season has arrived for sowing them. Promptness in sowing when that time comes, is doubly important in dry areas.

The depth to sow.—The best depth at which to sow seed is influenced: (1) by the soil; (2) by the moisture present; (3) by the character of the seed; and (4) by the season. These influences may act separately or more or less in conjunction.

The more loose and spongy the soil is and the greater the degree of its porosity, the more deeply may seeds be planted and the greater also is the necessity for planting them relatively deeply. In such soils, the young germs may readily push their way up to the light, a result that would not be so easily attained by the same in stiff soils. Seeds, therefore, should be planted less deeply as the density of the soil increases.

The moisture in the soil is a more important factor relatively in dry than in humid areas, and it exercises a correspondingly greater influence on the results. When moisture is sufficiently present, it is comparatively easy to determine the depth for planting seeds, providing their habits of growth are understood. It is different, however, when the moisture is more or less lacking. If the moisture has left the upper section of the tilled area, to insure prompt germination the seed must be put down far enough to reach the moisture below. When seed is thus planted more deeply, the extent to which it will stand such increase in depth must be considered. About 2 inches is a very suitable depth for planting several kinds of cereals in the semi-arid country, but should the moisture table be from 3 to 4 inches below the surface, it would be necessary to plant the seed thus deeply. Such cereals as wheat and speltz, also some others, would stand such deep planting, but this would not be true of flax.

Should the proper time come for sowing and should the moisture be so lacking as to prevent germination, it may be an open question as to whether sowing should be done or deferred for a time, at least until moisture comes. On the whole, it would seem better to sow, trusting to the hope that rain may come. Especially would this seem to be wise in the case of winter wheat, as, should it fail to grow, a crop can be obtained the following summer from the same land, the only actual loss being that of the seed and the labor of sowing. In the spring the seed and the crop may also be lost, but this will occur but rarely, so rarely that the hazard from such sowing is not very great. The greatest hazard is incurred from improper moisture conditions when there is enough moisture to start germination in part but not enough to complete the same. While it is possible to start germination followed by cessation of the same, and this in turn followed by a continuance in growth, and while this may be repeated more than once, growth under such conditions is never satisfactory.

The seed exercises an important influence on the depth to which it should be planted. When the moisture conditions are correct it may be said without hazard that the larger the seed the more deeply as a rule may it be buried with safety. In humid climates, the aim is to bury small seeds, as timothy, shallow. In some instances they are given no other covering than that which rain brings; in the same areas wheat is buried to the depth of two or more inches. This method of covering timothy and other small seeds in the semi-arid country would almost certainly fail because of the dry conditions that come later. While, therefore, the difference in the depths to which the various kinds of seed are to be planted because of a difference in size, is not to be ignored, when planting them in dry areas the necessity is imperative to plant all seeds far enough below the surface to shield the

young plants that spring from them sufficiently to protect them at least measurably well from the harmful influences of drought.

The season may influence the depth to which seed should be sown by the amount of moisture which it puts into the soil or withholds from the same. In times of prolonged drought, the soil, other things being equal, dries to a greater depth than when the weather is the opposite in character. This, of course, influences the depth to which seeds must be buried, if they are to grow.

The nurse crop and sowing.—In humid areas the rule is to sow grasses and clovers on land which will also sustain a grain crop the same season. The grass crop is thus established without losing the crop of one season in order to establish it. In some instances this would not be practicable in semi-arid regions. If two crops are sown thus, there is a contest between them for moisture during the period of growth. The grain crop, that is, the nurse crop, makes the more vigorous growth, and, therefore, it gets the larger share of the moisture to the injury of the other crop in proportion as its power exceeds that of the other to draw on the moisture in the soil. The nurse crop also weakens the other crop by its shade in proportion as it is strong or weak. Moreover, while the nurse crop is maturing, its draughts upon soil moisture are unusually large, leaving so much less for the grass or clover crop at a critical time. The hazard is present that when the nurse crop is harvested the plants will succumb to the hot sun which shines down upon them at that season from a torrid sky. In humid areas these influences are also operative, but not to the extent, save in a few instances, of destroying the crop that is being nursed.

It may be legitimate in dry areas to use a light nurse crop (1), when sowing certain grasses for making pastures of more or less permanence, and (2) when the soil

on which the crop is sown is so light as to lift with the wind. Under such conditions it may be proper to sow a few pounds of oats to the acre with the understanding that the oats are to be prevented from maturing by grazing them, or by cutting them for hay while yet green, as may be deemed best.

In but few instances should grasses or clover be sown with a nurse crop in the semi-arid belt. It may be legitimate to sow them thus under some conditions, where the normal rainfall is 15 to 20 inches, and especially when it approaches the latter figure. But when it is less than 15 inches, the instances are rare when such sowing is legitimate. It may be possible so sow alfalfa with a nurse crop and get a stand, even when the rainfall is less than 15 inches, but the wisdom of sowing it thus is to be doubted, as the plants will have less vigor than if the crop were sown alone, and this will react adversely on the yields in the future. The conditions, therefore, in the semi-arid belt almost completely eliminate the nurse crop from the system of farming.

The time for planting.—The time for planting, as well as that for seeding, is influenced by: (1) the crop; (2) the soil; (3) the season. It should, as a rule, be done relatively early as compared with planting in the humid areas.

The species and variety of the product planted exercises a marked influence on the best time at which to plant in semi-arid areas: The aim should be to grow such species only as are relatively hardy for the locality, and the same is true of the variety. For this reason both species and variety should be given more care and study than may be necessary when growing the same in the semi-arid belt. To attempt to grow species or variety where the conditions are not fitted, or even illy fitted for growing them, would be a great mistake under any con-

ditions, but doubly so under those which obtain in semi-arid countries.

The soil is usually in a condition to admit of planting seed earlier under dry than under humid conditions. This arises in part from the peculiarities of the soil, but more from the limited precipitation that usually falls early in the season. In the semi-arid belt it seldom happens that the usual season for planting is delayed by undue wetness in the soil, but it does sometimes happen that delay follows because of lack of moisture in the soil. Should the season for planting come in the spring, and yet the soil is too lacking in moisture to bring germination to the seed, the wisdom of planting or of withholding the same until moisture comes will depend somewhat on the usual season of normal rainfall. When this comes during the period of growth, it may frequently be wiser to plant than not to plant, as seed in the soil when rain falls will usually start more quickly than seed put into the soil after rain. But the hazard should be avoided in planting, as in sowing, of putting seed into soil when in a condition to start germination without perfecting the same.

The season, of course, influences the time for planting equally with the time for sowing. This influence alone may make a difference of at least several weeks in the best time at which to plant a certain variety of seed. Latitude also is, of course, a potent influence, and so is elevation. Both must be taken into account when determining the best time at which to plant. Altitude alone may make a difference of several weeks in the favorable season for planting in the same locality. Among the reasons why planting may be done in soils less warm than those in humid areas, and also relatively earlier, are the following: (1) The crops planted are intrinsically hardier, and, therefore, can endure more hardship; (2) the soils are less moist, and, because of this, lack of

warmth in them is less hazardous than lack of warmth in the same in humid areas; (3) the injury from frost in dry areas is much less than injury from frost of the same temperature would be in humid areas. It has been noticed frequently that the thermometer may fall several degrees below the freezing point, especially in mountain areas, without injury to the vegetation. This result follows, probably, because of the more dry condition of the atmosphere. When plants are damaged by frost, they also recover more readily than plants thus injured in humid areas. This furnishes an argument in favor of early planting.

The methods of planting.—The methods of planting will consider: (1) planting in hills; (2) planting in drills, and (3) planting on the broadcast plan. From what has been said, the place for broadcasting will be very limited.

Hill planting should be practised in preference to drill planting where it will answer as well all the ends sought. It has the following advantages over drill planting: (1) The ground is stirred over a larger area of the surface, which means that the conservation of moisture may be more complete on the whole; (2) the crowding of the plants is more easily prevented, which makes easier the regulation of the distribution of moisture, but too much must not be made of this advantage; (3) the cleaning of the soil may be more complete than would be possible when the crop is planted in drills without the aid of considerable hand labor; (4) there is also some saving in the amount of seed sown.

Drill planting is, in a sense, necessary under certain conditions, even with some crops that are frequently grown in hills. Take corn, for instance. When grown for fodder it is rather more easily harvested with the corn harvester. There is some saving also in the labor of sowing and harvesting. When the crop is listed drill-

ing is essential. The same is true of that system which drops such seeds as corn and potatoes in the open furrow while sod is being broken. Certain other crops must be grown in drills rather than hills from their nature and habits of growth. Such are rape and millet. But these come under the head of crops sown rather than planted. Many of the crops planted in dry areas will be grown in hills rather than in drills.

Planting on the broadcast plan will virtually have no place in the dry area, nor has it much of a place anywhere. But sowing thus may sometimes be given a place in dry areas with certain crops that are usually sown in rows. It is easily possible to obtain a fair crop of rutabagas, for instance, when the seed is broadcasted on newly plowed breaking. The same is true of field beans. These are crude methods, but they may help out the settler who is just beginning work on his homestead.

CHAPTER X

CROPS THAT MAY BE GROWN IN DRY AREAS

The range of the crops that may be grown in dry areas is wide, but not so wide as in humid areas. This applies not only to species, but also to varieties within the species. It would be fair to concede that dry areas have adaptation less high than humid areas: (1) for growing hay and pasture plants; (2) for growing roots and tubers; (3) for growing fruits and vegetables, and (4) for growing forest trees and windbreaks. This is not true, however, of small grains and of certain cultivated crops nor is it true of all kinds of hay, for the average yield of alfalfa in dry areas is more than the average yield of many hay crops in humid areas. But it is in the production of small grains that the dry areas chiefly excel. The labor of growing these crops is relatively greater in dry areas, but the compensation comes in part in the large yields obtained, in part from the little loss of the crop and in labor from bad weather, and in the slight loss in fertility from leaching.

Crops that should be grown.—The crops that should be grown are the following: (1) Those that will grow best under a light precipitation; (2) those that will best endure a dry atmosphere; (3) those that mature early rather than late. Some crops that should not be grown will also be considered.

The amount of precipitation called for to grow crops of different species varies greatly. Clover crops call for a higher precipitation than alfalfa. Oat crops need more rain than wheat or rye. Corn calls for more moisture than the non-saccharine sorghums. Cottonwood trees must have more moisture to grow them at their best than white willows, and white willows do not require so much as diamond willows. Crops of the same species

may also differ much in the amount of moisture called for to grow them in their several varieties. Durum wheat, for instance, can better endure dry conditions than fife wheat. Western rye grass can stand more drought than timothy, and common red clover calls for less moisture precipitation than alsike clover. The contrasts mentioned are not in all instances the outcome of a greater or a less amount of water actually used in growing the crop. It may and does arise in part from the greater power which some crops have to gather moisture from lower depths than others. Thus alfalfa can draw moisture from lower depths than clover, and rye from lower depths than oats. Those crops, therefore, that have proved best adapted to succeed under dry conditions, should be given the preference in semi-arid regions.

Much that has been said with reference to the ability of plants to grow on a limited rainfall, or to the lack of the same in them, will apply equally to the ability of the same plants, or to the lack of ability in them, to endure dry atmospheric conditions. The crops that do not usually grow at their best in a dry atmosphere include the Canadian field pea, the common vetch, clover in many of its varieties, flax when grown for fiber and such vegetables as turnips. This does not mean that these crops cannot be grown under dry atmospheric conditions, but that they cannot be so well grown under these conditions as under conditions the opposite. The temperature exercises an important influence. Peas and vetches, for instance, will flourish much better in the higher elevations where the temperatures are moderate than in the river basins where they are hot. These differences should all be recognized when growing plants in dry areas, and the farmer should govern himself accordingly.

In dry areas crops that mature early rather than late should be given the right of way, so to speak. This will

apply to both species and varieties. All winter crops, as, for instance, winter wheat, winter barley, winter rye and winter oats, mature earlier than spring-sown varieties of the same. This means that these should be grown in preference to the spring-sown varieties whenever the climatic conditions will admit of growing them with measurable success in the winter form. These will all mature earlier when grown in the winter form than if sown in the spring, and as a result they are injured much less by the drought and heat of the late summer than the same species when they are sown in the spring form. This means, therefore, that such species as mature early should be given the preference. It means also that early maturing varieties within the species should be given the preference, other things being equal. The crops that should not be grown under semi-arid conditions include all crops that call for a copious rainfall and a moist atmosphere to grow them at their best. This will narrow considerably the number of species that may be grown, and also the number of the varieties. It will exclude nearly all varieties of crops that flourish at their best under moist conditions. None of these should be grown other than in a tentative way under dry land conditions. To attempt, for instance, to grow rape, kale and serra-della extensively in semi-arid areas by the same methods under which they are grown in humid areas would be most unwise, notwithstanding the fact should not be overlooked that on some of the higher elevations these crops may be grown with a fair measure of success, even in the presence of dry atmospheric conditions.

Cereal crops that may be grown.—In this discussion will be considered the place for the following cereal crops in dry areas, viz.: (1) wheat; (2) flax; (3) rye; (4) barley; (5) oats; (6) speltz, and (7) peas. Buckwheat may also be grown where the elevation is not too high, but experience in growing it in such areas is limited as yet.

All of these may be grown with more or less success under semi-arid conditions. The winter wheat crop will always be the leading money crop among small grains in many semi-arid areas. This is owing to the fact, first, that it always finds a ready market, and usually at good prices; second, that the yields are generally more sure than from the spring varieties, since it ripens in advance of the hottest, and especially of the driest, weather, and they are also considerably larger; third, owing to the time when it is sown and harvested, it aids in the better distribution of the labor of the farm, and, fourth, it aids in the cleaning of the land through the specific methods of preparing the soil which it calls for. This does not mean that spring wheat may not be grown in the same areas, and in some instances even more successfully than winter wheat, but it does mean that in a very large portion of the semi-arid area winter wheat will be a safer crop than spring wheat. The winter wheat crop has special adaptation for following summer-fallow, as it begins to use the moisture that has been stored up in the soil at a much earlier period than it can be drawn upon by any spring crop, should the same be planted on the land. Where the winter temperatures are very extreme, however, winter wheat may not be successfully grown in the dry country, unless some kind of winter protection is furnished to the crop.

Spring wheat will be an important crop in all time in the dry country, but in the larger portion thereof it will be relatively less important than winter wheat. It will be less important than the former in proportion as the winters are mild and in proportion to the extent to which the precipitation falls in the autumn and winter months. As previously intimated, the winter climate in some parts of the semi-arid belt is so severe that winter wheat is not an assured success without it is in some way protected in winter. Spring wheat, therefore,

will always be more important, relatively, than winter wheat in much of the dry areas of the Dakotas, and in the eastern portion of the dry areas in western Canada. Precipitation increases in the autumn and winter, as the Cascade Mountains are approached. The areas, therefore, other things being equal, that have the lowest adaptation for growing spring wheat are those nearest to the Cascades, and the measure of suitability should be increased as these are receded from. Where the bulk of the precipitation falls in winter, too much



DRY LAND WHEAT NEAR KALISPELL, MONTANA.

Courtesy Great Northern Railway Co.

of it leaves the soil before crops of spring wheat may be matured.

The place for flax in much of the dry area is a very important one, but it will not be of equal significance in all areas. It grows in reasonably cool rather than in warm temperatures. Because of this, the growth of flax will be pursued to a much greater extent in the northern areas of the semi-arid belt than in those farther

southward. As the latitude recedes toward the equator, the elevations most suitable to the growing of flax ascend. The crop when grown in dry areas is produced almost entirely for the grain. The conditions are too dry for growing the best quality of fiber. In the future large quantities of flax will be grown in the Dakotas, as in the past. The adaptation of these states for growing flax has been abundantly proved. Many of the farmers, however, have made the grievous mistake of sowing flax infected with wilt. Such seed was in very many instances sown unconsciously at the first. Later, in some instances, it was the outcome of deliberate carelessness. This means that much of the area formerly devoted to growing flax crops cannot be so used for a term of years, until the wilt dies out in the land. The farmers who try to grow flax in new areas should profit from the knowledge of this experience.

Montana will doubtless become a great flax producing state. The conditions on Montana benches are more than ordinarily favorable. In some instances record-breaking crops have already been obtained. That portion of the Canadian provinces in the dry area of the Canadian west have adaptation equally high.

Winter rye will doubtless prove a more sure crop and over a wider area than any other cereal that can be grown in the dry area. The nearest competitor to it in this respect is probably speltz. Rye can grow under conditions more dry than would be suitable for wheat, and it is less harmed by the extremes of heat and cold. Better crops of grain will be obtained from rye in the northern areas of the dry belt than in the southern, as in the case of wheat. But when winter rye is grown mainly to provide pasture, it may furnish more of the same in many of the areas southward, for in these it has a longer time in which to grow.

While the winter rye crop may be grown successfully in areas too dry and cold for wheat, there are conditions of drought and cold in which it will not succeed. Under some conditions it may not germinate in the autumn from lack of moisture. Under other conditions it may germinate so feebly that the plants cannot withstand the injury which may come to them from winds, cold and dry. Spring rye may be grown over an area equally wide, but it will not yield so well, as a rule, as the winter variety.

Barley in some of its varieties will grow well in dry areas. The variety that has shown highest and most general adaptation is that known as the white hulless, a variety without beards on the heads or hull on the grain. The merit of this grain for dry areas is enhanced by the early season at which it matures, which brings it to the ripening stage before the weather of summer reaches its hottest, and especially its driest, stage. As this barley is not suitable for malting, it is to be grown for feeding rather than for commercial purposes. Some varieties may also be grown successfully for malting, but probably not over areas so wide as the hulless varieties. The Mensury, which is a six-rowed variety and bearded, has shown at least fair adaptation for being grown over the more humid portions of the dry region. This variety will grow to a greater height than the white hulless, which in some instances is so short that reaping is difficult, but the latter will grow under conditions more dry than would be suitable for the former. These barleys, as in the case of other cereals, have highest adaptation for the northern areas of the dry belt, and for the elevated plateaus of the states farther south. Some winter varieties may be grown where the winters are mild. Barley will be a relatively important crop in all the future in dry areas, more especially for food uses.

The place for the oat crop in dry areas is important, but less so relatively than in humid areas. This arises from the somewhat greater difficulty found in growing it. It is more easily injured by frost in the spring than certain other cereals, hence it cannot be sown safely quite so early, which hinders it from making use of the moisture in the soil at so early a period. Moreover, the oat crop calls for relatively more water to grow it than these, hence the adaptation of the oat crop for being grown over wide areas of the dry country is not so complete as that of some various other cereals. In some areas the winter oat may be grown where the spring varieties would not succeed. Especially is this true southward, where the bulk of the precipitation comes in the late autumn and winter months. As a rule, the varieties that usually prove the most satisfactory are those which call for a relatively short period in which to grow and which mature relatively early.

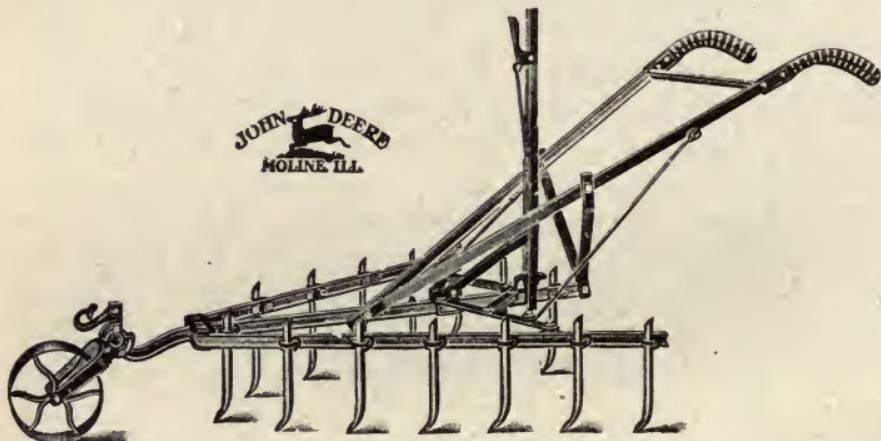
Speltz is a hardy and rugged grain. Its distribution in the dry belt will fully equal that of rye, and will probably exceed that of wheat. It has much power to endure cold when the plants are young, hence it may be sown early—as early, as a rule, as it will be proper to work the soil. It would also seem safe to say that it will be less injured by dry and hot conditions than most other grains. When its properties come to be better understood than at present, the crop will be more extensively grown than has been the case previously in the semi-arid area. The grain furnishes good food for all classes of domestic animals kept upon the farm, when properly fed to them. It is especially valuable in furnishing food for horses. This crop will probably prove more satisfactory southward in the dry area than other cereals, because of its ability to stand up under both heat and drought.

The field pea, very frequently designated the Canadian field pea, will come to be extensively grown in dry areas, but not in all parts of the same. The pea cannot endure the same amount of drought and heat as speltz, for instance, hence its best growth will be in the more humid portions of the dry belt, and especially where the elevation is so high that extremely hot weather seldom or never comes. The soil in the semi-arid country is well supplied with the food constituents that will produce large yields in grain from peas when grown under proper conditions. On some of the mountain plateaus, very large crops of peas have been grown, and also on the prairies in the northern part of the dry region. But where the precipitation runs quite low, the attempt should not be made to grow peas. Southward the cow-pea may be grown in certain areas, but it is not really a drought-resistant plant.

Fodder crops that may be grown.—This discussion will consider the place: (1) for corn; (2) for sorghum; (3) for the non-saccharine sorghums, and (4) for millets and also mixed grains. It will be observed that fodder crops in the discussion means such crops as are grown mainly for fodder, but which may also furnish some grain. For instance, the corn referred to may have on it nubbins, that is, small ears of various sizes bearing mature grain. In the semi-arid area, the question of providing fodder is one of much significance, since the hay-producing plants are not numerous. These crops, except in the case of the small grains, call for cultivation while in process of growth.

The corn crop is destined to be the most important among fodder crops that can be grown over fully two-thirds of the dry area. In the remaining third, that is, in the third that lies southward, the sorghums will, to a large extent, at least, take its place. It should be remembered, however, that corn, even for fodder, cannot

be certainly depended on to escape the autumn frosts at elevations much beyond 4,000 feet above sea level. The high adaptation of corn for such production is found in the fact: (1) that it will furnish more fodder than any other plant that can be grown in the area specified; (2) that it furnishes fodder of an excellent quality; (3) that it is one of the surest of the crops that may be grown, and (4) that growing it puts the ground in a good condition for growing a crop of small grain. Of course, the yields obtained will vary much, but not less than two tons of cured fodder should be obtained per



THE DEERE 14-TOOTH STEEL LEVER CULTIVATOR.

Courtesy Deere & Webber Co., Minneapolis, Minn.

acre yearly. The quality of the fodder is superior, because of the relatively large amount of leaf growth which it contains, because of the fineness of the stalks, and because of the bright character of the fodder, cured as it is in a dry atmosphere and in the absence of rain. It is one of the surest of the crops grown, because of the cultivation that it calls for while it is being grown. This makes it possible to grow a crop under conditions that would not produce a grain crop. The cultivation given to the corn aids in so conserving moisture that a crop of

grain may be made to follow it almost any season without the hazard of failure.

It is not to be understood that corn can be grown so successfully in the semi-arid country as in the corn belt. So large a tonnage of forage cannot be obtained from it, nor so large a yield of ears. In its habit of growth it is more dwarfish, and only quick maturing varieties can be grown in the more northerly areas of the semi-arid country. In much of the same it is necessary that it will mature in from 90 to 120 days in order to escape the frosts of autumn. The coolness of the nights are against the rapid growth of the corn, but the long hours of the summer sunlight tend to counteract that handicap.

While the corn crop in the dry area will probably be grown more for fodder than for any other purpose, this does not mean that it will not be grown in numerous areas mainly for the grain. The yields, while relatively less than in the corn belt, are relatively large in proportion to the production of stalk, hence; when the farmer can afford the time, he may husk his corn, but, since it is labor-saving to feed it in the bundle and since it is greatly important that large areas shall be grown, because of the influence which such growth will have upon grain production, it is probable that for every acre that is husked several acres will be fed without husking. In some instances, also, small varieties may be grown and grazed down by sheep or swine when ripe.

The place for sorghum is not so wide in the semi-arid region as for corn. In northern areas the mean temperature is too low to grow sorghum at its best. In southern areas some of the non-saccharine sorghums will do better, as, for instance, Milo maize and Kafir corn. The place for sorghum will be in the central portions of the semi-arid country rather than in the extremes thereof, and in the warm rather than the cool portions

of the same. The place for the non-saccharine sorghums in the dry region covers a relatively large area. These include Kafir corn, Jerusalem corn, brown durra and Milo maize. Of these Milo maize stands highest in favor, but Kafir corn will also be grown over wide areas. All these plants have much power to resist drought, and especially the two last named. Both will be grown to provide fodder and also grain for various classes of farm animals, at least as far north as the parallel 40, that is, as far north as the latitude of Denver.

The place for millets in the dry country will depend much on the variety grown, and on the manner of growing them. The broom corn variety or varieties have highest adaptation for such areas among the varieties at present grown. In order to grow them at their best, it will probably be necessary to plant the seed in rows and to cultivate them more or less during the period of growth. When grown thus, it would seem safe to say that this class of millets may be grown over nearly all of the dry area. The same may also prove at least measurably true of some other varieties.

Certain grains may also be grown in admixture to provide fodder and also hay. The combinations best suited to such growth are not well understood as yet. It is probable, however, that the Canadian field pea and oats, or the same and barley of the hulless varieties, will stand highest in favor except where the bulk of the precipitation comes in winter. In such areas the sand vetch and some winter cereal may yet be extensively grown.

Hay crops that may be grown.—Hay crops cannot be grown in so great variety in the semi-arid as in the humid regions, nor can yields as large be obtained except in the case of alfalfa. Hay plants must be grown where the land is to be tilled, or some substitute must take the place of these. Many grass crops call for much water to grow them in paying quantities. The same is

true of clovers. While they are growing, it is not practicable to cultivate them so as to conserve moisture, save in exceptional instances, hence it is not possible to increase the yields to anything like the same extent as in the case of other crops in the growing of which it is possible, to some extent, to conserve moisture by cultivative processes during a part, at least, of the period of growth.

The grass plants that will not grow at their best in semi-arid areas include almost all, if not, indeed, all varieties that have been grown under domestication. Nevertheless, some of these may grow reasonably well in favored situations, as at certain of the foothills and in other locations where subterranean waters serve in a greater or lesser degree to sub-irrigate the land. The yields from native grasses on ordinary soils are not enough to justify long continuance in seeking hay from such a source. The rainfall is not enough to grow clovers at their best. Sainfoin is more promising, but it has not been much tried in the semi-arid country.

Among the grass plants of most promise for hay are: Russian brome, slender wheat grass, frequently called western rye grass, tall oat grass, and meadow fescue. The best distribution of these is not known at the present time. Russian brome may be grown over much of the dry area, but it grows much better over the northern than over the southern portions of the same. Without some kind of renewal, it does not continue to give large yields of hay for more than, say, two crops. Slender wheat grass will produce relatively fair yields for a considerable period. It will grow under very dry conditions, but does not grow so well in hot southern areas as in those farther north. This grass soon becomes very woody if not cut promptly at a certain stage in its growth. Tall oat grass may be grown over a large portion of the dry region. The adaptation is probably more suited to

mild climates rather than to those that are severe, hence this grass will be grown southward rather than northward. While this grass may be made to serve a useful end in many areas, it is not probable that its popularity will ever reach high water mark in comparison with some other grasses, because of some lack in palatability of a high order. The ability of the grass to stand hard conditions is very considerable. Meadow fescue would seem best adapted to central portions of the dry area and probably to those north of these. The salt bush, sometimes called salt sage, may be grown with some success in very dry areas. It is not easily established, but when once well started will, under some conditions, reseed itself. It will provide both hay and pasture, but it is a woody plant. The indefiniteness of statement about these grasses is justified, on the ground that they have been so little tested as yet in semi-arid areas.

Alfalfa is undoubtedly destined to become the hay crop of the semi-arid country, and for the following reasons: (1) It may be grown successfully over nearly all the tillable portions of the semi-arid area. Where the rainfall averages not less than 10 inches per year, the possibility of growing alfalfa successfully for hay should not be questioned. (2) The yields to be expected from it will probably be larger than those obtained from any other valuable hay plant that can be grown. While those yields will vary much, it would seem safe to set them down as being not much less than two tons per acre yearly on an average, after the crop has become established. (3) It will add largely to the nitrogen content in the soil by taking the same from the air and depositing it in the soil. (4) It will keep the land well supplied with humus in the large store of vegetable matter which it furnishes in its roots. No other plant grown in dry areas can equal it in this respect. (5) It will act as a subsoiler in the extent to which its roots permeate the

same. They fill it with openings in the form of numerous channels as their roots decay, and as rain falls in any large quantity on the surface it sinks down in these openings, adding to the store of moisture in the subsoil. (6) It is at least equal, if not superior, in nutrition and palatability to any other hay plant that can be grown in the semi-arid country. All these conditions point to the future supremacy of alfalfa as a hay crop and probably to some extent as a pasture crop in these areas.

Some of the cereals will be grown more or less for hay. This means that they will be cut at some stage short of maturity. While all the cereals suitable for such a use will be grown more or less to provide such hay, wheat, oats and barley will be more frequently devoted to such a use than the other cereals. If peas are grown for hay, it will be in admixture with other grain. Where alfalfa can be grown reasonably well, hay from cereals is too costly a substitute. White hulless barley ranks high in suitability for furnishing such hay.

Roots and tubers that may be grown.—These two classes of roots will be considered separately, and also certain hazards to be avoided in growing them. Both classes call for cultivation while they are being grown, hence under dry land conditions they are more safe than some other lines of production. The term "roots" is here used in the sense of field roots grown for live stock. These include turnips and rutabagas, mangels and sugar beets, also carrots. The habits of growth in rutabagas and turnips do not differ greatly. The distribution for both, therefore, is about the same. Neither endures well hot summer temperatures, hence it will be at once apparent that the place for both is in northern areas of the dry country, and on the elevated plateaus in other sections. Good crops of these may be grown at elevations more than 5,000 feet above sea level. These plants, therefore, will furnish food for live stock in areas that

would be too cold for the safe production of fodder corn. The place for mangels and sugar beets covers a wider area than that for turnips and rutabagas, as the former will stand more heat than the latter without languishing. Both may be grown in nearly all the tillable areas of the semi-arid belt, save on the very high elevations. In such locations they may take injury from frost both in the spring and in the autumn.

The place for carrots is much wider than for any of the classes of field roots discussed above. They will stand more frost than turnips without injury, and more drought than mangels or sugar beets. Western soils, generally speaking, also seem very well adapted to their growth.

But two classes of tubers will be extensively grown in the semi-arid west, at least for many years to come. These are potatoes and artichokes. The Irish potato is referred to. Sweet potatoes and peanuts may be grown to a greater or lesser extent in the central and southern portions of the dry belt, but it will be under irrigation rather than in its absence.

The Irish potato may be grown successfully on a relatively small amount of moisture. This characteristic makes it one of the safest crops for the settler to plant on spring breaking. It does not succeed so well, however, in the central areas of the dry belt as in those farther north, except on the high elevations, and on these the hazard of injury from frost is imminent. In the southern areas of the dry region, it does not succeed so well as in the central areas. The advantage that the northern area has over the central and southern comes chiefly from the cooler temperature which it possesses. Because of this fact, the plan is good which aims to bring seed from the north every two or three years. The short season in which the potato matures, especially in

the earlier varieties, gives the crop high adaptation for certain portions of the semi-arid country.

Artichokes will only, or at least mainly, be grown as food for live stock and especially for swine. This fact will tend much to restrict the area of their growth. Nevertheless they can be grown over wide areas of the semi-arid country. The mild character of the winters in much of this area also favors the easy harvesting of the crop when grown, as it may be harvested by swine, even during the winter months, should this be desired.

Peanuts may be grown in many areas where the moisture supply is limited and where the climate is sufficiently mild. They may be grown for live stock, for the market and also to provide food for live stock, especially swine, which feed upon them where they grow.

In growing these crops, certain hazards are to be avoided. Unless germination is secured with considerable promptness, the hazard is present that in a very dry season it may not be secured at all, hence the importance of having the ground well prepared where these crops are to be planted. Unless they are started relatively early, the hazard is present that the plants will not be able to make sufficient progress when the dry weather of summer comes to insure proper development. The hazard from early freezing is to be considered. This is greatest in the potato and the artichoke, and least in the carrot. Turnips will stand very hard frost in the spring, but in the autumn they will stand much freezing, especially those of the rutabaga types. Mangels and sugar beets will not stand much freezing, either fall or spring.

It is to be remembered that though all these crops can be grown in the semi-arid country, it is not probable that they will be extensively grown for the market unless in the case of the Irish potato. All these crops may be more successfully grown under irrigation. This

applies also to the Irish potato, except in so far as quality is concerned. The quality of the potato grown without irrigation is much superior. For use on the farm, however, all these crops may be grown with more or less advantage. But their introduction will probably be gradual.

Fruits and vegetables that may be grown.—The discussion will dwell: (1) on the place for small fruits in dry areas; (2) the place for large fruits; (3) the place for vegetables, and (4) the place for fruits that may yet be introduced. As these have not as yet been grown over much of the dry area, the discussion on the growing of fruits and vegetables cannot be so complete as could be desired. It is not to be expected that these products will become staples in the semi-arid country, nor is it to be expected that they will be grown extensively for the market. It would not be easy to grow them under dry conditions so as to compete with the same under conditions where irrigation is practised. This does not mean, however, that they may not be grown in many instances at a profit, for this has been done both in the line of fruits and vegetables, even where the annual precipitation has been less than 15 inches.

The small fruits that may be grown include currants, gooseberries, raspberries and strawberries, and along with these may be included plums and cherries, and also grapes. The currants and berries mentioned may be grown in practically all the tillable portions of the semi-arid country, and the same is true of plums. Cherries, however, will not endure the winters in the northeastern portions of the semi-arid area. Whether raspberries will have to be laid down in winter and covered, and whether strawberries must be covered to insure a crop, will depend on the latitude. That all these may be grown in ample supply to meet the needs of the farmer need not be questioned, but the best methods of growing them are not generally understood as yet as

applicable to dry conditions. Nor has proper preparation been made for growing them, as on the bench lands where the winds blow freely and strongly it will be necessary to grow them inside of shelter belts when these have been provided. It will also be a decided safeguard where water can be readily obtained to have a small reservoir supplied by the windmill which lifts the water supply. This water reserve may not be needed in all seasons, but in those that are exceptionally dry it may be drawn upon, especially at that season when the crop is maturing and when it is more liable to hazard than at any other time. In some instances, grapes, if grown, would have to be covered in winter, and in the northerly areas it is questionable if summer frosts will admit of the complete maturing of the fruit.

By large fruits is meant such fruits as apples, pears, peaches and quinces. Apples especially may be grown in much of the semi-arid area, pears less well and peaches only in southerly areas. Some good apple orchards have been made a success commercially where the rainfall averages about 15 inches annually. Under such conditions, however, there is some hazard that the crop may suffer somewhat from lack of moisture during the ripening period: Under other conditions, as when subterranean water is near, this hazard may not be present.

Much of what has been said of small fruits will apply to the growing of vegetables, but of course it will not be necessary to confine the growing of these within shelter belts, nor is the severity of the winters to be reckoned with as in the case of fruits. Nearly all kinds of vegetables may be grown that belong to the temperate zone, but not so as to compete successfully in the market with vegetables grown under irrigation. This does not apply to the early varieties, as many of these may be ready quite as soon from non-irrigated as from irrigated land. It is in varieties that come on later that the gar-

dener with irrigating waters has a tremendous advantage, as he has also in the succession of garden crops which he may grow on the same land. Under specially favorable situations, the truck gardener in dry areas may make a success in his work, but, ordinarily, the dry farmer should be content with a supply of vegetables grown for home use. Some fruits may be yet introduced which in other countries have shown ability to grow under extremely dry conditions. The olive industry, which has been tried tentatively gives much promise of success. This fruit has been grown successfully in some of the countries of the old world where the annual average rainfall does not exceed 10 inches. It is also possible that the sycamore fig, the Chinese date, some nut-bearing trees and also some other fruits, may be grown successfully under equally trying conditions. It would not be possible to forecast at the present time the extent to which such fruits may be grown.

Trees and windbreaks in dry areas.—The discussion will dwell: (1) on trees for shelter; (2) on trees for forest growth, and (3) on trees for fence posts. There are areas in the arid country so completely arid as to preclude the hope of growing on them trees or shrubs of any kind. But the hope of succeeding with some varieties may certainly be cherished where the rainfall is not less than 10 inches annually. Where it is 15 inches, success is assured where proper methods are followed. As a rule the growing of windbreaks should precede the growing of trees, or at least it should precede the planting of the same. This at least is true of the Great Plains country, which to so great an extent is exposed to the action of strong winds. Trees planted to form windbreaks of the pliant order, as willows for instance, take much less harm from the rocking of the winds when they are young, hence the aim should be to have the windbreak well started before planting forests on its lee-

ward side, which is the proper place for planting them. It is doubtful if any tree will render greater service in furnishing a windbreak than the white or gray willow, but doubtless various other sorts may be used. The need for such windbreaks is very great, hence the farmer should try and make ready to plant a windbreak as soon as he begins work on his farm.

The extent to which forest trees will be, or should be, grown in the semi-arid country will depend much on the precipitation. That some of these may be grown successfully under very dry conditions is evidenced in the fact that nature has grown them unaided, as evidenced in the growth of such species as the yellow pine and the red cedar where the rainfall is very light. The same is true of the juniper. It would not seem probable, judging by the indications at the present time, that forest trees would be grown for lumber to any considerable extent on the benches of the semi-arid country, but of course what the future may bring forth cannot now be safely forecasted. Should groves be planted, however, the aim should be to start them inside of a windbreak.

As time goes on, the need for posts to aid in fencing the land will be felt. The wise farmer will set about providing for it at an early date. Where the mountains are not distant, a source of supply will be always accessible. Under other conditions, fence posts may be grown. Among the trees that are found suitable are the willow, the catalpa and the locust. The willow has highest adaptation for the Great Plains country, the catalpa for the middle regions of the semi-arid belt, and the locust for those central and south. All these will grow more slowly than in humid climates.

Cultivated crops that may be grown.—The discussion will include the following classes of crops that may be cultivated with more or less profit in dry areas: (1) cereals; (2) fodder crops; (3) legumes, and (4) various

other crops. These may be cultivated with more or less profit. Such cultivation will prove relatively more profitable under dry than under humid conditions, and chiefly because of the influence which it exercises on moisture conservation. The cultivation has reference to stirring the soil above and around the plants as shown in chapter XII, the implements used being the harrow and some form of cultivator.

There is no kind of cereal grown in the semi-arid country that will not be profited by some form of cultivation given to it during the period of growth. As a rule such cultivation will be given to cereals included under the head of small grains, by the aid of the harrow. More commonly these are sown by the grain drill in the ordinary way and the harrowing is done chiefly after the crops have reached the surface of the ground. Planting cereals in spaced rows has been tried, that is in rows wide enough to admit of cultivating between them, but the results obtained do not seem to justify the expense of such cultivation. This at least is true of the increase that such cultivation brings to the crop. It is doubtful, however, in such instances, if a sufficient allowance has been made for the influence which the cultivation given may exert on the next crop. Peas, probably more than any other cereal, have been thus grown in spaced rows, but the benefit from growing them thus has not been determined as yet. The degree of the harrowing that may be given to cereals is discussed elsewhere (see p. 156). For the place for these crops, see pp. 390-399.

With fodder crops the case is absolutely clear. Fodder crops as used here means the coarse fodders, as corn and the sorghums. Cultivation for these is absolutely indispensable. It is given while the crop has not yet appeared, and subsequently. It is given with both the harrow and the ordinary corn cultivator of various makes, and it is continued usually, or at least it ought

to be, until the crop gets too far advanced to admit of cultivating it longer. The place for these crops has already been referred to (see p. 199).

The legumes that may be grown are included in some instances in the crops previously discussed. Alfalfa, for instance, is included in the list of the hay plants and peas in that of the small grains. To these may be added field beans. It is at least questionable if alfalfa will be grown to any great extent in spaced rows and cultivated while growing in order to furnish hay, and for the reason that it can be grown fairly well without such cultivation. But it is more than probable that it will be grown thus for seed. The extent to which the seed industry may yet develop from seed grown on these lines cannot safely be forecasted at the present time. That the crop when grown for hay will be disced more or less severely every year when sown on the bench lands, is a foregone conclusion. The bean crop, which may be safely grown in much of the dry area, must be given careful cultivation while it is being grown.

Other crops that call for cultivation during the growth period include roots and tubers, fruits and vegetables, windbreaks and trees. All the field roots grown must be grown by the aid of cultivation, save in such instances as when the seed may be scattered broadcast on breaking. The same is true of potatoes and artichokes, save when potatoes are grown on breaking, the tubers being dropped beneath the proper sod furrow while the land is being plowed. The aim should be, however, to avoid growing them thus. The cultivation of fruit will be necessary from year to year under dry land conditions. Such cultivation will probably have to be kept up as long as the shrubs and trees are to be kept in bearing. Of course all vegetables will call for cultivation. The same is true also of windbreaks and forest trees. The cultivation of these must be kept up until the leaves will form a sufficient mulch to adequately protect them.

CHAPTER XI

GROWING GRAIN CROPS IN DRY AREAS

The chief of the small grains grown in Montana, and in fact in all the states north of Salt Lake City, include the following: Winter and spring wheat, winter and spring rye, flax, barley, oats, peas and speltz. The aim has been to name these in the order of relative importance viewed from the standpoint of possible profitable production based on the climate and soil conditions. But it does not follow that the relative importance thus assigned to them will correspond with the extent to which they will be grown by the farmer, at least for many years to come. There can be no question, however, about the place that shall be assigned to wheat in the semi-arid region. It will probably continue to hold the premier place among the revenue producing crops on the unirrigated land during the centuries that are yet to be.

GROWING WHEAT, WINTER AND SPRING

While both winter and spring wheat may and will be grown on the lands of much of the semi-arid country, winter wheat will, in nearly all instances, be the more important crop. This will follow, first, from the fact that it will produce much larger yields than spring wheat; such at least has been the case in all areas practically that have been found favorable to the growth of winter wheat. The difference will probably be not less than 50 per cent. in favor of winter wheat on the average. It will follow, second, from the fact that winter wheat will mature earlier than spring wheat and will, therefore, be much less injured by the drought and heat that characterize the summer months. It will follow, third, from the fact that it so changes the time of the sowing and the reaping, that the farmer can grow this crop without adding to the

expense for hired labor. The adaptations of the conditions for growing winter wheat successfully in the semi-arid country are indeed remarkable, whether the bulk of the precipitation comes in the autumn and winter months or during the period of greatest growth. The winter wheat crop, because of the very large yields that are frequently obtained, will, in many instances, pay for the land that grew it in a single crop. This does not mean that spring wheat may not be grown with much



DRY LAND DURUM WHEAT GROWN NEAR GREAT FALLS, MONT
Courtesy Great Northern Railway Co.

success in many areas, but that the attention should rather be centered on the growing of winter wheat where it may be grown with remarkable success.

Soils.—The soils of the larger portions of the arable farms of the western states have high adaptation for the growth of winter wheat. They are exceedingly rich in the mineral constituents that favor grain production, they may, as a rule, be easily penetrated by the roots of the wheat plants and they very readily retain moisture

that falls when properly managed. The clay loam soils and the sandy loam soils underlaid with clay, and the volcanic ash soils of the farther west, have very high adaptation for growing wheat with reference, first, to the food constituents which they contain; second, with reference to the easy penetration by the roots of plants; and, third, with reference to their ability to hold moisture. The proportion of the arable land that is well adapted to the growth of wheat in the semi-arid west is unusually large.

Soils that are unsuitable for wheat include alkali land, light coarse sands and soils that lie quite near the underlying rock. Alkali lands are unsuitable in proportion to the alkali and the degree of the same. Lands strongly impregnated with black alkali are wholly unsuited to the growth of wheat, and in fact all other crops, and the same is true of those strongly impregnated with white alkali. But small amounts of the latter are not seriously prejudicial if indeed prejudicial at all. Light and especially coarse sands will not sufficiently supply the plants with food and moisture, hence the yields on these will be small, and lands underlaid with rock near the surface will not sustain good growth under dry conditions.

Place in the rotation.—In dry areas, the place that wheat will occupy in the rotation will depend upon many conditions, such as the amount of the precipitation, the degree of the plant food in the soil and the mechanical condition of the same. Where the precipitation is about 20 inches, wheat crops may be grown from year to year with reasonable success on many western soils for a more or less limited number of years. The duration of these is proportional to the amount of fertility in the land. But the wisdom of such a rotation after two or three or even a larger number of crops are taken in succession after breaking the land, is to be questioned, because of the

drain on the fertility, and also on the humus, without any replenishing of either because of the increase in weed life which is sure to follow, and because of the increase of insect life and of fungous diseases that invariably results. When the precipitation is about 15 inches, one crop of winter wheat may be grown in alternation with summer-fallow for a number of successive years—how many, will depend on the store of plant food in the soil. The increase of weed and insect life should not obtain in this case, as in the former, but it depletes fertility and humus very materially, and because of this it is not to be commended, notwithstanding the fact that for several years there may be no diminution in the yields.

The aim should be therefore, in dry areas, to make winter wheat follow the bare-fallow or a cultivated crop, as corn, the wheat being drilled in between the corn rows in order to get it sown in season. In areas where the winters are cold, the winter wheat must have protection, as in the Dakotas. In such areas it may follow: (1) on the summer-fallow on which a small amount of corn has been drilled very late and left uncut to furnish protection; (2) between standing corn which is cut later, a few rows of bare stalks being left standing every few rods to furnish protection; (3) amid the stalks of some dwarfish kind of corn from which the ears have been removed in some way, and (4) when drilled in amid the stubbles, preferably of a barley crop because of the early harvesting of the same. Winter wheat is sometimes grown after a crop of winter wheat or other small grain, the land being plowed or disced. The practise is not a good one. If the autumn is dry, the crop will fail for lack of proper germination. Spring wheat should as a rule be grown on fallow land or on land that has produced a cultivated crop. It will follow a cultivated crop more frequently than winter wheat, as the cultivated crop is not har-

vested sufficiently early to admit of following with winter wheat.

The wheat crop should be followed by summer-fallow or by a cultivated crop where the rainfall is not more than 15 inches. Where the rainfall is less than 15 inches, a grain crop may succeed but it may also fail, dependent on the character of the season. The cultivated crop that follows will more probably be corn because of the extent to which that crop will be grown, but any annual crop that is cultivated will suffice. Where the rainfall is more than 15 inches it may be in order to grow two crops of grain in succession, especially after land that has been fallowed, but it is better to make the second some crop other than wheat.

The aim should be to avoid growing wheat after wheat in immediate succession, but it may be allowable under the following conditions: (1) Where the rainfall is between 15 and 20 inches per year while the land is yet new; (2) where the land is summer-fallowed every other year while the soil is yet new, and well stocked with plant food and humus; (3) where wheat and corn are grown in alternation for a number of years; (4) when a second crop is taken from land that has been summer-fallowed without re-plowing for the same. But in all instances it will be found necessary to modify these rotations after the land has been cropped for a number of years. In dry areas wheat should not be made to follow other grain crops.

Preparing the soil.—In dry areas the land is more frequently prepared for growing wheat by what is known as the summer-fallowing plan. It will also be much grown in the near future after a cultivated crop, especially after corn. But it will also be grown more or less by methods that are hazardous. These will be considered.

Land that is summer-fallowed will consist of breaking or of land that has been previously cropped. The method of handling is practically the same, and it is in outline as follows: It should be plowed when it has the largest amount of moisture in it. This, in the Plains country and in the prairies northward, will occur between the opening of spring, and, say, the first of July. June is the favorite month in which to do the plowing, as then the soil will probably have the largest amount of moisture in it, and in that month the farmers have time for such work. Where the precipitation falls in the late autumn and winter, the plowing should be done as soon as the moistened soil conditions will admit of doing the work.

The plowing should be deep on nearly all kinds of soil. The exceptions are light, sandy soils, and shallow soils underlaid with unresponsive subsoil. Such plowing may be costly at the first, but in the lapse of years the extra cost will be more than repaid.

When the land is thus plowed in the Plains region, it should at once be compressed, preferably the day that it is plowed. The objects sought in thus compressing it are, first, to so smooth and firm the surface that the implements of tillage that are to follow, especially the harrow, will do more effective work, and, second, to press the loosened soil so that the air and sun will not draw moisture so readily from the soil. But in areas where the precipitation comes mainly in the winter, such compression may under some conditions prove detrimental on certain soils. The aim in plowing these thus early is to allow moisture to penetrate them easily at a season of the year when the moisture is but little drawn from the soil.

The implements that will best serve these ends will depend, to a very considerable degree, on the character and condition of the soil. In some instances the smooth

roller will do effective work, especially in compressing newly broken sod. One objection to the smooth roller is that, while it firms the soil above, it leaves it uncom-pressed below. The corrugated roller will aid more in crushing lumps than the smooth roller where these occur. The planker will aid in levelling up the soil where this may be necessary, in powdering lumps, and in compressing the soil, but the compression is on and near the surface as in the case of the roller. On stubble land the subsurface packer should do good work, as it firms the soil below. On breaking and sod land generally, the disc does very good work when rightly used, and in the absence of a better implement it may also be used to compress stubble land.

The next operation is harrowing with the straight tooth harrow, the object being to form a dust mulch on the surface of the soil to prevent the escape of moisture that is continually moving toward the sur-face, save when it has enough water in it to result in a downward movement of the same. This dust mulch must be maintained through the season, chiefly, if not en-tirely, through the use of the ordinary harrow. The necessity for renewing the mulch will depend to a con-siderable degree on the frequency with which the summer rain falls, and also on the nature of the soil. The more frequently that rain falls on fallow land, and the greater the tendency to encrustation, the greater is the necessity for frequently renewing the dust mulch. When encrusta-tion follows, as it does usually after every considerable rain, the crust forms cracks in drying, and through the openings thus made the moisture will rapidly escape. The remedy consists in running the harrow over the ground promptly, as soon as it has become dry enough to admit of doing the work effectively and without any injury to the land. It is not necessary to use the har-row thus after every little shower that falls. Should

light showers fall frequently and at short intervals, the land will not form cracks or openings so numerously as after a heavy rain.

The fallow land must also be kept clean. This is imperative, as in proportion to the extent to which weeds grow on the land, just in that proportion will moisture be taken from the soil. Weeds will draw off moisture more heavily than grain plants because of their stronger inherent powers of growth. Should moisture be conserved during the early part of the fallowing process, and weeds are then allowed later to grow on the same, the weeds will remove the moisture thus conserved, and will thus so far undo what has been done. To prevent such a result, it may be necessary to use the harrow more frequently than would be necessary for renewing the dust mulch to prevent the escape of moisture. Annual and biennial weeds may be most easily destroyed when they are just beginning to grow. But the use of other implements may be necessary in order to destroy perennial weeds and volunteer grains that have become deeply rooted (see p. 120).

When the bare-fallow has been managed thus, in nearly all instances, there will be moisture enough in the same to germinate winter wheat when sown on fallow land, even in very dry seasons. But to this there may be some exceptions, as when the ground is lacking in moisture in the spring when it is plowed, and when no moisture virtually falls on it subsequently. Such was the condition of fallow land in the spring and autumn of 1910. In numerous instances, when the winter wheat was planted it did not germinate. But this will seldom occur.

When wheat follows a cultivated crop, the treatment of the land that is best suited to the needs of the cultivated crop will also be best suited to the needs of the wheat crop that follows. The cultivated crop that may be

thus grown will include corn, potatoes, field roots and beans, and in some instances peas, more especially of the dwarfish varieties. When a cultivated crop is grown on land, and when the work is rightly done, the land has been virtually summer-fallowed. The objects sought in the cultivation are virtually the same, viz., to prevent the escape of moisture, and also the growth of weeds. The crop



DRY LAND KUBANKA WHEAT, FERGUS COUNTY, MONTANA.

Courtesy Northern Pacific Railway Co.

thus cultivated during the process of growth draws on the soil moisture in proportion to its needs. This drain may be considerable, especially when the growth is strong. The soil moisture will, therefore, be reduced by the amount thus used, hence it is reasonable to conclude that the soil which has produced a cultivated crop will contain a less amount of moisture than summer-fallowed land alongside of it. But experience has shown that where

the rainfall averages 15 inches per annum the soil will contain enough moisture after a cultivated crop to produce a reasonable crop of wheat or other small grain, even in a very dry season. The average annual precipitation that is necessary to insure a profitable return in wheat or other small grain after a cultivated crop has not yet been determined. Of course it can only be determined approximately, but on many soils it would seem safe to say that such a result may be looked for where the annual precipitation is even less than 15 inches, as low probably as 12 to 13 inches.

Sowing.—The following methods of sowing winter wheat are somewhat hazardous, notwithstanding that they are frequently tried in the semi-arid belt: (1) Sowing on plowed or disced land after a crop of small grain; (2) sowing amid the stubbles without plowing; (3) sowing very late in seasons when moisture is much deficient in the land.

In the coldest portions of the dry belt, as the Dakotas and portions of Canada, wheat cannot be depended on to pass the winter safely on stubble land, either disced or plowed. In areas less cold it may not germinate properly, nor indeed at all, before the following spring. Of course, if the ground is moist when the seed is sown, it may produce a good crop, but this seldom happens. The practise is defended on the ground that though the seed should not germinate properly the only loss is the seed, which is usually not more than three pecks per acre, and the labor of sowing it. In this justification there is some force, and yet the practise is hazardous.

When wheat is drilled in amid the stubbles after the grain has been cut, a reasonably good crop is sometimes secured even in the colder portions of the semi-arid belt, but the hazard is present, first, that the seed may not germinate sufficiently early in the autumn because of the lack of moisture, and, second, that the

yield will be small should a dry season follow, because of lack of sufficiently vigorous growth. The object sought in planting wheat thus is to insure protection for the plants in winter through the holding of the snow, and by the breaking of the force of the cold winds because of the presence of the stubbles. When winter wheat is thus sown the ground should not be disced previously to the sowing, as this would to a considerable degree remove the protection from the plants. The land should also be free from weed life, else the weeds will crowd the next season. Barley stubble is usually preferred for such sowing, as the crop may be removed early to admit of sowing the wheat early.

Winter wheat may be sown so late in some localities that it will not germinate before the advent of winter. Reasonably good crops may be obtained in this way, but they seldom or never equal those crops that are sown in season. This method of sowing can only be made to succeed where the winters are not severe, and even in these it is not to be commended. There is the hazard that germination will be imperfect and the plants begin to grow so late that they have but little advantage over spring wheat plants as to the time of maturing. Should the seed not germinate until the arrival of warm weather in the spring it is not likely that it will reach the heading out stage. The time beyond which late germination will fail to produce heads has not as yet been well defined.

Where the conditions are suitable winter wheat is to be preferred to spring wheat for reasons already given. The winter cold of the Dakotas, and of the portions of Manitoba and Saskatchewan included in the dry belt, makes the growing of winter wheat considerably more hazardous than that of spring wheat. In nearly all of the remaining portions of the semi-arid country, the conditions are more favorable to the growth of winter wheat, and more especially where the larger portion of the

precipitation falls in the winter and early spring. Where the two crops grow about equally well, the greater hazard to spring wheat of injury from drought is probably more than offset by the hazard to winter wheat which may result: (1) from germination started but not completed; (2) from alternate thawing and freezing which in some localities may do harm where the winter precipitation is considerable; (3) from drying winter winds accompanied by protracted periods of severe cold.

In the semi-arid areas hard and semi-hard wheats of both winter and spring varieties are chiefly grown. The growth of the latter, all of which incline to softness and starchiness of varying degrees, is chiefly confined to Inter-mountain areas. They are being superseded with more or less quickness by the hard wheats, because of the superior milling qualities of the latter.

The variety of hard winter wheat most in favor is the Turkey Red, south Russian in its origin, and the Kharkow or Kharkov, not greatly dissimilar. The Turkey Red is hardy, yields well, and is of high gluten content. It is now being grown in all the Great Plains country that is not too cold for the successful growth of winter wheat. It is probable that these varieties will yet displace to a very considerable extent the semi-hard wheats of the Inter-mountain states. The principal varieties of the latter are of the Defiance type, but various other varieties are still much grown. In eastern Washington and Idaho the Palouse Blue Stem, the Forty Fold and Red Russian are popular. In eastern Oregon the Red Chaff and Foise are in favor. In California and other southwestern states the Little Club and Defiance are much grown.

The spring wheats most in favor in the more humid portions of the dry areas are Red Fife and Blue Stem, which are in high favor in the Dakotas and in Manitoba and Saskatchewan. They are of excellent milling qual-

ty, but they do not grow under very dry conditions as well as the Durum varieties. The latter are resistant to drought in a marked degree and they also yield relatively well, hence they will be much grown in the more dry portions of the semi-arid areas. They are less high in favor for milling than the Turkey Red, the Red Fife and the Blue Stem, and consequently do not bring so high a price. The Kubanka is the favorite Durum



DRY LAND DURUM WHEAT, CASCADE COUNTY, MONTANA.

Courtesy Northern Pacific Railway Co.

wheat. In dry areas Durum wheats yield much better than other spring wheats as a rule.

In Washington, Oregon, Idaho, Utah and states of the southwest, club or square headed wheats are much grown, and for the reason that they do not shatter readily when ripe. Because of this quality they are well suited to being harvested in a large way by headers and combined

machines which head and thresh the grain in one operation. The Polish and Macaroni wheats, being drought-resistant and good yielders, are in some instances grown for feed.

The time to sow winter wheat is influenced by latitude and altitude. The difference between the best season for sowing the crop in the extreme northern area of the wheat belt and the extreme southern is more than a month. In the northern areas winter wheat must be sown earlier and spring wheat later by the difference mentioned. In these areas August is the favorite month for sowing winter wheat; in central areas September and in southern areas October. Sowing thus early gives the plants stronger and deeper root growth, which enables them better to withstand winter weather, and it gives stronger top growth, which furnishes better winter protection. In southern Alberta and in some parts of northern Montana, wheat is sometimes sown in July, but sowing thus early may tend in some instances to incur the hazard, first, of infection by the Hessian fly, and, second, of drawing so much on the powers of the plant that growth the next year will not be sufficiently vigorous. This to some extent may be checked by grazing. Early planting is usually to be preferred, as it may prevent loss by drought in the later fall, heaving by frost, and drying out and perishing by cold.

Generally speaking, spring wheat may be sown as soon as the ground is fit for cultivation in the spring. This may not always apply where the winters are characterized by warm spells, followed by severe freezing weather. About parallel 49 wheat sowing is usually done in the latter half of April, though in some instances it is sown earlier. Where the frost goes deeply into the soil, sowing on autumn-plowed land may frequently begin while the frost is not yet melted far down below the seed bed.

Sowing wheat on the broadcast plan should never be attempted in dry areas where it can be avoided. It is impossible to bury the seed so that the germination will be even and complete. In humid areas such sowing is attended with much less hazard. Sowing with the drill has the following advantages: (1) The seed is distributed uniformly and is buried at an even depth. (2) It may usually be sown where the soil is sufficiently moist to insure germination. This may not be possible in many instances with much of the seed sown on the broadcast plan. (3) The pressing of the soil around the seed, which is favorable to quick germination. (4) A saving in the amount of seed called for. This saving is probably not less than one peck per acre. (5) Burying the plants so deeply that they may be harrowed at certain stages of growth without the hazard of taking many of them out.

There may also be the advantage in some instances of protection in winter through the depression made by the drill marks. To some extent these tend to shield the plants from winds and to cover them with snow.

In nearly all soils the press drill is a favorite in dry areas but there may be conditions when the shoe drill may answer better. The size of the drill may be suited, of course, to the needs of the farm. When the wheat is sown amid standing corn of normal size, it is put in with a small seeder drawn by one horse which runs between the rows. The large drill is used for sowing the crop amid corn stalks of some low growing varieties which are not to be removed but from which the ears have been taken.

The depth of planting depends on the kind of soil, its physical condition, and its moisture content. The more sandy the soil, the looser it is, and the farther from the surface that the moisture is the more deeply may the seed be planted.

When the moisture is sufficient at the time of sowing the seed, there would seem to be no advantage from sowing it more deeply than 2 to 3 inches. But when moisture is lower down, winter wheat especially may be put down 3 to 4 inches in order to reach it. Fairly deep sowing tends to aid the plants in severe winter weather and also in time of drought.

The quantity of seed to sow varies with the soil, the time of seeding, the variety and the climatic conditions. A good soil, under dry conditions, can take more seed than would be suitable for a poor soil. Late sowing calls for more seed than early sowing, as the plants stool less. The large wheats call for more than the small ones. The more moisture that the soil contains, the thicker may be the seeding. It would seem correct to say that about half the amounts of seed called for in humid areas will suffice for dry areas. When the plants are present in too large numbers, there is not enough moisture in the soil to meet their needs. They will be dwarfed in their growth. The heads will be unduly small, nor will the grains in them be of normal size. Early in the season the thicker stand will be the more promising, but this condition will probably be reversed at harvest time. The plants of a thin stand will stool more than those of a thick stand. Ordinarily with a rainfall averaging 15 inches, 3 pecks of the small grained wheats will suffice per acre when sown on good land. Of the larger grained wheats, as the Macaroni, 4 pecks may be needed. Where the rainfall is much less than 15 inches, the seed may be reduced by, say, one-half peck. Where the rainfall is not more than 10 inches, one-half bushel may suffice. Some authorities recommend sowing very small quantities of seed, as low as 20 to 30 pounds per acre. Such small amounts would seem to be too low for average conditions. It is safer to err in sowing too much seed than in sowing too little, as when the plants are in ex-

cess their numbers may be reduced by the aid of the harrow to any thickness of stand that may be desired.

Care during growth.—Under some conditions no further care of the crop may be necessary from the time that it is sowed until it is reaped. Under other



DRY LAND WHEAT, 50 BUSHELS PER ACRE.

Holter Ranch, Lewis and Clark County, Montana.

Courtesy Great Northern Railway Co.

conditions it may be more or less advantageous to harrow the crop after it has begun to grow. In other instances it may be advantageous to use the roller, and yet again it is considered helpful to the crop to graze it off in the autumn when the top growth is over-rank and strong.

In the autumn when moisture is sufficiently present, and when the soil does not encrust, it may not be necessary to use the harrow or the roller on the crop at that season. Oftentimes either implement is so used, but in instances not a few it will be found advantageous to use the harrow when the grain plants begin to show. One objection to autumn harrowing is found in the obliteration of the depressions made by the grain drill, which to some extent may increase the hazard to the plants from winter exposure. In the spring there is a decided tendency to encrustation in much of the soil of the west that has been sown to winter wheat. The crust formed must be broken to prevent the escape of moisture, to furnish the necessary aeration and to accelerate the formation of nitrates. Usually the best implement to use in order to accomplish these ends is the harrow. The time and manner of the first harrowing will depend somewhat on the strength of the grain, the character of the soil, and the degree of the encrustation. If the grain plants are small and delicate the harrow used must be light, so as not to bury or tear out the plants. If the soil is loose and not impacted, it may not be necessary to use the harrow. If the soil is very compact and much encrusted, it may be necessary to use a heavy harrow, the teeth being erect and the harrow weighted; and there may be instances in which the disc rightly used or the alfalfa renovator will render better service. Instances are on record in which winter wheat has been severely disced with positive advantage to the crop. The encrustation must be removed if the crop is to make a sufficient growth. This work should be done as early in the spring as it may be done without injury to the land. Proper stirring of the surface at the right time may prevent such encrustation. The subsequent harrowings called for will be largely dependent on weather conditions. Some seasons one harrowing may suffice. At other times the crop may profit from

several harrowings. Wheat has been harrowed with profit when it has reached the height of one foot, but harrowing at a stage of growth thus advanced is seldom necessary.

The number of the harrowings called for by spring wheat may run from none at all to fewer than four or five, but under what may be termed normal conditions, it will seldom be necessary to harrow more frequently than two or three times. In many soils the weeder may



DRY LAND HEADED WHEAT.
Culver-Opal City District, Oregon.
Courtesy Northern Pacific Railway Co.

do more effective work than the harrow, especially when these are very loose, but when on impacted soils the weeder will be found of but little use.

Should the soil encrust in the autumn, it may be advantageous to use on it a corrugated roller instead of a harrow, more especially when the soil calls for firming below. But it will seldom be advantageous to use this implement in preference to the harrow on spring wheat or other grain sown on autumn-plowed land.

The extent to which winter wheat may be pastured in dry areas will depend: (1) on the severity or lack of

severity in the winter weather: (2) on the advancement of the grain as the result of early sowing, and (3) on the amount of the rain that falls in the autumn months and the period covered by such rainfall. Where the autumns are short and dry and the winters are long and severe, winter wheat should seldom or never be pastured, as pasturing will remove the covering which the top growth would otherwise furnish. In other words, the aim should be to avoid the necessity for pasturing winter wheat in areas where protection for the crop is in a sense a necessity. When the crop is sown quite early, as early as July or early August, in seasons of more than the usual amount of precipitation, the growth may become so advanced that grazing will be advantageous to the crop. In some areas, as, for instance, the Flathead valley in Montana, where the autumns are long and moist, the preceding summer weather being usually dry, the grazing of winter wheat is regularly practised. It is followed, in part at least, to obtain a source of autumn pasture, which from other sources is usually in short supply. The profit from such grazing, though apparently seldom challenged, is more or less problematical as far as the author has been able to ascertain. No experiments have been conducted to test the influence of such depasturing on the yields of the crop, nor have any been conducted to throw light on the question as to the best season for grazing the same. When the winters are mild and the precipitation is considerable at that season, care must be taken to avoid grazing should the soil be unduly wet.

Harvesting.—As far as practicable, the crop should be harvested at an early rather than a late stage of ripening in order to prevent shelling in the grain. This does not apply equally to the club varieties of wheat, as these do not shell readily. But it does apply to such varieties as the Turkey Red, and wheat of the Durum types. The loss from these through shelling as a result

of being whipped about by the winds after reaching maturity may be material. Such loss is increased by the plumpness of the grain, which favors loss from the source named. The more plump the grain, the more readily does it shell. Wheat is ready for being harvested when the stem has turned yellow for a few inches below the head. The culms will at the same time have assumed a yellow tint for several inches from the ground upward, notwithstanding that the other portion of the stem may be still green. A few days delay in cutting may result in very serious loss through shelling, but this does not apply to the club or square-head varieties.

Except when grown in very large areas, wheat is harvested with the grain binder, stood up more commonly in round rather than in oblong shocks, and threshed from the shock. In dry areas wheat is not commonly stacked, as rains during the harvest season are almost unknown. Shocks well made will usually stand for several weeks without injury, save what may come through birds and rodents.

When grown in a large way in the dry west, wheat is harvested, in many instances, by the aid of the header. This machine cuts off and gathers the heads without removing the straw. The heads are thrown into heaps until they can be threshed. Should rain fall before the time of threshing, the grain may be seriously damaged, but this very seldom happens. This method of harvesting, which is relatively cheap and very expeditious, is almost universal where the club varieties of grain are grown in a large way. But when the grain is very short it may leave many heads ungathered.

Where very large areas are grown, the crop is sometimes harvested by using the combined header and thresher. This machine, which is, in some instances, drawn by 25 to 30 head of horses or mules, or both, heads the grain and threshes it in the one operation. It

is left in sacks, which are dumped on the ground from the platform of the machine as threshed. The sacks are then gathered and drawn to the railroad station to be carried by rail to the place of shipment or of final use. The dry harvest conditions make this method of handling grain entirely practicable.



HARVESTING 600 ACRES TURKEY RED WHEAT WITH A COMBINED HARVESTER IN ROSEBUD COUNTY, MONTANA.

Courtesy Northern Pacific Railway Co.

Where the crop is threshed from the shock, the work is usually done by machines which go from place to place. Some of these take their own crews along with them with board and lodging. This method of threshing is very convenient for the farmer, but it is usually costly because of the prices charged. It will doubtless be found economical for several farmers to combine and buy a small thresher and do their own threshing.

The yields, of course, vary with the conditions. Crops of winter wheat have been grown giving yields of 60 to 70 bushels per acre. These are, of course, very exceptional and rare. On summer-fallow land and after a cultivated crop, the average should not be less than 25 bushels. Drilled in amid the stubbles of a preceding crop of grain, it will usually be much less. Maximum crops of spring wheat may be placed at about 40 bushels, with an average of, say, 15 to 20 bushels in well prepared soils.

GROWING RYE, WINTER AND SPRING

The place assigned to rye in the past in semi-arid areas has been of but little significance. The great use that may be made of it in such areas is not, apparently, well understood by many of those who till the soil. In wide areas its growth has not been attempted, notwithstanding that it may be grown with advantage for more uses on the farm than any other cereal. These include growing it: (1) for the grain; (2) for hay; (3) for pasture, and (4) for green manuring. The methods to be followed in growing it for these several uses are, fortunately, nearly the same. The chief difference lies in the amounts of seed to use, but there is some difference, also, in the time that is most opportune for sowing the seed.

Rye, especially of the winter varieties, may be grown under a greater variety of conditions than any other cereal adapted to semi-arid areas. It is the hardiest of all cereals viewed from the standpoint of climatic conditions. It would seem correct to say that it will stand more heat and drought than any of these. With reference to cold, it is the hardiest of the cereals, by far. The variations in the time for sowing it are greater, and it will grow on a greater variety of soils. It may be grown successfully in the coldest portions of the semi-arid west

and with almost unfailing certainty, when it is properly grown. Compared with wheat, it will grow on a poorer soil, in colder latitudes and under drier conditions. It is also much more valuable as a pasture crop, owing in great measure to the long period through which it will grow when kept down by rather close grazing. In this way it has been kept in the soil and producing for two or three seasons under conditions peculiarly favorable to its growth. The straw has not as yet been used in certain industries in the west as it has been in the east, but there are no inherent reasons why it should not come to be so used. One of the chief objections to growing it in a country adapted to the growth of winter wheat is the extent to which it volunteers from shattered grain.

Soils.—Other things being equal, the returns from rye will be liberal in proportion as the soils on which it is grown are rich in the elements of plant food. But it is usually sown on land relatively low in fertility and under conditions of preparation that are inferior, the better soil, and that also with the better preparation, being reserved for crops that are less able to grow under hard conditions. Rye can gather food more readily from the soil than other small grains, hence the power which it has to grow on poor soils.

The best soils for rye are those that are deep, rich and friable, and in which the subsoil is reasonably open rather than dense. A sandy loam is more suited to the needs of the crop than a dense clay loam. Under some conditions it may be grown with considerable success on light sands, even light enough to lift more or less with the wind. The largest yields, however, will be obtained from soils in which the clay element is quite pronounced. It would be correct to say that rye may be successfully grown on the major portion of the tillable soils of the semi-arid west.

Soils that are illly adapted to the growth of rye are those that are over-impregnated with alkali, those that are known as pronounced gumbo, those that consist largely of coarse gravel, and those that are quite shallow and underlaid with hard-pan or rock. Reasonably good crops may be grown where the alkali is not too pronounced and also on gumbo soils under some conditions. The chief difficulty with the latter is mechanical. They are not easily tilled.

Place in the rotation.—No cereal grown in dry areas can so readily accommodate itself to a rotation as rye. It would seem correct to say that it may be assigned any place in the rotation, but not, of course, with equal adaptation.

It will grow excellently well on summer-fallow land or on land that has produced a cultivated crop, but land thus prepared can seldom be spared for rye. It will grow well on sod land that has been properly prepared. The winter variety may follow a crop, as described below (see p. 239), when it is to be used first as pasture and later for the purpose of providing grain. It may also be drilled in between the rows of standing corn late in the season or sown later if the land can be spared for such a use. Spring rye will follow a grain crop with more of certainty in its growth than almost any other cereal, providing the land has been properly prepared.

As rye is more commonly sown on land out of condition than other crops, the aim should be to follow it with the bare-fallow or with a crop that calls for cultivation during the period of its growth.

More commonly rye will follow grain than any of the other cereals for the reason that under such conditions it may succeed where other grains will fail. Where the precipitation is considerable in the autumn months, rye may be sown on newly plowed stubble and and yet succeed. Where the rainfall is short, it suc-

ceeds better when simply drilled in amid the stubbles. But the best crops of rye are grown on land that has been cultivated or that has been summer-fallowed.

Preparing the land.—The preparation given to the land when preparing it for rye is usually less perfect than that given to it when preparing it for wheat. This does not mean, however, that careful preparation of the soil for rye will not be as abundantly repaid as it would be in the case of wheat, but it does mean that rye will grow better relatively than wheat under imperfect preparation of the soil.

When rye is grown on summer-fallow land, the conditions of preparation are virtually the same as for wheat (see p. 218). The same may be said of it when it follows a cultivated crop, with the difference, however, that after such a crop rye may be sown later than wheat. It may usually be sown with safety after such cultivated crops as corn and potatoes have been removed from the land.

When rye is sown early in the season, as early as, say, June or July, in order to provide pasture for live stock, the land is best prepared by plowing it the previous autumn. Before it is so plowed it may be a wise plan to disc it. But when not so prepared it may be plowed in the spring, especially in areas where the precipitation comes mainly during the period of growth in the crops.

Notwithstanding the hardiness of winter rye, it is easily possible to sow it under conditions that invite failure. These include: (1) sowing so late in the season that the plants do not germinate at all, or if they do germinate they are so delicate that stern winter weather will destroy them; (2) sowing winter rye on land in the dry autumn that has not in it enough moisture to produce healthy germination or, indeed, any form of germination; (3) sowing winter rye in the early spring. It

will grow vigorously for a time, and may thus be made to provide considerable pasture, but it will not reach the earing stage, at least under many conditions.

Sowing.—With reference to varieties, but little can be said. Rye is simply rye in the mind of the western farmer, but in time there will be distinct varieties of



DRY LAND RYE.
Holter Ranch, Lewis and Clark County, Montana.
Courtesy Great Northern Railway Co.

rye, some of which will no doubt be possessed of superior merit. Some foreign varieties have already been introduced which promise considerable in the line of increased production.

Rye of the winter varieties may be sown at any time from, say, early June until late September or even Octo-

ber, according to the object for which it is grown. When sown to provide grazing, it may be sown as early as, say, June or July. When thus sown, it will furnish grazing during the summer and also the following spring. But the amount of the grazing the following spring may not equal that of rye that has been sown later, and that has not been so grazed the preceding autumn. When rye is sown to produce some grazing autumn and spring, followed by a crop of grain, it is more commonly sown in August or September. When it is sown late to provide grain, as in October, it will usually be wise not to graze at all, either spring or fall, because of the somewhat delicate character of the growth.

The method of sowing is much the same as for wheat. The aim should be, in all instances, to sow rye with the drill rather than broadcast, for reasons that will be apparent. Especially is this true of rye that is sown amid stubbles. When thus sown the drill buries the seed to a depth that will enable the plants the better to resist the influences of adverse winter weather. When sown amid standing corn, the small one-horse drill must needs be used. When sown after the corn has been harvested, the ordinary seed drill will do the work sufficiently well, but there may be instances in which the disc or the disc and harrow may profitably precede the drill.

Rye should be buried to the depth of 2 to 3 inches in the soil under average conditions, but there may be instances in which the seed should be buried more deeply in order to reach soil moisture; especially is this true in the dry autumn. The more deeply that the seed is sown up to a certain limit, the better will it withstand drought, and the less easily will it be injured by the harrowing process.

Rye does not stool as much as wheat and oats, and therefore should be sown somewhat more thickly, espe-

cially when compared with wheat. When sown for the grain, not fewer than, say, 5 pecks of winter or spring rye should be sown where the rainfall is about 15 inches for the year. When sown for pasture mainly, or for hay, as much as 2 bushels of seed may sown. The grazing of the plants reduces the drain on soil moisture that would otherwise follow. When sown for burial, reasonably thick seeding, as in the case of sowing for pasture, will best serve the purpose.



DRY LAND RYE, ROSEBUD COUNTY, MONTANA.
Courtesy Northern Pacific Railway Co.

The care of rye.—The care of winter rye involves, chiefly, the harrowing of the crop and the pasturing of the same. Much that has been said with reference to the harrowing of winter wheat will also apply to winter rye. But when winter rye is sown as early as, say, June or July, to provide autumn pasture, it should be harrowed more times than winter wheat and usually in pro-

portion as the season for growth is longer in the former than in the latter. The rye crop, like the wheat crop, may also call for discing rather than harrowing in the spring-time, because of the impaction of the land. The same may be true of the crop while it is being grazed.

When sown early for grazing, the grazing should be close, or the rye may tend to exhaust itself and also to draw too heavily on the moisture in the soil. When sown in the fall season at the usual time for furnishing grain, there are instances in which the crop may be hurt by leaf rust if left ungrazed. But when sown late the crop will produce more grain, as a rule, when not grazed either autumn or spring. In the semi-arid country, rye should not be grazed with undue severity when a grain crop is to be obtained from it, nor should spring-sown rye, as a rule, be grazed when it is to produce a crop of grain. Close grazing in the spring will materially prolong the season of pasturing, as it tends to prevent the formation of heads.

Harvesting.—Rye is ready for harvesting when the stems turn yellow for, say, 9 to 12 inches below the head. While it is greatly important that it shall be promptly harvested to prevent scattering seed that may volunteer later, it will not take injury so readily as wheat from deferred harvesting, as it does not shell so readily as some kinds of wheat, nor does the straw break down so readily.

On small areas it is usually cut with the grain harvester and cured in round shocks in the field. In large areas it may be headed like wheat. In sufficiently large areas the combined header and thresher would be the proper implement to use, but it is seldom grown on a scale so extensive as to justify this method of harvesting.

It may be threshed as wheat (see p. 233). It is seldom or never fed in the sheaf when grown alone. The grain, judiciously fed, makes excellent food for all classes

of live stock, and in some countries it is extensively used in making bread. The yields vary greatly. The yield will be about 15 to 18 bushels per acre. Maximum yields run as high as 40 bushels.

When harvested for hay it should be cut from the time of early bloom until the grain has neared the dough stage. At the latter stage the hay will probably contain more nutriment, but it will be less palatable because of increase in woodiness. It does not make first-class hay. It may be cut for hay with the mower, but preferably with the binder and cured in long rather than in round shocks.

For green manure.—In the semi-arid country, rye may be buried for green manure with greatest advantage when the land is to be summer-fallowed. When buried so that a spring crop may follow it the same season, the burial will take place too late to meet the needs of the crop if the rye is to be buried at that stage which will be most helpful to the land. The crop should usually be buried when it is nearing the earing stage, but before the ears appear, as, if the rye is allowed to reach a stage of growth too advanced, it will not decay quickly enough in a dry soil. Impaction should follow the burial of the crop to hasten its decay.

GROWING FLAX

Next to wheat, flax will be the most important cash crop grown on the bench lands of many parts of the semi-arid west, and more especially in the Great Plains region, where much of the rain falls during the period of growth. It will grow on a relatively small amount of rainfall, and it may be grown with more success than any other cereal on spring-plowed land in a season when the moisture supply is not plentiful.

Soils.—Flax will grow well on any of the soils of the semi-arid west that will grow goods crops of wheat.

This means that it will grow on the major portion of the tillable area in the same. The best soils for this crop are the clay loams of the benches that are sufficiently supplied with sand to make them readily friable. Flax, like other cereals, does not grow well on light sands or coarse gravels, on cloddy soils, on those that cement readily on the surface after rain or on alkali lands.

Place in the rotation.—Flax may be given any place in the rotation where the conditions pertaining to growth are suitable, but the crops furnished will differ greatly with the rotation. The best crops will probably be obtained from it when grown on land carefully summer-fallowed or after a cultivated crop, but land thus prepared is usually devoted to the growing of a plant less rugged than flax. Overturned sod, whether heretofore unbroken prairie or other sod, furnishes an excellent preparation for flax. Because of this, it is very frequently made the first crop on new breaking, and for the further reason that it is the safest grain crop that can be grown under such conditions, especially when the sowing is not too long deferred. Where the normal rainfall is more than 15 inches, flax may frequently be made to follow a grain crop, but where it is less, such sowing should be avoided. On new land it is quite feasible to grow two crops in succession with good, healthy seed, but such a rotation is not to be commended. Under some conditions it may be in order to follow flax with grain. The plan, however, is safer which follows flax with summer-fallow or with a cultivated crop, as corn. The flax crop dries out the soil and loosens it to such an extent that the hazard to the next crop from drought is increased. The prevalent idea that flax should not be grown on land more frequently than every six or seven years is not well founded, providing the conditions for growing it are right and the seed is free from disease germs.

Although flax is more frequently grown as the first crop on breaking than any other crop, unless it be wheat, the wisdom of making it the first crop in preference to wheat is to be questioned. Experience has shown that when wheat is the first crop and flax the second, the returns from the crops that follow, covering a period of, say, four to five years, will be greater.

Preparing the land.—Flax calls for a seed bed fine on the top and firm below, though good crops have been grown on a seed bed rough and soddy. One that has a smooth as well as a fine surface is much to be preferred, as the crop grown on it may be harvested with much less loss by waste. A properly prepared summer-fallow or a cultivated crop well cared for furnishes an ideal seed bed for flax. As the crop is not sown very early, careful attention should be given to the conservation of moisture, subsequent to the advent of spring, by the judicious use of the disc or harrow or both.

When sod is broken for flax in the early summer, it is managed on the summer-fallow plan (see p. 170). When sown on spring breaking, the land should be plowed, if practicable, in the early spring and as deeply as 6 inches. It should then be pressed down at once with a roller and disced and harrowed until a fine seed bed is made, and as free as possible from sods. The seed should be sown, as a rule, not later than May 15th, to avoid undue hazard should the season turn dry. This does not contradict the fact that good crops of flax may be grown on sod land plowed quite shallow and in many instances left unsown as late as June 15th, in northern areas, but in all such sowing there is the hazard that failure may follow.

When wheat or other grain is the first crop, and when the breaking has been done fairly deep and flax is sown as the second crop, it would seem to be the better plan to prepare the ground for flax by discing it

rather than by plowing, that the sod buried may not again be brought to the surface until it is more decayed. The first discing should be given as soon as possible after the harvesting of the grain and the second the following spring, with such harrowing as may be necessary.

Sowing.—But few varieties, or strains even, of flax have been introduced into the United States, much less into the semi-arid country. In the latter it is grown exclusively for grain production, and only what may be termed the common variety is sown. Improved strains will doubtless come in the near future.

The time of sowing varies much, even in the same locality. In common practise it covers a period of fully six weeks. In proximity to the Canadian border, the period during which flax is sown runs from, say, May 1st to June 15th. The common idea that flax is easily destroyed by frost in the spring is not well founded. It will not stand so much frost as wheat and some other crops, but spring frosts of considerable severity will not kill it. To eliminate the elements of hazard from flax on spring-plowed land in a dry season, it should be sown not later than May 15th. This does not mean that in some instances good crops may not be grown on spring-plowed land sown late, and which was also plowed late and shallow. The favorite time for sowing flax in northern areas is the month of May. Southward it should be sown earlier. The hazard from late sowing comes, first, from dry weather that may follow the sowing, and, second, from frost that may overtake the crop when in the boll stage.

Before sowing flax, unless the farmer is fully assured that the seed is absolutely free from wilt spores, he should not fail to treat it with a 40 per cent. solution of formaldehyde and water. One pint of formaldehyde is used to 40 gallons of water. The solution is best applied with a spray pump that will throw a fine

spray. When applying it to the seed, it is spread thinly on a floor. While one person sprays the seed, a second person rakes it over to prevent the seeds from adhering as they would if not so stirred. The dampening should be thorough and complete. The seed should then be covered with a covering of some kind for a couple of hours, that the fumes may have opportunity to permeate the mass. When this dread disease once gets into the soil, it remains in the same for several years, and while it does, flax should not be again sown on such land.

It is much safer to sow flax with the drill than broadcast, as complete germination from drill sowing is much more sure than from broadcast sowing. The hazard from broadcast sowing increases with the lateness of the sowing and increasing dryness in the weather. On many soils the press drill does the best work, as its use facilitates quick germination in the seed.

The seed should, as a rule, be sown shallow rather than deep. In loose and very porous soils it may go down to the depth of 2 to 3 inches. In heavy soils and moist, it may not be buried more than 1 to 2 inches without weakening the early growth of the plants. Flax seed has not much power to sustain growth in plants that are buried deeply before they reach the surface. In dry weather, nevertheless, the seed must be put down to moisture before it can reach the surface.

The amount of seed to sow will run between the extremes of 1 and 2 pecks. On well prepared land $1\frac{1}{2}$ pecks per acre will suffice, where the rainfall is about 15 inches in a year. Where the seed is purchased, the farmer should guard carefully against the introduction of foul weed seed.

Care of the crop.—After flax has been sown, but little can be done with it to promote growth by way of manipulating the soil, as the plants are easily injured when young. If the crop is sown on land more or less

cloddy, or soddy on the surface, or covered with no little trash, as when strong stubbles are prepared by discing for receiving the seed, the harrow can seldom or never be used on such land after the crop is up, without doing more harm than good. This means that the harrow cannot be used on a flax crop sown, as it so frequently is, on land plowed shallow and on which pieces of broken sod are strewn. The harrow may be used, however, in some instances, if the land becomes much encrusted on the surface soon after sowing the flax, or even at a later period. When the surface is smooth and fine, the harrow may, in many instances, be used with advantage when the plants are, say, 3 to 4 inches high. When the ground is cloddy, the roller or the planker should be run over the land before sowing the seed. The weeder will, in many instances, serve a better purpose than the harrow on a growing crop.

Harvesting.—The crop is ready for harvesting when the greater portion of the bolls have turned brown. The stems will still be green. The cutting should be promptly done in dry areas, as the crop usually ripens up quickly, and if not cut until over-ripe, much loss may result from the shedding of the bolls during the process of harvesting.

The crop is best cut with a reaper that will lay the grain in loose sheaves of suitable size for easy lifting. The grain will dry quickly, and is best threshed from the sheaf. But in case of necessity it may be stacked. Should the straw be unusually long, it may be bound while being cut.

The crop is threshed as other grain is threshed. The yields in the semi-arid country run all the way from no return on poorly prepared land in a dry season to 30 bushels per acre in a bountiful season. The average crop should be not far from 10 to 12 bushels in dry areas.

GROWING BARLEY

The barley crop ranks high among the crops that will be grown in the semi-arid belt. This arises from the fact: (1) that it furnishes varieties with adaptation for brewing and other varieties specially well adapted to the feeding of live stock; (2) that it furnishes brewing barley of the highest quality; (3) that it matures early in the season and before the weather reaches the maximum of heat or drought, and (4) that it furnishes a valuable forage that, in some of its varieties, may be fed as hay in the unthreshed form, alone or in conjunction with other crops. It may also be made to furnish good pasture for swine in case of need. This, at least, is true of some of its varieties. It may be grown in some areas by sowing both in the autumn and in the spring.

Soils.—Barley will grow in good form on many of the soils of the dry west. The clay loam soils of the Plains country are well adapted to its growth. With a reasonable sprinkling of sand they are further improved. The volcanic ash soils of the west have shown high adaptation to the growth of barley. The same is true of soils in the foothills of the mountains, which are rich in humus. Soils low in adaptation are sands and gravels that will soon lose their moisture supply. On the latter the growth of straw is so light that the heads are small, and the yields, also, are correspondingly small.

Place in rotation.—Barley, like wheat, may safely follow the bare-fallow and also a cultivated crop. When thus grown the yields are usually larger than those obtained from wheat, and when of the brewing varieties the price is frequently as high as that of wheat, because of the high quality of the same. Where the rainfall is reasonably liberal, barley may also be made the second crop on well prepared land after summer-fallow, where the rainfall is 15 inches and more. Barley, under certain

conditions, may be followed by a winter crop drilled into the stubbles, as winter wheat or winter rye. It may also be followed by a cultivated crop, as corn, or by summer-fallow. The best crops of barley will come after summer-fallow or after a cultivated crop.

Preparing the soil.—Barley is a crop that grows rapidly, hence the seed bed should be in good condition. It does not feed so deeply as some of the other cereals. It is greatly important when growing barley that the seed bed shall be in good condition, mechanically, and well stored with readily available plant food. The preparation of summer-fallow and of cultivated land is the same, virtually, as for wheat (see p. 218). Where the rainfall exceeds 15 inches and where much of the rain falls in the growing period, barley may be sown late, as an aid in the cleaning of the land. This follows, first, from the opportunity given to harass weeds from the opening of spring until the barley is sown, and from the rapid growth of the barley, which makes it possible to mature it before many weeds can ripen their seeds. But where the rainfall is very light such a course would be followed by absolute failure in the crop in a dry season.

Sowing.—The varieties of barley may be classified: (1) as winter or spring; (2) bearded brewing barleys, which are two, four and six rowed; (3) bearded six-rowed barleys which are hulless; (4) beardless two and six-rowed barleys which retain their hulls, and (5) beardless barleys which are also hulless. The Tennessee is probably the best known of the winter varieties. The northerly limit for the growth of winter barley has not as yet been definitely defined, but it would seem safe to say that it may be grown with success as far north as central Oregon. Among the best of the brewing barleys are the Chevalier, Goldthorpe and Mensury. The two former are two-rowed and the latter is six-rowed. One of the most valuable of the bearded hulless varieties

is the blue or purple hulless, which weighs very heavily. Valuable brewing barleys that retain their hulls are frequently grown with much success in the semi-arid west. The barleys most generally grown are those that are beardless and also hulless. The white hulless is a favorite variety. One objection to these barleys is that they are carried on weak straw, and a further objection is that they are too hard for most kinds of feeding, in the unprepared form. Nevertheless they are the most popular of the dry farm feeding barleys, more especially those of them that are six-rowed. More commonly barley is white, but blue and black and various shades are by no means uncommon.

Barley should, as a rule, be sown early, but not quite so early as wheat under all conditions of growth. Though not so rugged as wheat, nevertheless it will stand freezing that is somewhat severe without serious injury. Far north, in dry areas, it is not usually sown before May 1st. Far south in the same, it may be sown nearly two months earlier. It may be grown on higher elevations than almost any other grain, because of the short period called for in order to mature it, but when grown in such areas the sowing must be late.

This crop is almost invariably sown with the grain drill. The advantages from sowing it thus are similar to those which follow sowing wheat in the same way (see p. 173). The same is true of it whether sown alone or in combination with some other grain. Barley should not be sown quite as deeply as wheat, but the difference is not marked. From 2 to 3 inches should be the rule, with variations to suit the needs of the soil and the depth of the moisture at the time for sowing.

The amount of seed to sow will vary from, say, 3 to 5 pecks under the varying conditions met with in the dry country. From 3 to 4 pecks per acre will meet the needs of nearly all the varying soil conditions where the

rainfall is approximately 15 inches per year. When sown alone to furnish hay, not less than 5 pecks should usually be sown.

Care of the crop.—About the only care than can be given to barley on non-irrigated lands after it has been sown, is to harrow it as frequently as may be necessary and at the time that may be opportune in each instance.



DRY LAND WHITE HULLESS BARLEY, DAWSON^{CO.}, MONTANA.

Courtesy Northern Pacific Railway Co.

It may usually be harrowed with profit when the blades begin to show, whether the ground is or it not crusted, for many weeds will be thus destroyed just when they begin to form roots. Subsequently the number of the harrowings must be determined by the character of the weather and the severity of the same that may be present in each instance. Usually from two to three harrowings will suffice.

Harvesting.—Barley should be harvested at an early stage of maturity, more especially when it is to be devoted to brewing uses. The best time at which to harvest the crop for such a use is when the stalk has turned yellow for a few inches below the head, the heads having assumed a yellowish tint, though still shaded with green. Such early harvesting favors the bright color so much desired by the brewers. This bright color is further favored by the dry and bright character of the weather that usually characterizes the harvest season. To secure this color with barley grown in various localities that are humid, bleaching must needs be resorted to. Varieties for feeding should also be cut thus early, as, when not cut early, the loss is usually quite material from the breaking off of the heads. When cut for hay the crop should be harvested when the grain is in the dough stage. For such a use the beardless varieties have highest adaptation.

The crop is cut with the harvester and is cured in shocks, long or round, usually the latter, and from the shocks it is drawn to the stack or threshing machine. If the shocks are to remain for any considerable time in the field, they should be capped, especially the brewing varieties, to prevent loss of the bright color through undue exposure. When stacked, the curing should be complete before the grain is thus put up, lest musting of the grain should follow from fermentation. Threshing is done in the usual way, that is, by using the grain separator. Of course the saving in labor is very considerable when this can be done from the shock. The average yields are from 30 to 35 bushels per acre.

GROWING OATS

There is no food crop for live stock which is more desirable to grow in dry areas than oats. In some of their varieties they may be grown quite satisfactorily

on a rainfall of 15 inches and even on less than that amount, but it is not so easy, nevertheless, to grow good crops of oats with assured certainty in the semi-arid belt as some of the other small grain crops. This arises, first, from the fact that oats may not be sown quite so safely early in the season as these, and, second, because of the heavier drain on soil moisture which it is claimed is necessary to meet the needs of the crop. This crop is



DRY LAND CANADIAN WHITE OATS, FERGUS CO., MONTANA.

Courtesy Northern Pacific Railway Co.

of both spring and winter varieties. The latter of course, can only be grown in the milder latitudes. It is grown both for the grain and to provide hay.

Soils.—The oat crop will grow on a wide range of soils, but it does not succeed well in the semi-arid country on soils that lose moisture readily. Loam soils that are reasonably friable and moist have highest adapata-

tion for the growth of oats. They will also grow better relatively on soils that are impregnated with considerable quantities of alkali than any of the cereals. Soils naturally dry and leachy and low in the elements of fertility are illly adapted to the growth of oats, but they have greater power than wheat to gather plant food under untoward conditions.

Place in rotation.—The oat crop may be given almost any place in the rotation, but, of course, not equally well. The most favorable conditions for oats are on summer-fallowed land or on land that has grown a well cared for crop. But where the rainfall is more than 15 inches, the crop may come as the second on land thus prepared, as wheat is usually assigned the first place on fallow or cultivated land. It does better, relatively, on sod newly broken than many other crops, but it should not be sown on such land unless it has ample moisture in it to insure germination. Where the rainfall is less than 15 inches, farmers should be slow to sow oats after other grain, unless the previous season has been of a character to store the subsoil with an ample supply of moisture. This crop should, as a rule, be followed by the bare-fallow, or by a cultivated crop, such as corn. Under very dry conditions, oats will not succeed after a grain crop, no matter how the land may be prepared.

Preparing the soil.—When the oat crop is sown on fallow land, or on land that has grown a cultivated crop, the preparation of the land is the same as for wheat. When it is sown on sod land newly broken, the breaking should be done early and should be reasonably deep. A good, fine seed bed should be made, though firm below. The aim should be to have the surface as free as possible from sods, that the harrow may be used on the growing crop, if necessary, without detriment to it. If oats is the second crop on breaking, it may be better to disc the ground autumn and spring rather than plowing it,

when preparing it for oats. If oats is made the second crop after summer-fallow, the land should be worked in the autumn by the aid of the plow or disc and harrow, or by the aid of all of these, as may be thought best.

Sowing.—The best varieties to sow will be influenced by soil and climatic conditions. The quick maturing varieties have been found the most suitable in dry seasons, as the dry weather of the approaching harvest



DRY LAND SIXTY-DAY OATS, CHOTEAU COUNTY, MONTANA.

Courtesy Northern Pacific Railway Co.

season will injure the crop less than if maturity in it was later. In reasonably moist seasons, varieties that are slower in maturing will give larger yields, but since it cannot be known beforehand as to the character of the season, it is safer to give the preference to early maturing varieties. Of the spring varieties the Sixty-day oat is one of the most popular, because of the early season at

which it matures. The straw is short, which is so far against it, and the kernel is small, but it will frequently produce a crop where later varieties would fail. Nearly akin to it is the Kherson. The Burt and Swedish Select have proved satisfactory. Where the rainfall is reasonably ample, such later maturing varieties as the Scottish Chief, Black Beauty, Lincoln and White Abundance may give larger yields than the early varieties. The Texas Rust Proof is one of the best winter varieties. In Utah the Boswell is well spoken of.

Oats are not so hardy as wheat, and because of this should not be sown quite so early. Usually, however, after the wheat, spring rye and speltz crops have been sown, it will be quite safe to sow oats. It is hazardous to sow them late. The winter varieties should be sown early enough to give them a good start before winter. The sowing of oats in the spring should be completed before it is time to plant corn, that is, not later, as a rule, than the middle of May in northern areas.

The crop should invariably be sown with the drill where it is to be had. If a drill is not obtainable, it may be a wise plan to sow the crop broadcast and cover it with the disc, but under such a condition of sowing it is not possible to cover the seed uniformly.

The oat crop does not require burial so deeply as will best meet the needs of the wheat crop. With ample moisture near the surface, 2 inches would be amply deep for oats in heavy soils, but in light and humus soils it may be advantageous to plant them more deeply. They will not germinate, of course, until they reach moisture.

On well prepared land, 4 pecks of seed will be enough for average soils, with many varieties. But some varieties may call for more seed, as when they are possessed of a very large kernel. The stooling properties, of course, have a bearing on the amount of seed that should be used. It should seldom or never exceed 5

pecks to the acre, and in many instances 4 pecks will be ample.

Care of the crop.—The oat crop may be harrowed in much the same way as the wheat crop. The extent of the harrowing that may be given is practically similar. The instructions that bear on the harrowing of wheat will apply about equally to oats.



DRY LAND OATS, FLATHEAD VALLEY, MONTANA.

Courtesy Great Northern Railway Co.

Harvesting.—The oat crop is ready to harvest when the heads have assumed a whitish yellow tint. The stem above the ground and below the head for a few inches in each instance will have assumed a yellow tint, but the body of the stem will still be green. If left till over-ripe, there will be serious loss from shelling through swaying caused by passing winds. For hay the crop should be cut a little under-ripe.

The binder is more commonly used for harvesting the crop for the grain, and in some instances also for hay. In other instances the mower is used to cut the

hay crop. The header may be used, but the areas grown are not usually large enough to make such harvesting advantageous.

The oat crop is generally cured in the round shock in areas where strong winds prevail. The crop may be readily and safely stacked when cured, or it may, of course, be threshed from the shock. The ordinary thresher is commonly used. The average yields on dry land will be about 40 bushels, with maximum yields of, say, 75 to 80 bushels.

GROWING SPELTZ

Speltz, more properly designated emmer, is of comparatively recent introduction. It holds the grain which it produces tightly in the chaff scale and consequently resembles barley more than wheat. It is markedly drought-resistant, but the yields differ much in different localities. In the west it is grown solely for the purpose of providing food for live stock, for which it has a value ranking almost equally high with barley. Heretofore spring varieties, mainly, have been grown, but during recent years Buffum has evolved some winter varieties of much promise that have proved hardy on the plateaus of Wyoming and Colorado.

Soils.—Since speltz is a rugged plant, it may be grown on a wide range of soils. Of course those that are well stored with plant food and that hold moisture well will give the best crops, but good crops may be grown where the moisture content is low. It would seem correct to say that it will grow on soils lower in plant food than would be suitable for barley, but has not more power than barley to grow on alkali or gumbo lands.

Place in the rotation.—The best crops of speltz grown in the semi-arid country will come after fallowed land or land that had grown a cultivated crop, but such

land is more wanted for less rugged crops, as wheat and oats. Where the precipitation will admit of it, this crop is frequently made the second one after summer-fallow or otherwise cultivated land. This rotation, however, should not be attempted where the precipitation is quite low. Where it is below 15 inches per year, speltz should, as a rule, be followed by summer-fallow or a cultivated crop. Speltz may be grown on breaking, but it will not grow so well on such land as some other crops, as, for instance, flax.

Preparing the soil.—When speltz is grown on summer-fallow or after a cultivated crop, the preparation of the land involved is the same as for wheat (see p. 218) and for the other cereals discussed. When it is made the second crop in succession after these, the land should in nearly all instances be plowed in the autumn, and preferably after discing, with an interval between the discing and the plowing, which should be followed at once with the harrow. Early stirring in the spring is also, of course, essential. Should the speltz follow a crop sown on sod, discing autumn and spring without plowing may, in some instances, furnish the most suitable preparation that may be given to the land.

Sowing.—The introduced varieties of speltz are not many and the introduction has been so recent that they have not been much advertised in the past under distinctive names. Black winter emmer is probably the best of the winter varieties.

As speltz is very hardy, it would seem safe to say that it may be sown as early in the spring as the land is suitable for working. It will then mature early, but not so early as winter wheat. That autumn-sown should be put into the ground as early as winter wheat.

The grain is best sown with the drill, but it may be covered with a disc in the absence of a drill. Because of the relatively large size of the grain, it is more easily

uncovered by rain than some other grains when the crop has been harrowed in.

The seed may be put in with best advantage to the depth of, say, $2\frac{1}{2}$ to 3 inches, but there may be some necessity for modification in order to meet the needs of different soils and weather conditions.

Speltz does not stool so abundantly as some other cereals. This fact, linked with the large size of the seed, calls for heavier seeding than in the case of some other cereals. Not less than 5 pecks should be sown per acre on average soils.

Care of the crop.—The crop should be harrowed much the same as other cereals. What was said with reference to harrowing wheat will apply about equally to the harvesting of speltz.

Harvesting.—Speltz should be harvested while the stems, except below the head and near the ground, have not yet assumed a decidedly yellowish tint. The hazard from loss in harvesting comes from the breaking of the heads of over-ripe grain. The binder is used in harvesting the crop and the grain is generally cured in the round shock. It is threshed in the ordinary way. The yields run all the way from, say, 10 to 70 bushels per acre, with an average somewhere between 25 and 35 bushels.

GROWING PEAS

This crop will have an important mission in the semi-arid country when its merits shall have become generally known in the same. But its adaptation is by no means equal for all parts of this area. It will grow much better on the loam soils of the cool and elevated plateaus than on the silty soils of the hot valleys, in the absence of irrigation. It will be grown for the grain, for forage, for swine pasture and for fertilization.

Soils.—Loam soils, mild and moist, have high adaptation for peas, but they will also give good returns in

sandy loams; that is, sandy soils with enough of the clay element in them to make them retentive of moisture are specially well adapted to the growth of this crop. They will fail on loose and coarse sands and gravels under dry conditions.

Place in the rotation.—Where the rainfall is less than 15 inches, peas will give the best returns by far from summer-fallowed land that has grown a cultivated crop. But where the rainfall approaches 18 to 20 inches, peas may be made to follow a grain crop of the previous year, regardless of the character of the same. They grow well on sod that has a fair amount of moisture in it, whether of new or older breaking, but the best returns will come when the sod has been prepared on the summer-fallow plan. Usually this crop may be followed by small grain, whether grown in the usual way or as a cultivated crop, but when grown by the latter method the results will be much more satisfactory from the grain crop. Peas, from their recumbent habit of growth in the later stages thereof, act somewhat as a mulch and thus far they prevent the escape of soil moisture.

Preparing the soil.—When grown on fallow land, the preparation of the soil is the same as for wheat (see p. 218). When grown after small grain, the aim should be to prepare the land by plowing and harrowing or by discing. The plowing and harrowing should be done in the autumn, but to this method there may be the exception of first sowing the peas and then burying them with the plow, a method that is sometimes followed when the rainfall is reasonably copious.

Sowing.—The varieties to sow will depend somewhat on the object for which the crop is grown. When grown for the grain, what is designated as the Canada field pea of one of the small varieties is usually sown. This may mean that the variety may be the Mummy, the Golden Vine, the Prussian Blue, or some other of the

many varieties of the Canadian peas that are grown. The colors embraced will be white, yellow, gray or blue, according to the variety grown. The Mexican is sometimes sown in the higher mountain valleys to provide grazing. When sown for plowing under to enrich the land, the large Marrowfat varieties will best serve the purpose. When garden varieties are grown, especially in the absence of irrigation, the dwarf and early maturing varieties will probably give the best results.

Peas should be sown early, as early in the season as the ground is in condition for being worked. Late sowing has been the cause of many failures in the attempt to grow peas. Only when sown on irrigated land and when the crop is to be buried as a fertilizer will it be in order to sow the crop late. Under dry conditions such sowing would result in certain failure.

Ordinarily the crop is sown with the grain drill. When thus sown, it should be buried deeply. This is important because of the favorable bearing which it has upon resistance to drought. Care must be taken not to use a drill that will break the peas in the act of sowing them. They may be covered by discing when drill sowing is not possible. The common harrow does not provide a sufficiently deep covering for the peas. A shower following such a covering will uncover many of the peas. When sowing the garden varieties they are frequently put in with a hand drill, but may be sown with a grain drill by using only such of the spouts as may be necessary. In some instances, double rows are planted, making the two rows thus planted about 6 inches apart. The distance between the rows, single or double, is from 30 to 42 inches, according to the variety. They should be far enough apart to admit of easy cultivation.

Field peas are, in some instances, sown thus, but whether it will pay better to grow them thus than in the ordinary way, under average conditions of growth,

has yet to be proved. When sown broadcast, and plowed under, the seed should be harrowed before the land is plowed, lest the peas should lodge in rows corresponding to the width of the plow furrows when this work is done. They may also be buried lightly with a drill before the land is thus plowed.

The depth to which the seed will be sown depends on the soil and the method of sowing. The aim should be to plant the peas deeply, as deeply, as a rule, as 3 to 5 inches, not only to enable the crop the better to withstand drought, but also to make practicable the careful and thorough harrowing of the ground before the crop is up. When it is to be irrigated, planting thus deeply is not a necessity.

The amount of seed to sow will depend: first, on the normal amount of rainfall; second, on the kind of the peas; third, on the method of sowing, and, fourth, on the object for which the crop is grown. Where the normal rainfall is about 15 inches, about 5 pecks per acre of the small varieties will suffice for sowing the crop in the usual way. When sown in rows for being cultivated, from, say, 1-3 to 1-2 the usual amount should prove ample. When small dwarf varieties are sown, as much as 1 to 2 bushels are sometimes sown in drills that are to be cultivated, but the latter amount would seem to be excessive for such sowing. From 25 to 50 per cent. more seed is usually called for when very large peas are sown as compared with those of ordinary size. When the crop is grown for burial, more seed may be used than if grown for the grain, especially when the crop is to be irrigated.

Care of the crop.—The aim should be to thoroughly harrow the ground while the peas are yet from 1 to 2 inches short of the surface. This, in ground possessed of numerous weed seeds, is important, as subsequent to the appearance of the plant above ground, if the crop

should be harrowed, the work must be done in a cautious way, otherwise it may harmed more than benefited. When planted in rows wide enough for cultivating between them, such cultivation may be given as soon as the line of the row can be distinctly traced. It should be sufficiently frequent to keep the land clean and to prevent the escape of moisture. It cannot be continued longer than the period when the peas become recumbent. This period is hastened or retarded by the kind of pea, and the character of the wind and rain storms. The short, stocky garden varieties stand best against the influences of storms and may, therefore, be cultivated for a longer period than tall-growing varieties. The garden varieties are usually gone over once by hand, to remove from the rows any plants of a different variety that may be present.

Harvesting.—Peas are ready for being harvested when, say, the lower two-thirds of the pods are fully ripe. When cut at this stage of maturity, the straw makes excellent fodder, when cured in the absence of rain. When the crop is grown for the grain and also for the straw, it is best harvested by the aid of a pea-harvester, that is, an attachment fastened on the cutter bar of a field mower. This attachment has guards which run under the prostrate vines and lift them up so that the knives can cut them. Two work hands follow and bunch them with the aid of forks, at the same time lifting the bunches out of the way of the horses that draw the mower. In, say, two days of good weather they may be drawn and threshed or stacked, as may be desired. In the Plains country they should be at once lifted when dry, lest the winds should carry the bundles far over the unfenced country. The stacks will not withstand rain as some crops do, unless topped out with some more resistant substance.

The field crop is threshed by the ordinary grain thresher, but in order to prevent breaking the peas the concaves are removed and replaced with others made of strong wood, as oak, and which are furnished with only a few teeth. Careful attention must also be given to the regulation of the speed in threshing. In this way the breaking of the peas may be reduced to a minimum.

In some instances field peas are harvested by the use of the old-fashioned revolving horse rake. The objection to this mode of harvesting is, first, the extent to which the straw becomes impregnated with dust, thus lessening its feeding value, and, second, the extent to which the peas are shelled in the process of harvesting. They may also be harvested by the use of the ordinary horse rake, but the loss from shelling when thus harvested is also very considerable. On small areas a farmer may cut them or pull them, as the phrase is ordinarily termed, with the scythe, and may use the old-fashioned flail in threshing them. In this way the farmer may grow his own seed more cheaply than he can buy it. The average yield is about 20 bushels per acre. Maximum yields are, say, 45 bushels.

Field peas may also be harvested by sheep and swine in the semi-arid country. This is made easily practicable by the dry weather at the harvest season. When the matured crop is thus grazed off by sheep or lambs, it is usual to sow some oats with the peas. This aids in sustaining them, and in consequence the waste is less than it would otherwise be. This method of harvesting the crop is regularly practised in the San Luis valley of Colorado, and it is capable of being extended to many mountain valleys in the semi-arid country. One acre of peas thus grown has been found capable of sustaining say, 10 lambs while being fattened. The sheep and lambs are turned in on the crop as soon as it has reached early maturity. The plan which divides the area by the use

of movable hurdles finds most favor when this crop is being grazed. Any waste through shelling may be virtually avoided by allowing swine to follow the sheep as gleaners. This method of harvesting insures the consumption of the greater portion of the entire crop.

The pea crop may also be harvested by swine. When thus harvested, the crop may be sown alone better than with other grain. The swine may be allowed to feed upon the crop beginning with the early stage of ripening and continuing the same until the crop is consumed. The last of the gleaning should be done by other swine that are not being fattened during the process of gleaning. The straw will be lost for feeding uses by such gleaning. The dry harvest season in the semi-arid country makes such gleaning entirely practicable.

When the crop is grown to furnish seed for table use, it may be harvested with the pea-harvester as outlined above, or it may be cut with a bean harvester. The threshing is very frequently done by using the same machine that is used in threshing beans (see p. 299).

When the crop is grown to provide green manure, it may be sown on irrigated land that is to be summer-fallowed the same season. The sowing should take place quite early. The crop should be buried when coming into bloom, and a spring cereal crop will usually be made to follow. On such land, the food furnished by such a crop is usually considered too valuable for such burial. When sown on irrigated land for such a use, the peas are usually sown after a grain crop has been harvested for the season. Where the seed is home grown and cheap, this method of adding vegetable matter and fertility to the land is very satisfactory.

CHAPTER XII

GROWING CULTIVATED CROPS IN DRY AREAS

In all areas where the rainfall is less than could be desired, the growing of cultivated crops will always have a relatively important place. This arises in part from the degree of the certainty with which these crops may be grown with success, and in part from the excellent preparation which they make for the growing of the small grains that follow them in the rotation.

The more important of the crops that must always be given cultivation in these areas to grow them at their best are: (1) corn; (2) the sorghums; (3) potatoes; (4) field beans; (5) field roots, and (6) artichokes. These are probably valuable in the order named. Of course, various other valuable plants, as alfalfa, are given more or less cultivation during the period of their growth, but when growing them cultivation is not always imperatively necessary.

GROWING CORN

Beyond all question, corn is by far the most important cultivated crop that will ever be grown in the semiarid country. The great significance of the crop for such areas lies in the fact, first, that it will be the most important source of fodder obtainable, with the possible exception of alfalfa; second, that it is the surest important crop obtainable from spring-plowed land and from land that has produced a crop of small grain the previous year; and, third, that a crop of small grain may be grown after corn which will give a fair return almost any season. This crop will be grown for the fodder alone, for fodder and grain combined, and for the grain alone. For the fodder only it will be grown under climatic conditions that will not properly mature the crop because

of high latitude or altitude. For the combined purpose the chief aim sought in growing it will be fodder. But the more grain that it will grow in addition to the fodder, the more valuable will it be. For the grain only or mainly, it will be grown to provide food for swine that will harvest it in the field, and in some instances, in the more favorable locations, the ears will be snapped from the standing crop as is done in the corn belt. For the fodder and grain combined, it may be grown in paying quantities in the most northerly sections of the United States, up to the elevation of 4,000 to 4,500 feet. Farther south it may be grown at an altitude higher in proportion as it is farther south. The area devoted to the growing of corn in the near future will probably be second only to that devoted to the growth of wheat.

Soils.—Corn will grow on any soil well adapted to wheat. This means that it will grow under proper conditions on nearly all the bench lands of the semi-arid west, save on lands that are impregnated with alkali. It will also grow on lands which contain a quantity of humus in excess of the need of the wheat crop. The soils with highest adaptation for the growth of corn are rich, friable loams. Sandy loams are even better adapted relatively to the growth of corn than to the growth of wheat. Stiff clays, leachy gravels and alkali lands are ill adapted to the growth of this plant.

Place in the rotation.—Corn may be given any place in the rotation. Generally speaking, however, it would not be wise to grow corn on summer-fallowed land or after a cultivated crop, as ground thus prepared is usually wanted in order to grow upon it crops of small grain. It is one of the best crops to grow on sod land, whether new breaking or sod formed by tame grasses or by clovers, including alfalfa. It is also one of the safest crops to grow after small grain. There are conditions, doubtless, in which the moisture supply may be too small

after such grain to grow a crop of corn, but this will seldom occur. Such a result need not be feared with a rainfall of 12 to 15 inches on land properly prepared, providing the larger proportion of the rainfall is in the growing season. The place more commonly assigned to corn will doubtless be after small grain.

Corn should almost invariably be followed by small grain or by alfalfa. The moisture conserved by the cultivation given to the corn insures the success of the grain crop when it is properly grown. It would be safe to say that where the rainfall is from 12 to 15 inches, as good crops of small grains may be obtained after corn as after the bare-fallow. Where the rainfall is between 15 and 20 inches, as in some parts of the Dakotas and western Canada, the grain crops that follow corn are frequently better than those grown on fallow land, because of the tendency to lodging in grain grown on the latter.

Preparing the soil.—The preparation that puts the land in the best condition for growing a crop of corn will depend on the place given to this crop in the rotation. When corn is planted on new breaking or on any kind of sod land, the best crops will be obtained from land that has been broken the previous year and handled on the summer-fallowed plan (see p. 168). But good crops of corn may be usually grown on such land when spring-plowed, providing the plowing is done at a depth that will admit of making a fine and good seed bed, and that it is done sufficiently early to give ample time for making such a seed bed. The land should be plowed deeply, not less than 6 inches, and as early in the season as the work can be profitably done. It should be at once compressed, disced and harrowed, so as to make about 3 inches of fine soil on the surface. When the land is plowed thus deeply, the sods will be buried so far as not to interfere seriously with the after processes of cultivation. If

moisture is reasonably plentiful, sod land may be plowed just before planting the corn, and the results may be entirely satisfactory, as the grass on land plowed at such a time aids in the quick decay of the sod.

The homesteader may, and does, grow corn by breaking sod land shallow and strewing the seed by hand in, say, every third furrow. Reasonably good crops have



DRY LAND FODDER CORN, GROWN NEAR BROADVIEW, MONTANA.
Courtesy Great Northern Railway Co.

been grown thus and without any further labor than that of dropping the seed, which soon produces growth that comes up through the overturned sod. The best crops of corn cannot be obtained from planting it thus, nor does it put the land in the best condition for the crop that will follow. When corn is planted thus, every care should be taken to disc the ground and smooth the surface after the corn has been planted, and before the crop has

reached the surface of the ground. Even though further cultivation should be omitted the ground is so far made capable of retaining moisture.

In all areas where the land has been cultivated for a term of years, corn will generally be grown after a crop of small grain. When it is thus grown, the aim should be to plow the ground in the fall, and as early as possible. It may be advantageous, as when there is some moisture in the subsoil, to double disc it as soon as the grain has been removed. The plowing should be deep and the harrow should immediately follow. Subsoil packing of ground thus plowed will seldom be necessary. In the spring, as soon as the season will admit of it, the land should be disced and harrowed, and, if necessary, should be stirred once or twice again with the harrow at intervals before the corn is planted. If the land cannot be plowed until spring, the aim should be to plow it early and deeply. Subsurface packing will then be in order to firm the seed bed below, should moisture in the ground be lacking at such a time. Planting corn on spring-plowed land in dry areas is usually much more hazardous than on autumn-plowed land.

If farmyard manure is applied, this is best done before the land is plowed, whether in the autumn or the spring, and by a manure spreader. If the manure is fresh and has much litter admixed with it, the application should be light, less than ten loads rather than more per acre, lest the straw in the manure should maintain too porous a condition of the soil. When the manure is possessed of a small amount of litter, it may be applied on autumn-plowed land at any time subsequent to the plowing, and incorporated with the surface soil when the seed bed is being prepared.

When manure can be thus applied, the benefits are speedily apparent. The time has not yet arrived for the

discussion of fertilizers for corn in the semi-arid west, as the need for these has been but little felt.

Planting.—It cannot be said with the assurance of certainty at the present time which are the best corns for each particular section of the dry country. This can only be determined by experiment, and the time for such experimentation has not been sufficiently long. A few years hence much more will be known with reference to varieties and their adaptation for dry areas than is known at the present time.

It would seem correct to say, however, that four distinct classes of corn will be found suitable for the semi-arid country. These are: (1) flint corns; (2) dent corns; (3) sweet corns, and (4) flour corns. The flint corns are best adapted to extreme northern conditions. The dent corns have adaptation to conditions less severe. The sweet corns may be grown over a wider area than the flint or dent varieties, and the flour corns are best suited to southern conditions. Varieties may yet be evolved with more complete adaptation to the environments of each locality than those that are now grown.

When determining as to the variety that shall be grown, the object sought in growing the crop should be carefully considered. If grain is the principal object sought, the fodder being a secondary object, those varieties should be grown which will give the largest yields under the average prevalent conditions. But if fodder is the primary object, then varieties should be grown which will give the largest amount of good fodder. The more grain production that can be linked with such fodder production, the more valuable will be the fodder thus produced.

In northern areas the best varieties for producing grain include the Squaw corn, the Gehu and Golden dent. The Squaw corn is a low-growing variety, grown by the Indians, long years ago. It is a flint corn, white in

color and very dwarfish in its habits of growth. It is peculiarly well adapted to dry areas. The Gehu is somewhat larger and is also a white dent. The Golden dent is still larger than the Gehu. All these varieties mature in less than 90 days under average conditions of growth. They are too dwarfish, however, in their habits of growth to render them valuable for the production of fodder. They also produce ears so near the ground that they cannot be harvested satisfactorily with the aid of the corn binder. In those areas the best varieties for fodder mainly, will include the Mercer flint, the Triumph, also a flint corn, and the Northwestern dent. The last named produces grain with a reddish tint. It is more grown for fodder at the present time than any variety grown in the northwestern states. These varieties will mature inside of 100 days and they will produce from 2 to 3 tons per acre of cured fodder.

In the central states of the dry belt such varieties as the Minnesota No. 13 and Stowell's Evergreen sweet will give results that should prove satisfactory, when these are properly grown. The former should be grown primarily for the grain, and the latter for the fodder. Both varieties will mature in about 100 days. Other varieties will also give good results, as for instance, the Pride of the North. But the best varieties are yet to be evolved.

In southern areas of the dry belt larger varieties and of slower maturity may be grown, but in the semi-arid areas of the south it will doubtless be found that some of the non-saccharine sorghums will better meet the needs of the farmer than corn because of their greater ability to grow under dry conditions. These include Kafir corn and Milo maize (see p. 285).

When corn is grown primarily for fodder in dry areas, a variety should be preferred that will furnish a fair amount of fodder, that is leafy in its habit of growth, that will mature in the interval between the last killing

frosts of spring and the first killing frosts of autumn, and that will make sufficient growth to admit of being harvested by the aid of the corn harvester without breaking off a large percentage of the ears, and that will mature nubbins which will add materially to the value of the corn fodder. At the present time, it would be hazardous to say which variety will best meet all these conditions, but it is correct to say that Northwestern dent is more generally grown than any other variety.

The time for planting corn will, of course, vary with latitude and altitude. Near to the Canadian boundary it will be, say, May 15th to June 1st. When corn is planted later, it is much liable to be injured by September frosts in the autumn. In the latitude named, corn planted as early as the middle of May is more or less liable to be cut down by frosts, but even so it is better to have growth thus retarded by frost in the spring than to have the crop injured by frost in the autumn. In the northwestern states the crop is much less harmed by such a visitation than in the corn belt, owing probably to the much greater inherent hardihood of the varieties grown. These varieties will also be less harmed by planting them in a soil not yet warmed and in weather that is still cold. This may arise first, from the inherent vigor of the seed, and second, from peculiarities of soil and atmospheric conditions. Those who plant corn, therefore, should not be deterred from planting because of lack of complete propitiousness of the weather when the proper time arrives for planting. Going southward the season for planting advances. Near the Mexican boundary it may be planted in April, the time varying with the altitude.

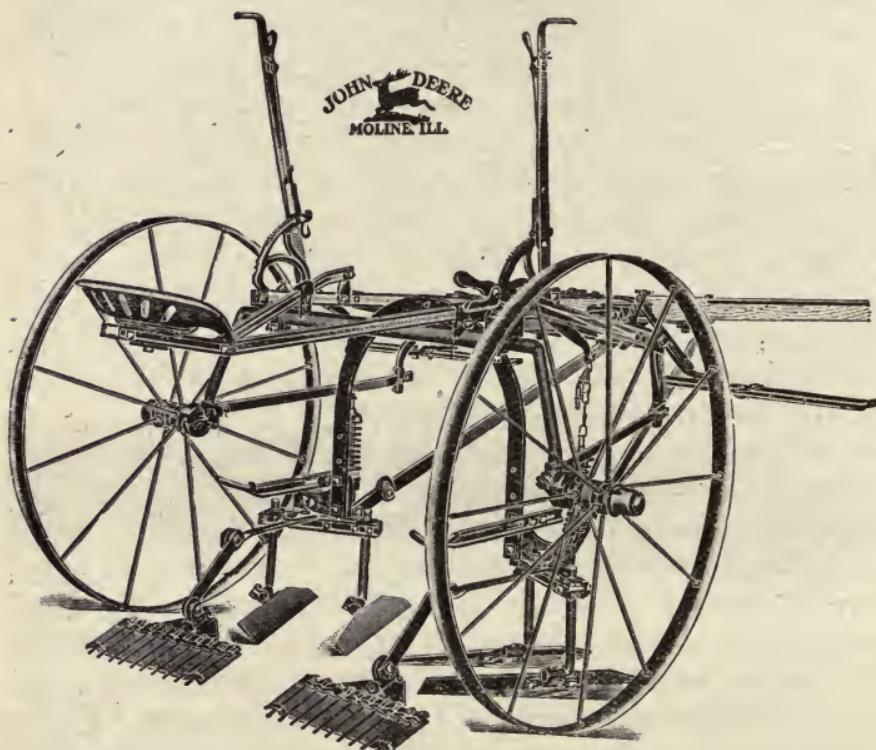
The method of planting will depend: (1) on the condition of the soil as to the presence or the absence of weed growth; (2) on the object for which the corn is chiefly grown, and (3) on the crop that is to follow the

corn. When weeds are abundant, the cultivation and therefore destruction of weeds will be more complete when it is planted in hills. The retention of soil moisture may also be secured in larger degree, since a relatively larger area of the surface is stirred when cultivation can be given more than one way, which is the case in hill planting. When the corn is planted to produce ears mainly, it is usually planted in hills, but may also be planted in drills. When it is grown chiefly for fodder, it is usually planted in drills, because of the greater facility with which it may be harvested with the corn harvester, but it may also be planted in hills. When planted in drills, the grain drill may usually be made to do the work without investment in other machinery, and this fact furnishes a strong argument in favor of drill planting. When corn is to be followed by winter wheat or winter rye, the stalks or a portion of them being left to protect the grain in winter, the corn that has been grown in drills will furnish the most complete protection.

When planted in hills, the use of the check-rower is indispensable where large areas are to be grown. Small areas may be planted with the hand planter, after the ground has first been marked off in squares with some kind of marker. The hills are usually made $3\frac{1}{2}$ feet apart each way. When planted in drills the ordinary grain drill is commonly used, but the horse corn-planter may also be used. Only those drill tubes should be used which will plant the corn at a suitable distance between the rows. The distance most in favor is $3\frac{1}{2}$ feet, as in the case of hills. In dry areas and especially in the north-erly portions of the same, it is not necessary to have as much distance between the hills or rows as in areas more favorable to large growth. Especially in the northern portions of the semi-arid belt, the habit of growth in corn is more or less dwarfish relatively. The

openings into the tubes not wanted may be closed by covering them with a sack or some such material.

Corn may usually be planted to the depth of, say, 2 to 3 inches. With ample moisture in the soil the shallower planting would seem to be preferable. But to insure germination, there are instances in which the planting would be even deeper than 3 inches. The more



THE SURFACE CULTIVATOR.

Courtesy Deere & Webber Co., Minneapolis, Minn.

light and porous the soil, the deeper may be the planting of the seed.

The amount of seed to plant will vary: (1) with the kind of corn; (2) the use that is to be made of the crop, and (3) the normal amount of the precipitation. The

small-growing varieties of corn may be planted more closely than those that are larger. As corn in northerly areas is more dwarfish in its habits of growth than corn grown southward, it may be planted more closely. But such planting can only be carried so far, in areas where moisture may be deficient, or it will be adverse to growth in the corn. When corn is grown mainly for the fodder the planting may be thicker than when grown mainly for the grain. Usually it should not be grown so thickly, however, as to prevent the growth of nubbins on the stalks. Experience can alone determine this in each locality. In very dry areas it may be necessary to plant the seed so distant as to preclude the possibility of securing large yields. With a rainfall of, say, 15 inches, the aim should be to have not fewer than 4 stalks in a hill, and when planted in drills for fodder, the aim should be to have from 4 to 8 inches between the plants.

The amount of seed called for will also be influenced by the size of the seed. For hill planting less than one peck will usually suffice for an acre, and in many instances considerably less. For drill planting as much as two pecks of the large varieties with large kernels may be called for.

In dry areas many growers favor planting corn by the method known as listing. Furrows are opened with a plow called a lister and the seed is planted in the bottom of the furrow in rows or in hills. The chief advantage claimed for the system is that it starts the corn farther from the surface than when planted in the ordinary way, and that in consequence it roots in a more moist soil. The labor involved in preparing the soil is also less. The cultivation of the ground is usually all given after the corn has begun to grow. Under some conditions better crops may be grown thus than in the ordinary way. The chief objection to the system is, that

should heavy rain fall soon after the corn is planted, and this does occur occasionally; it may wash out some of the seed and bury more of it. There is the further objection that evaporation for a time at least will take place from a larger surface than would occur in level planting. If the land has been carefully plowed the previous autumn, the advantage to be gained from list-ing is at least problematical.

Care of the crop.—In nearly all instances the plan is to be commended which harrows corn in dry areas once or twice before it is up. If but one harrowing is given, it ought to be given usually just when the points of the corn plants are ready to appear. If two harrowings are given, the first should occur about a week after planting the corn under normal conditions of weather. In both instances the teeth of the harrow should be given a far enough backward slant so as not to injure the sprouted corn. Myriads of weeds just starting into life will thus be destroyed. Subsequent to the appearance of the corn plants, one or two harrowings will be helpful, but when giving them care should be taken not to bury the corn plants, which is much liable to occur if the crop is harrowed when one to two inches high. In many instances the weeder judiciously used will do the work better than the harrow. Neither the harrow nor the weeder should be used on ground unduly moist, or when the corn plants are wet with dew or rain. The grower is in the best position to determine when and to what extent harrowing should be done.

The cultivator should follow close upon ceasing to use the harrow. A cultivator that will take in two or three rows should be used where large areas are to be cultivated. The objects sought from cultivating are: first, to destroy weeds, and, second, to prevent the escape of soil moisture. Ordinarily such cultivation should be level and shallow lest the corn roots should be broken

that run near the surface, but should a crust form below the dust mulch, it ought to be broken up by deeper cultivation. Usually cultivation does not continue longer than the season of tasseling in the corn, but in dry weather it may pay well to continue it longer. The interval between the cultivations must be determined in a great measure by the grower on clean land. No advan-



DRY LAND FODDER CORN, GROWN NEAR SHERWOOD, N. DAKOTA.
Courtesy Great Northern Railway Co.

tage can result from cultivating when soil moisture is not escaping unduly. It is seldom necessary to cultivate more frequently than, say, each 10 to 14 days. In dry areas late cultivation may have an important bearing on the crop that follows, because of the moisture which it may save to the soil.

When corn is listed it is usually advantageous to use on the crop, during the growth period, the harrow,

the weeder and the cultivator, and in the order named. The harrow attacks weeds that may be starting and gradually works soil into the furrows around the corn, which in time are filled. The weeder may be used later. The cultivating is much the same as for other corn.

Harvesting.—Corn may be harvested in semi-arid areas: (1) by snapping off the ears; (2) by cutting, shocking, and then husking; (3) by cutting and curing for feeding without husking, that is, by feeding in the bundle; (4) by cutting and curing in the silo; (5) by allowing swine to consume the ears from the uncut stalks, and (6) by grazing it off with sheep when mature.

The snapping off of the ears by hand may best take place when some dwarfish kind of corn has been grown on ground to be planted to winter wheat, the wheat being drilled in among the stalks that are to furnish protection for it in the winter season. The dwarfish nature of the growth may interfere with harvesting the ears otherwise than by hand in the absence of sheep and swine. In dry areas the grazing of stalks from which the ears have been removed can scarcely be said to be profitable. They become so dry and brittle that they rank low in palatability.

When the corn is large enough to cut with the binder, the ears may be husked in the ordinary way or with the aid of the corn shredder. In northern areas it may not be easy to secure enough dryness in the stalks to make it easily practicable to preserve them in the shredded form. But this will not apply to corn in southern areas of the dry belt.

In dry areas corn will more commonly be cut with the corn harvester, cured in the shock and fed in the bundle from the shock or from the stack. The great bulk of the corn crop in those areas will be harvested and fed in this way. Where the snowfall is very light, it may answer quite well to draw and feed the corn from



DRY LAND CORN, ROSEBUD COUNTY, MONTANA.

Courtesy Northern Pacific Railway Co.

large shocks made late in the season by putting a number of small ones together. Where the snowfall is considerable the corn should be drawn and stacked in very narrow stacks on the approach of winter. They may contain but two lengths of sheaves with the headslapping the middle.

In areas where corn possessed of considerable bulk is grown it may be cured in the silo if so desired. It should then be cut when beginning to glaze and should be run through a cutting box with blower attached to carry it into the silo. Where the bulk obtained from the variety grown is small, it will not pay to harvest corn thus.

When some kind of corn has been grown with a view to sow wheat in it, in the early autumn, it may be effectively harvested with swine. The labor of harvesting is thus so simplified that large areas may be grown in this way. The swine may begin such harvesting as soon as the ears have reached the roasting stage.

When harvested with sheep or lambs, the grazing may begin at a similar stage in the growth of the corn. Care must be exercised at the first in turning in both the sheep and the swine, lest they should eat to their injury. This method of harvesting corn would seem to be the most economical that can be devised, as nothing virtually is wasted save a small portion of the base of the stalk. Such grazing also leaves the land in good condition for the grain crop that follows. It is specially helpful to lands so light as to blow. The treading firms them and the stubs of the stalks to some extent check the force of the winds.

The yields of the grain will depend much on the variety. The small kinds, as the Squaw, should furnish 20 to 35 bushels per acre. Larger kinds may furnish 40 to 50 when well grown. Maximum yields will seldom exceed 75 bushels. The yields of green fodder may run all the way from, say, 5 to 15 tons per acre with an

average of, say, about 8 tons. This would mean an average of about 2 tons in the cured form. Of course under irrigation in the warmer valleys, enormous crops may be grown.

GROWING SORGHUMS

The sorghums may be classified as sweet and non-sweet, that is as saccharine and non-saccharine. The saccharine sorghums include several varieties. The distinction between these relates more especially to growth characteristics and more particularly to such of these as relate to maturity. The saccharine sorghums are of the same class, but the non-saccharine are of several classes. The more important of these for the semi-arid country are Milo maize of the class known as Dhuoras, or, as sometimes written, Durras, and Kafir corn. These are of several varieties. The sweet sorghums are of tall growth, and usually sustain a dark colored panicle somewhat spreading in character. The sweet character of the fodder makes it much relished by live stock.

Milo maize is forging to the front as one of the most valuable food plants southward in the semi-arid region, hence it is worthy of more than a passing notice. This plant, at one time very tall, is now so dwarfed that the standard sorts average about $4\frac{1}{2}$ feet in height, and the dwarf sorts about $3\frac{1}{2}$ feet. The advantage from such modification in the handling of the crop will be readily apparent. The heads of Milo maize are relatively large and compact. When the stand is thin, the heads become so large that they turn down by their own weight, otherwise they stand erect. The stalks are stout and short jointed. The roots fill the soil near the surface. When moisture is lacking, as in the case of sorghum, the plants stop growing until rains come again. The Durras are valuable as both fodder and grain plants, but for the

iatter use they are relatively much more valuable than for the former. As a food for horses, cattle, sheep, swine and poultry the grain from Milo maize is nearly as valuable as the food from corn. It may be grown successfully save on the high elevations from the northern border of Colorado southward.

The Kafir corns are less tall and more stocky than the sweet sorghums. They sustain erect, compact and stubby heads. They are more succulent in the stem and leafy in the growth than Milo maize, and in drought periods they retain their greenness for a longer period than the Milo maize plants, hence they are somewhat superior to these for fodder uses.

The saccharine sorghums are better adapted to northerly areas of the dry belt than the other sorghums. Above the parallel of 45 they do less well than corn, and below 40 less well than the non-saccharine sorghums. The Dhuoras may be successfully grown as far north as, say, 41, on the lower altitudes, and on elevations even higher than 4,000 feet in southern Colorado. Kafir corn calls for somewhat warmer seasons and requires more time in which to mature growth. They are all drought-resistant, and probably in the following order: Kafir corn, Milo maize, sorghum. Each of these may cease to grow for a time and may subsequently continue growth when rain has added sufficiently to the moisture, but Kafir corn is best able to endure long periods of drought and to recover from the same. The seeds of all of these are low in germinating power, and the plants grow but slowly at the first. They should not be planted until both soil and season are reasonably warm.

Other sorghums may be grown, as, for instance, Jerusalem corn, rice corn, broom corn, and Kaoling. The latter is a Chinese grain sorghum, characterized by early maturing qualities. Shallu is a sorghum introduced by the Louisiana experiment station about 1890. In certain

quarters it has been greatly over-rated. None of the sorghums have been found equal in all-round adaptability to sweet sorghum, Milo maize and Kafir corn.

Soils.—All the sorghums will grow well on the average soils of the bench land country and also of the river valleys when irrigated. But all of these do much better on loam soils than on stiff clays and on light lands. The ability to grow them in good form on bench lands that will grow crops of grain need not for one moment be questioned. On alkali soils they will grow as well or better than most crops, but the degree of the alkali present will, of course, have an important bearing on the results.

Place in the rotation.—The place in the rotation for the sorghums is not far different from the place assigned to corn (see p. 270). They grow especially well on sod land properly prepared. They follow grain crops rather than the bare-fallow, as in the case of corn; they prepare the land for a grain crop when cultivation is given to them while they are growing. They draw more heavily on the moisture near the surface than corn, and this is so far adverse to the growth of grain where moisture is lacking. The natural order is, however, that grain crops will follow. Where the moisture is not too much lacking, they may alternate from year to year.

Preparing the soil.—The seed bed for all the sorghums should be deep, fine and moist, loose above and firm below. A cloddy seed bed is specially objectionable, since it is unfavorable to germination, which is naturally somewhat weak in the seed of all the sorghums. To insure such a seed bed, it may be necessary to use a planker or a roller when preparing the ground.

Stubble land should usually be plowed in the fall, and discing may frequently be helpful previous to the plowing. If the land is not plowed until the spring, it should be at once packed. The harrow should then keep

it fine and clean until the time for planting the seed. When sod land is plowed in the spring, the aim should be to make a loose seed bed without bringing up sods. The roller, disc and harrow, judiciously used, will make such a seed bed. Good crops of these sorghums have been grown by turning the sod over carefully, rolling it down smoothly and then drilling in the seed, as is sometimes done with the flax crop.



DRY LAND SWEET SORGHUM, ROSEBUD COUNTY, MONTANA.

Courtesy Northern Pacific Railway Co.

Sowing.—The Early Amber, sometimes called the Minnesota Amber, is the best variety of sorghum to grow in northern areas. The Early Orange does better farther south, but it is later in maturing and not quite so hardy. The Coleman also ranks high among the sweet sorghums. There are two types of maize, the yellow and the white. The yellow varieties, of which

there are several, are the more valuable. The extremes of height in the growth of these have been put at 2 to 12 feet. Both extremes should be avoided. The extremely dwarf varieties do not yield sufficiently, and the extremely tall varieties are illly adapted to very droughty conditions. The best variety of Kafir corn is the black hulled white. The stalks are leafy and the yields are relatively good. Red Kafir corn is also much grown, but to grow it calls for a longer season, and this also is true of the white variety. The aim should be to secure home-grown and acclimated seed in all instances.

The time for planting the seed will, of course, vary with soil, season, latitude and altitude. The warmer the soil, the earlier the season, the higher the latitude, and the lower the altitude, the earlier may these crops be planted. But they should not be planted until all danger from frost is past and until the weather has become reasonably and regularly warm. The seeds are easily injured in their germinating power by being planted in the cold soil, and in cool weather. The time for planting is from two to three weeks later than would be suitable for corn (see p. 274).

When the sorghums are grown mainly for seed, under very dry conditions, they may be best grown in hills, and may be planted with the hand-planter or the check-rower used in planting corn. For hand-planting the ground should first be marked out in squares $3\frac{1}{2}$ feet distant. When thus planted, the cultivation given may be more thorough than if the seed were planted in rows. When grown mainly for fodder, the aim should be to grow the crop in rows and usually to plant the same with the grain drill. The rows should be about $3\frac{1}{2}$ feet distant. Broadcast planting may answer where the rainfall is 20 inches, but it is seldom satisfactory when it is 15 inches or less.

The seed should seldom be buried more than 2 inches, but in some instances it may be necessary to plant it more deeply in order to reach moisture. It is slow to germinate, and this fact makes it possible to use the harrow with considerable freedom before the plants appear. This could not be done where the seed had been broadcasted without destroying many of the plants.

The amount of seed to plant will vary from, say, 3 to 4 quarts per acre to $1\frac{1}{2}$ bushels. The latter amount can only be used when the crop is grown as grain hay is grown, and in areas with a rainfall approximating or exceeding 20 inches per annum. The amount of seed used should be carefully adjusted to the amount of moisture that is in the soil and that may be expected to fall under normal conditions. From, say, 2 to 3 stalks should be the minimum number in the hills, and in the rows the plants may be from, say, 3 to 12 inches distant.

Care of the crop.—The harrow or weeder should be used on the crop once or twice before the plants appear. If used the second time it should be just before the plants appear. Thorough and careful harrowing at such a time may preclude the necessity for further harrowing until cultivation begins, but there are instances when the harrow or the weeder may be used with profit subsequently, but not usually until the plants have reached the height of, say, 3 to 4 inches. The cultivation called for is about the same as that which will best meet the needs of the corn crop (see p. 280).

Harvesting.—Small areas of the sorghums may be harvested by hand and put up in shocks like corn. Large areas may be cut with the corn harvester, and, under some conditions, with the grain binder. The mower is frequently used when the crop is grown on the broadcast plan. When thus cut, the sorghum is put up in large cocks, and in these it remains until it is fed. The sorghums are much liable to heat and mold in the stack.

The grain is sometimes removed by cutting or snapping off the heads by hand, at other times by using the header, and yet again by certain forms of threshing. Home supplies of seed may be secured by removing choice heads and suspending them beneath a roof until the season for planting draws near.

The yields of fodder are somewhat greater than those of corn, as their adaptation to dry conditions is higher. In the dry form, they will average from, say, 2 to 3 tons per acre. The yields of grain vary greatly with the season, but these also are higher than those produced by corn under similar conditions of growth. Milo maize produces more grain than the other sorghums. Under favorable conditions of growth, an average of 40 bushels per acre has frequently been obtained.

GROWING POTATOES

The potato crop is one of the surest for dry land conditions. There are instances in which it has been grown with reasonable success for many successive years where the annual precipitation is not more than 12 inches. When grown under dry conditions, the potatoes are of higher quality than when grown under irrigation. When grown under irrigation, immense yields may be obtained from judicious culture, but the tubers are more watery, and they soon become less valuable for seed than those grown without irrigation, hence the demand for such potatoes is likely to continue good. The best climatic conditions for potatoes are found in the northerly areas of the semi-arid belt and on the higher elevations southward. They do not flourish so well where the climate is hot.

Soils.—Sandy loams furnish the best soils for potatoes, but good crops may be obtained from any reasonably good loam soil. Stiff clays are objectionable, as much labor is involved in order to bring them into a good

condition of tilth. The potatoes also grow more slowly in such soils, and extra labor is involved in harvesting the crop.

Place in the rotation.—Under dry conditions, the best crops of potatoes may be obtained from sod or other land managed on the summer-fallowing plan. But such land can seldom be spared for potatoes. The best crops may probably be obtained by breaking sod and managing it as summer-fallow the season of breaking. On this the crop is planted the following spring, in some instances without further plowing, and in others after it has been deeply plowed. On older land it is frequently made to follow alfalfa which has occupied the ground for a limited number of years. More commonly, however, the crop is grown on stubble land, manured or unmanured. On new land two good crops may be grown in succession, in the absence of disease, but ordinarily the potato crop should be followed by a grain crop or by a seeding to alfalfa, as when well cared for it leaves the land in excellent condition for these.

Preparing the soil.—On new breaking, or even on other sod land, reasonably good crops of potatoes have been grown by simply breaking shallow and dropping the sets in, say, every third furrow and following with the roller and harrow, and without any cultivation subsequently. One strong objection to this method is the difficulty found in harvesting the crop. But the homesteader who is beginning his work may find it to answer his needs. The better plan is to plow the sod to a depth of 6 inches or more, to make a good seed bed on it, and to plant the crop in the same, so that suitable cultivation may follow. It is important that the sods shall be well buried so that they will not interfere with the subsequent cultivation. When grown on alfalfa land, it is frequently broken in the spring after the alfalfa has begun to grow. When grown on stubble land, the aim

should be to plow in the fall, and deeply. Where the conditions do not favor such plowing, the work may be done in the spring. Potatoes want a deep seed bed. Firming the lower seed bed is not so important for potatoes as for most other crops.

Planting.—Since, in the semi-arid belt, the weather is usually very dry after August 1st, the early varieties should be preferred, other things being equal. The most popular potato at present in much of the dry area is the Early Ohio, and it is probably the most profitable. The Burbank holds a prominent place among the later varieties. Other varieties that have been more or less grown are the Rural New Yorker, the Mammoth Pearl and the North Pole. While the time for planting potatoes will, of course, vary with latitude and altitude, the aim should be to plant the crop at as early a date as will be admissible because of the presence or absence of frosts. This crop is easily injured by frost at all stages of its growth. But the nipping of the young plants does not mean their destruction; it does mean, however, a considerably retarded growth. It is important to give the plants an early start in order that they may get all the benefit possible from the rains before they cease to fall for the season. The time for planting potatoes may begin about the time when corn planting usually begins (see p. 274), and it may be continued even later than would be suitable for corn, as, in some varieties at least, the potatoes will mature in a shorter time than corn. In areas where the winters are mild, potatoes are planted in the autumn, putting the uncut sets down in the soil below the lower frost line.

The crop may be planted in hills or in drills. The latter method is most commonly adopted when large quantities are grown, as the planting is then done by the aid of the potato planter. The hills are usually made from 3 to $3\frac{1}{2}$ feet distant, and similar distances should

be allowed between the rows. The seed chosen may consist, preferably, of medium-sized and shapely potatoes, planted singly and uncut when in hills or even in drills. More commonly, however, the seed is cut in large rather than in small pieces.

Deep planting is preferable to that which is shallow. In some soils, as those that are light, the aim is to put them in as deeply as 6 inches. Usually, however, they



DRY LAND POTATOES, CHOTEAU COUNTY, MONTANA.

Courtesy Northern Pacific Railway Co.

may be put down to the depth of 4 to 5 inches. In the absence of a planter, the seed is dropped by hand in furrows opened by the plow, and covered by running the harrow over the ground. The distance between the sets in the rows is usually about 18 inches, but they may be planted farther apart, if the lack of moisture should make such planting advisable.

The amount of seed called for will vary much with the size of the tubers and with the distance between the rows and sets, but 10 to 12 bushels will usually suffice for an acre.

Care of the crop.—In some soils the plan is good which uses the harrow on the planted crop from two to three or four times between the time of planting and the



DRY LAND POTATOES, NEAR KALISPELL, MONTANA.

Courtesy Great Northern Railway Co.

season when cultivation should begin, that is, when the plants are from 4 to 6 inches high. In other instances the weeder will give better results after the plants have reached the surface. The first cultivation given may usually be deep, especially if the plants are yet not far above the ground, but the cultivator so used should leave the surface of the ground level. The soil is thus left loose in which the potatoes may feed freely. The subsequent cultivations should be shallow, and they may be

continued even after the potatoes have reached the blossoming stage. Should the Colorado beetle give trouble, spraying with Paris green will be found effective, using a solution of 1 pound of Paris green to 20 gallons of water.

Harvesting.—The crop is ready to harvest when the tops die, but in dry areas no harm will usually follow if the tubers are not dug until late in the season, as injury from rain is seldom to be feared, which, of course, is not true of humid regions. Thus undisturbed, the tubers will keep nicely until they are wanted, or until the season arrives when the hazard is incurred that they may be injured by the freezing of the ground. The crop is dug: (1) by hand, using a fork with closely spaced tines; (2) by turning the tubers out with the plow and, after picking those that are visible, following with the harrow to uncover others; (3) with the potato digger, which is indispensable when large areas are to be dug. The tubers may be kept in pits or in cellars, but always beyond the reach of frost. The potatoes in the pits are placed in oblong piles rising up in the form of a ridge roof. They are then covered with a layer of straw, and over this one or more layers of earth, according to the needs of the climate. Along the ridge, suitable openings should be left for ventilation. Potatoes in cellars should be kept cool.

GROWING FIELD BEANS

This class includes two distinct classes. These are the common field bean and the soy bean. Each of these includes many varieties. The common field bean may be grown over much of the semi-arid area, as it grows on a great variety of soils and under very dry conditions. Moreover, the weather for harvesting the crop in dry areas is almost perfect. The common field bean may be grown with safety in a normal season as far north as

the Canadian boundary, if not, indeed, farther, and at elevations as high as 3,000 feet, if not, indeed, higher. The soy bean, however, may not be grown with much success north of the parallel of, say, 43, although in some varieties, as the New Era, it may be matured as far north as 45.

Soils.—Both classes of beans may be grown on a wide range of soils. The favorite soils for both, however, are loams, especially loams that have a considerable content of sand. While these crops will grow and produce on soils relatively low in fertility, they respond readily to fertilization. The volcanic ash soils of the west are well adapted to these crops. They may be grown on stiff clays, but not so well as on a better class of soils. There is no room for them on alkali lands.

Place in the rotation.—Both classes of beans are grown under cultivation and both are soil enrichers. Both may, therefore, be grown as cleaning and renovating crops. Both come with peculiar propriety after grain crops, and with equal propriety they may be followed by grain crops. They grow well on sod land in a proper condition of preparation. The aim should be not to plant them after other cultivated crops or on summer-fallow, as such land is wanted for the growth of cereals.

Preparing the soil.—The preparation of the land for beans is not far different from the preparation suitable for corn (see p. 168). As the crop is not usually planted so early as corn, a correspondingly longer time is given for cleaning the land by the aid of the harrow prior to the planting of the crop.

Planting.—The most suitable varieties of the common bean include the navy, the Mexican and the white wax. The navy is the most popular by far of the field varieties, especially the small navy. In California and some of the other states southward, the lima varieties

are grown. On and contiguous to the parallel of 45, the early dwarf varieties of the soy bean may be planted. Between the parallels 38 and 45, the medium dwarf, including such varieties as the early white, will be found suitable, also the medium early green, a variety that has found favor in certain sections of New England. Farther southward the standard varieties are more suitable. These include the medium late green and the medium late black. It is unsafe to plant either class of the two classes before the danger from spring frosts is past. When frozen down, the plants do not recover satisfactorily, as in the case of corn. This will mean that near the Canadian border planting will not be safe before about June 1st. The season for planting will continually advance as the north is receded from, save in certain areas of high altitude. The soy varieties should not be planted until both soil and weather have become reasonably warm.

Both classes may be planted in hills or in rows, but the latter method is the one that is most commonly adopted. The work may be done with the corn planter or with the grain drill. The distance between the rows and plants in the row will vary with the size of the plants of the particular variety. More commonly the rows are made 36 inches apart for the small varieties of both classes of beans. For some varieties of the soy beans the distance should be greater. The space between the plants will vary as the plants are large or small.

The depth to plant in average soils is from 2 to $2\frac{1}{2}$ inches, but in very loose soils or in those without moisture near the surface, it may be necessary to plant more deeply.

The amount of seed called for will vary much with the size of the seed. Usually from 2 to 3 pecks will suffice per acre, and in very dry conditions a less quantity will answer.

Care of the crop.—The crop will usually profit much from the careful stirring of the surface soil with the harrow or the weeder, before it reaches the surface. Subsequently, if harrowing is given, it should be done with great care, and usually only when the plants are too thick, so that if they are thinned somewhat by the process the crop will not suffer. After the plants appear, the cultivator is, all in all, the best implement to use. It should be run at first quite near to the line of the row. As with corn, the cultivations should be frequent and continued until the beans have reached the flowering stage. This work should never be done when the plants are wet with dew or rain. Some hand hoeing may be necessary to remove weeds that may start in the line of the row.

Harvesting.—The crop may be harvested by hand pulling, should the area grown be small. For large areas a bean puller, or, as it is sometimes called, a bean lifter, should be used. This implement cuts off the beans a short distance below the surface of the ground. They are then lifted by the aid of a fork and placed in rows or piles to dry. From these they may be stacked, if quite dry, and threshed later with a machine specially designed for such work. Soy beans are in some instances harvested by swine. For such a use they have high adaptation. In dry areas this may be done with little or no loss of grain, but, of course, the straw is spoiled for feeding.

The yields of the common bean average not less than 20 bushels per acre. The average yields from soy beans are probably not any more, but in some instances the large and late varieties give yields that are much larger.

GROWING FIELD ROOTS

The field roots that may be grown in the semi-arid areas include carrots, mangels, sugar beets, turnips, ruta-

bagas and kohlrabi. Carrots are mentioned first because of their pre-eminent adaptation to western soils, and especially to those of the volcanic ash type. Kohlrabi is a plant which produces what may be termed a bulb above the ground, in contrast to the turnip, which produces the same chiefly below the surface. Carrots and mangels will succeed under a wider range of climatic conditions



DRY LAND MANGELS, FLATHEAD COUNTY, MONTANA.

Courtesy Great Northern Railway Co.

than the other crops named, as they may not only be grown in areas that are relatively cool, but they may also be grown with success where the climatic conditions would be too warm for the successful growth of rutabagas and kohlrabi. The latter, therefore, have relatively better adaptation for the higher altitudes than the former.

While field roots may be grown successfully under dry conditions, it can scarcely be said with truth that they are as sure a crop as cereals. One handicap, some

seasons, is the lack of moisture to insure germination at the proper season, as in most instances they call for planting that is relatively shallow. Quite frequently there is also a lack of ample moisture during the latter part of the growing season to produce a maximum growth. Sugar beets, especially, may not produce yields that may be desired from this cause, hence the wisdom of growing them under a very light normal rainfall is to be questioned, notwithstanding the high sugar content which they may possess.

Soils.—The best soils for all kinds of field roots are sandy loams underlaid with subsoils of moderately porous texture. Soils with a considerable admixture of sand in the clay element which they contain have especial adaptation to the needs of carrots, turnips and rutabagas. Mangels and sugar beets will grow more successfully in clay soils when once started, but none of these crops should be planted on stiff clays. It is difficult to properly germinate them on such soils. Nor is it easy to keep them in a proper condition of tilth. The silty soils of the river basins are usually too porous for the proper retention of the needed moisture for these crops. Gumbo soils which carry considerable quantities of alkali may be made to produce enormous crops of mangels and sugar beets when irrigated, but when not irrigated it is not possible so to manage them as to secure the requisite tilth for these crops under normal conditions. Dry gravels and shallow soils are wholly unsuited to the growth of these crops.

Place in the rotation.—Normally the place for these crops is after small grain, not only because such a succession furnishes the best conditions under which they may be grown, but because when grown thus the land is being prepared for a crop of small grain to follow. Land that has been summer-fallowed will be more certainly followed by a good crop than stubble land; hence, under

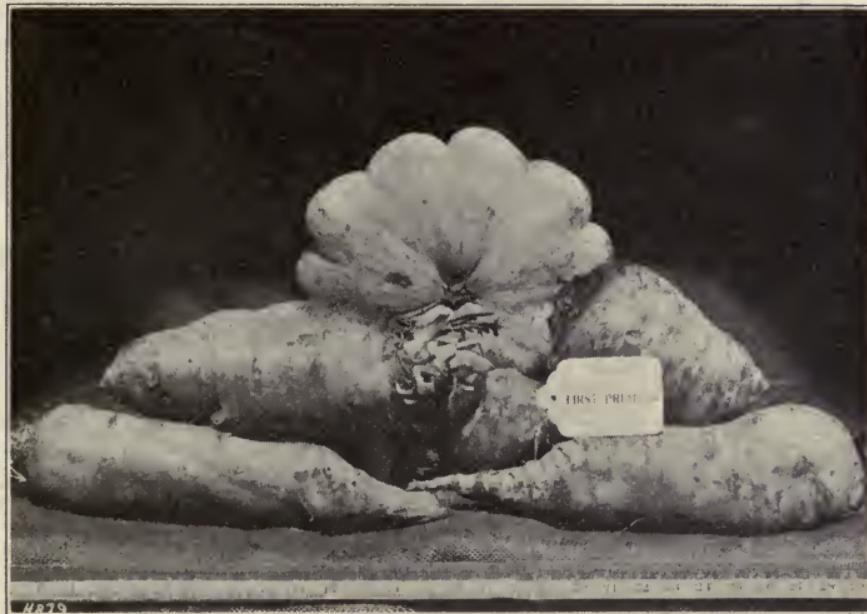
very dry conditions it may be advisable to grow them thus, not only to insure a crop, but also to increase the moisture content in the soil. Land thus managed has virtually the benefit of summer tillage for two successive years. The moisture thus stored in the soil will render the grain crop that follows almost an assured certainty. These crops may, in some instances, be grown successfully on alfalfa sod properly prepared.

Preparing the soil.—When root crops follow the summer-fallow it is seldom necessary to plow the land for them in the spring. In most instances deep discing will suffice, following with the harrow. When these crops follow the small cereals the soil may be prepared as outlined for the planting of corn (see p. 168). If the planting of the crop is deferred until a late period, say early June, the harrow should be freely used in the interval following the opening of spring. When these crops follow alfalfa, the land should be deeply plowed. This may not be practicable in the autumn. On land thus prepared the alfalfa roots may give trouble in cultivating the soil. This trouble may be greatly lessened by plowing the land to half the depth in the autumn and again to full depth in the spring.

Sowing.—The Mastodon carrot is one of the best varieties to grow, but Danvers half long is also good, having the special merit of being easily pulled. The Mammoth long red mangel and the Golden Tankard are among the most suitable varieties of this species. Any of the standard varieties of sugar beets, as, for instance, Vilmorin's Improved, may be grown. The old stand-by, the Purple Top Swede, still ranks high among the standard sorts of rutabagas, and the Purple Top Strap Leaf among the turnips. Carrots should be sown as soon as the ground is in proper condition to work in the spring. Mangels and sugar beets should not be sown until 2 or 3 weeks later, as they will succumb to frost. The best

quality, but perhaps not the largest quantity, of rutabagas, turnips and kohlrabi will be obtained from seed sown as late as May in northern areas.

In small areas the hand planter may be used in sowing any of these. In large areas the planter used in sowing sugar beets will best answer the purpose. But, with careful driving, the grain drill, or at least some grain drills, will sow any of these. When sowing carrots,



DRY LAND CARROTS, FLATHEAD COUNTY, MONTANA.

Courtesy Great Northern Railway Co.

mangels or sugar beets, it may be necessary to mix the seed with some substance, as dry earth, to prevent the same from feeding too fast. When the drill has a grass seed attachment that carries the seed into the drill tubes, the seed of rutabagas, turnips and kohlrabi may be distributed from this attachment. The openings into the grain tubes not in use must all be covered. These crops should not be sown in raised drills in the absence of irri-

gation, as this would result in the loss of too much moisture. The distance between the rows should be such as to meet the conditions of cultivation. Having regard only to the needs of the plants, the rows between carrots may be as close as 20 inches, mangels 30 to 36 inches, sugar beets 20 inches, rutabagas, turnips and kohlrabi 30 inches. The seeds of all these crops are preferably sown shallow, as shallow as 1 to 2 inches. Deeper planting will be more or less adverse to quick germination and also to strong germination, and yet it may be necessary to plant more deeply in order to insure germination. There is a marked advantage in having the soil pressed around the seed when it is planted, as is done by the press drill when it is used. Germination is then both surer and firmer.

From 2 to 3 pounds of seed should suffice per acre for carrots. It is usually considered wise to sow not fewer than 6 to 8 pounds of mangels and sugar beets to insure a full stand. From $1\frac{1}{2}$ to $2\frac{1}{2}$ pounds of rutabagas, turnips or kohlrabi should suffice.

Rutabagas and turnips may be sown on new breaking or on any overturned sod, more especially after it has been pressed down by the roller. The seed is broadcasted and is covered with the harrow. No cultivation is given subsequently. This method will, in most instances, bring a crop, even from early spring plowing the year that the land is first broken.

Care of the crop.—Whether the weeder or the harrow, or both, may be used on any of these crops after the seed has been sown will depend, first, on the depth to which the crop was sown, and, second, on the thickness of the stand secured. If the seed has been planted deeply, the weeder or a very light harrow may sometimes be run over the ground with profit after the seed has begun to germinate. After the seed is up, say, a couple of inches, one of these implements may sometimes be run over the

ground. The weeder will usually answer best. It should be run across the rows. Quite a number of the plants may be torn out, but that will do no harm, providing enough are left in. A few days subsequently cultivation should begin, and even earlier if the harrow has not been used. It should be reasonably deep at first, should be repeated every 10 to 14 days when practicable until the leaves reach far out into the row, and subsequently at longer intervals until the leaves almost meet between the rows. The ground should, in all or nearly all instances, be left smooth after the cultivator.

The aim should be to thin the plants before they get beyond the height of, say, 3 inches. This is usually done in the case of carrots, mangels and sugar beets, by striking a sharp hoe of suitable width across the line of the row, so that but few plants are left in the clumps unremoved. From these clumps all but one plant is removed by hand. In the case of rutabagas, turnips and kohlrabi, an expert workman will thin the plants almost entirely with the hoe. Carrots may be left from 4 to 6 inches apart, mangels from 8 to 12, sugar beets 6 to 7, rutabagas, turnips and kohlrabi 8 to 12. It may be necessary to use hoe and hand labor a second time on these crops to remove plants not needed and stray weeds.

Harvesting.—Mangels and sugar beets should be harvested before frost becomes severe, or it will so injure the exposed portions as to harm their keeping qualities. Carrots, rutabagas, turnips and kohlrabi may be left in the ground should this be desired, until the approach of the season when it will be locked by frost.

Carrots and mangels are usually lifted by hand and thrown into piles for being topped after a furrow has been turned with a plow which has loosened them so that they lie at an angle rather than upright. Sugar beets may be raised in the same way, but frequently they are raised or rather loosened by an implement that runs beneath

them. Carrots and mangels may be similarly loosened. They are then topped by hand and thrown in piles and covered with tops only until stored. Rutabagas and turnips are pulled by hand and thrown in heaps for topping, the same as carrots, described above. But in some instances they are topped with a hoe, pulled out of the ground with a heavy harrow, and are then lifted for storage. Kohlrabi may be harvested by first cutting off



DRY LAND TURNIPS, FLATHEAD COUNTY, MONTANA.

Courtesy Great Northern Railway Co.

the part above the bulb and then the stalk below the bulb with a strong and sharp hoe.

All these may be stored in ventilated cellars or in pits. When storing them in pits the same process may be followed as in pitting potatoes (see p. 296). In some instances mangels are harvested by swine, the portions left in the ground being raised for them by the plow or by a hand implement. Rutabagas, turnips and kohlrabi

may be harvested by sheep in mild areas. When harvesting these crops by swine or sheep the waste is less when the crop can be fed off in sections, by the use of hurdles that are moved as occasion may call for such removal. In northerly areas, such feeding off of the crop is usually inadmissible. The yields will vary greatly, but each class of roots discussed should furnish several hundred bushels per acre.

GROWING ARTICHOKEs

The artichoke, like the potato, is drought-resistant in a marked degree. It will grow under a wider range of conditions than the potato, and it is more persistent in its habits of growth. It would seem correct to say that it is the most hardy tuber grown. It is chiefly used in providing food for swine, and especially for swine that are being carried through the winter. More commonly the swine harvest the crop where it grew; hence, in northern areas, where the land is locked by frost during much of the winter, the artichoke does not fulfill so important a mission, relatively, as where the winters are mild. This plant is really a sunflower which produces tubers, and in the tubers lies its chief value, although the stalks are used to some extent in providing forage for certain kinds of live stock. The tubers are sometimes used as food for man. Instances are on record where this crop has been grown for successive years, and on the same land, from one planting, where the annual rainfall was not more than 10 inches.

Soils.—The soils that have highest adaptation for the growth of potatoes have also the highest adaptation for the growth of artichokes (see p. 291). It is of considerable importance that the artichoke shall be grown on land possessed of much friability, as swine can dig in such land more readily than in stiff clays.

Place in the rotation.—When artichokes are grown for but one year, the place in the rotation is virtually the same as for potatoes. But in some instances they are grown on the same land from year to year and without replanting. Moreover, the natural order for artichokes in the rotation is after a crop of small grain and also before a crop of the same.

Preparing the land.—The preparation of the land is about the same as for potatoes (see p. 292). But since artichokes may be grown on the same land from year to year, it is a matter of considerable importance that the ground shall be deeply plowed and that the preparation shall be thorough where the crop is to be grown thus.

Planting.—The common Jerusalem artichoke is the variety that is chiefly grown and that is best adapted to arid conditions. But under specially favorable conditions other varieties give larger returns. The time most commonly chosen for planting is the early spring, but in many instances the sets are planted in the fall. When planted in the fall, it has been found better to plant whole, but when planted in the spring the tubers may be cut as in the case of potatoes. Fall planting usually takes place late in the season and spring planting quite early. The advantages from fall planting are: first, that the work of planting may be done at a time when work is not pressing, and, second, that the crop is ready to grow as soon as the season for growth comes. Though these tubers should be frozen in the soil, their vitality is not destroyed, and, unless in instances of extreme freezing, it is not in any sense injured.

The tubers may be planted, as in the case of potatoes, by hand or with the planter, in hills 3 to $3\frac{1}{2}$ feet distant or in rows of similar distance. They should be far enough apart to admit of easy cultivation with the cultivators ordinarily used.

They should be planted to about the same depth as potatoes, that is from, say, 4 to 6 inches deep, according as the soil is light or heavy. The deeper planting should take place in the lighter soil. If planted deeply in heavy soil swine cannot harvest them so readily. The sets are placed from, say, 15 to 20 inches in the line of the row, and in hills 2 sets will usually suffice.

The amount of seed called for is considerably greater in fall planting than in spring planting, since in the former the seed is not cut. Usually 10 to 12 bushels per acre will suffice for fall planting and about 40 per cent. less for spring planting.

Care of the crop.—The artichoke plants will stand severe harrowing. The harrow or the weeder, or both, may be used upon the land several times from the time of planting until the crop has reached the height of, say, 10 to 12 inches. The cultivator will then follow as long as it may be found practicable to continue the work.

Should the crop be allowed to remain in the ground from year to year the excess of plants that may begin to grow in the spring should be removed by the cultivator. These plants will come from tubers left in the soil from the gleaning of the swine referred to below. They should be left in rows, or, what is even better, in squares wide enough to admit of cultivation between them with the usual implements. The care of this volunteer crop will be in outline much the same as has been submitted in the paragraph immediately preceding.

Harvesting.—Artichokes may be harvested, after removing the tops, by a fork or by a potato digger. They may also be harvested by swine after they have matured. This process may continue where the supply holds out until the following spring, when frost does not interfere with the gleaning, and when it will not interfere with the soil at such a time. In heavy soils the plow is used to bring the tubers to the surface as the swine may need them. Artichokes yield more freely than potatoes.

CHAPTER XIII

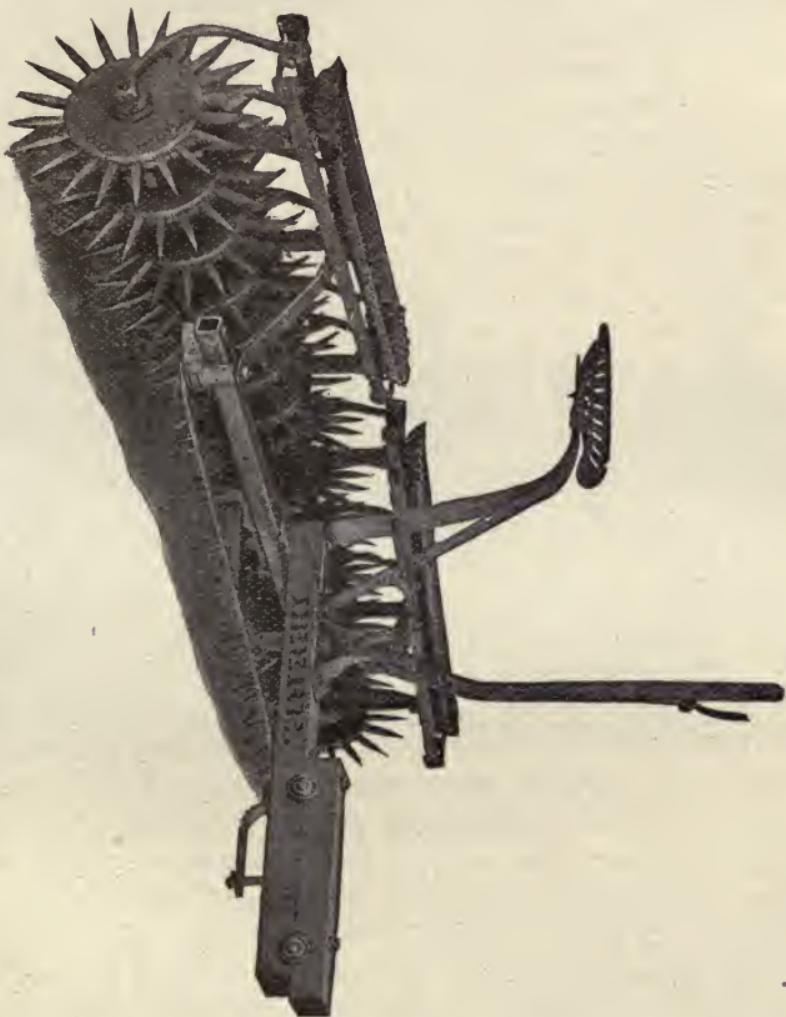
GROWING LEGUMES IN DRY AREAS

The legumes which probably rank highest in their adaptation to dry areas include alfalfa, the common clovers, sainfoin, vetches, cow peas and sweet clover, also the Canadian field pea, the common field bean and the soy bean. The three species last named have already been discussed. Of these the mission of alfalfa will probably be found more important than that of all the others combined. The great value of legumes in dry areas lies first in the fact that nearly all of them have much power to grow under dry conditions; second, in the enrichment which they bring to the soil; third, in the humus which they bring to the same, and, fourth, in their relatively high value in furnishing food for live stock.

GROWING ALFALFA

Beyond all question alfalfa is to be the great hay crop of the semi-arid west. Without alfalfa the problem of furnishing hay for the farmer of this region would be very grave. With alfalfa it is not difficult. The view was very prevalent until recent years that alfalfa could not be grown successfully in the absence of irrigating waters unless water was found not far below the surface of the ground. It is now known that where the soil and subsoil for alfalfa are suitable, it may be grown successfully where the water table is several hundred feet below the surface, providing the climatic conditions also are favorable to its growth. Where this beneficent plant can be grown, it will furnish hay for live stock, bring enrichment and humus to the soil, tend in a very marked degree to prevent blowing in light soils, and prove a most effective subsoiler through

the influence which its roots exert upon the soil and sub-soil in their growth and decay. The value of this plant to the dry land farmer can scarcely be overestimated. It has been ascertained during recent years that it may be



THE ALFALFA RENOVATOR.
Courtesy Deere & Webber Co., Minneapolis, Minn.

grown successfully on average soils where the annual precipitation is not more than 10 to 12 inches in a year.

Soils.—The best soils for alfalfa are loams, pronouncedly sandy in their composition, and underlaid

with a reasonably porous sandy and clay loam subsoil. Such soils are frequently found in river basins, and when they are, and ground water is within a few feet of the surface, the conditions for alfalfa are all the more favorable. It should be remembered, however, that alfalfa will grow successfully on the average clay loam soil of the semi-arid west, with a moderately clay loam subsoil, though the water table should be hundreds of feet below the surface. Alfalfa will also grow reasonably well on stiff clay soils, but on these it is more difficult to get a stand than on sandy loam soils. In an average year it will do well even on gumbo soils, but on these it may be greatly lacking in a dry season. Alfalfa will not grow well on soils composed mainly of vegetable matter. It will not succeed in dry areas on light sands or on gravelly soils much lacking in an inter-mixture of clay. It will not succeed in lands which are subject to overflow for any considerable portion of the year, nor will it succeed on land strongly impregnated with alkali. Shallow soils, also, and those underlaid with hard-pan which comes within a foot or two of the surface are most unfavorable to the growth.

Place in the rotation.—The normal place for alfalfa in dry areas is always virtually the same. This means that where the average rainfall does not exceed 15 inches the aim should be to sow alfalfa on summer-fallowed land or on land which has grown a cultivated crop the previous year. The reasons for such a rotation are found, first, in the fact that the land is or should be clean, and, second, in the fact that it should contain a relatively high moisture content. When the rainfall is more than 15 inches, it is not so necessary that this rotation shall be rigidly adhered to. In new areas it may be grown on land newly broken, as a means of obtaining quickly a supply of hay, but with the distinct understanding that this is not the best method of growing it. The objec-

tion to growing it after grain lies in the fact that such ground is more or less weedy, that it is frequently much lacking in moisture, and that in many instances it has not that completeness of fine and yet firm tilth that is favorable to the growth. It succeeds much better on land that has been broken for several years than on land that is absolutely new, under semi-arid conditions.



DRY LAND ALFALFA, YELLOWSTONE COUNTY, MONTANA.

Courtesy Northern Pacific Railway Co.

Alfalfa may be followed by various crops. Prominent among these are such crops as revel in a plentiful supply of humus in the soil, including corn, the sorghums; potatoes, sugar beets and other field roots, as rape and millet, especially when these are planted in rows and cultivated. Grain crops of the small cereals are next in order.

Preparing the land.—Ordinarily, when preparing the land for alfalfa, the plan is to be commended, at least in areas where the land is new, which begins the work one year before the seed is sown. The preparation consists in summer-fallowing the land, or in growing on it a cultivated crop to get the moisture well into the land. This is very important. The plan is also excellent which begins such preparation by applying about 10 loads, that is, about 10 tons of farmyard manure to the acre before the land is plowed for the summer-fallow or the cultivated crop, because of the favorable influence which it exerts on soil inoculation (see p. 316). Preparing the land thus leaves it in a clean and moist condition at the close of the season. The following spring the disc, followed once by the harrow and again at intervals if necessary, should put the land in good condition for receiving the seed. Such a seed bed should be moist, fine on the surface, and more or less firm below. When the land is plowed for the fallow or for the cultivated crop, it should be plowed deeply. Should the seed be sown on breaking, it should also be plowed deeply and well pulverized on the surface.

Sowing.—In the areas of the dry belt that lie southward, hardihood in the plants with reference to standing cold in the different varieties does not call for serious consideration, but this is not true of the northern areas thereof. In the latter, preference should be given to seed that has been grown well northward, as in Montana or on similar parallels. Drough-resistant varieties are being introduced, but none of these have up to the present time shown superiority in this respect which would justify supplanting the varieties commonly grown with them.

Usually the aim should be to sow alfalfa seed as early as the danger from frost to the young plants ceases. This, in the northern areas of the dry belt, would be in

late May or early June, and earlier in lower latitudes. Where the rainfall is reasonably copious in the autumn and winter, it may answer to sow the seed in the autumn. It may be wise in some instances to defer sowing for a time, to give opportunity for the more perfect cleaning of the land.

The seed should be sown in dry areas with some kind of drill. Otherwise much of it may not sprout because of the shallowness of the covering given to the broadcasted seed. When sown with a drill, it may be put down to moisture, may be buried to a uniform depth, and, in some instances, may be profitably harrowed before the plants have reached the surface and subsequently. A grain drill that feeds the seed from an attachment into the grain tubes will put the seed into the ground in about the best way possible. For ordinary sowing all the tubes are used. Quite recently, however, the method of growing alfalfa for seed by planting it in rows far enough apart to admit of cultivation between them is being tried. The most suitable distance between the rows and also between the plants in the line of the row has not yet been fully determined, but it is believed that this method of growing alfalfa seed will be found profitable in wide areas of the semi-arid region.

On heavy soils and with ample moisture, the aim should be to plant the seed shallow, that is, to a depth not much more than an inch. On light and open soils it may be put down 2 and 3 inches, in some instances, with positive benefit.

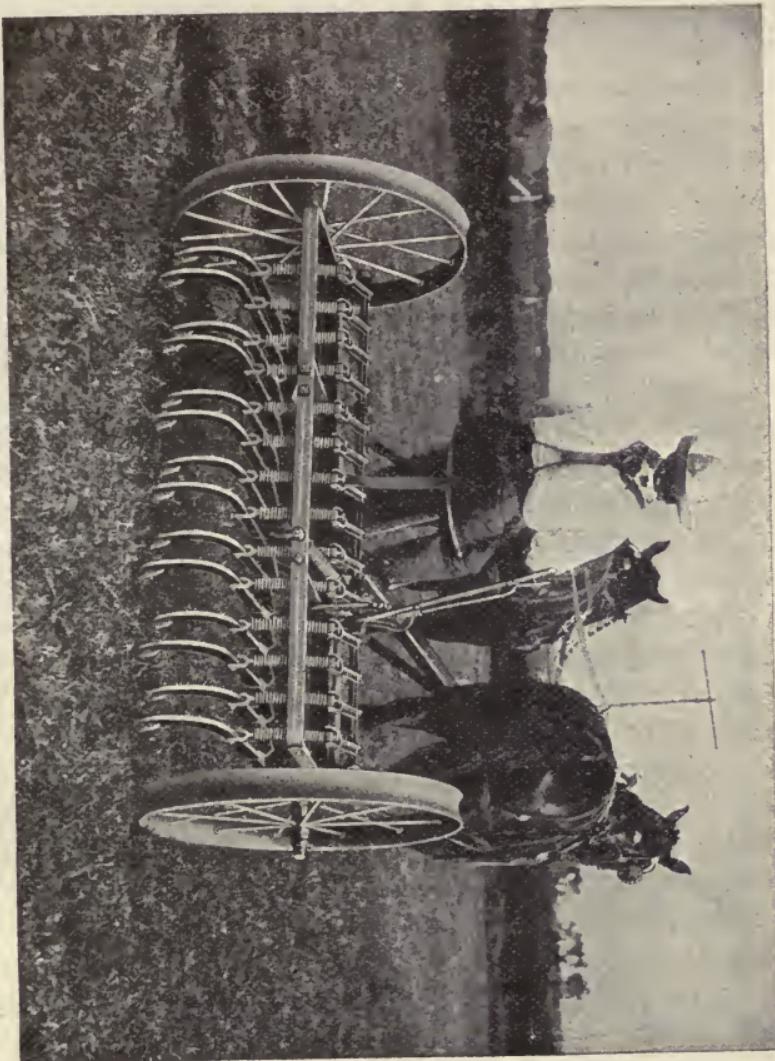
Where irrigation is practised it is common to sow 15. to 20 pounds of seed to the acre, that the hay product may be fine in its growth through the crowding of the plants. But in areas where the rainfall is about 15 inches or less, more than 8 pounds of seed are seldom sown, and in many instances this amount is still further reduced to 5 or 6 pounds.

Where the moisture is ample, the seed is frequently, though not in all instances, sown with a nurse crop. But in dry areas this should be done very seldom, if, indeed, at all. Where the plants are too numerous for the moisture supply, the root growth will not be so deep and strong as under other conditions, and the yields will be reduced in proportion. When growing this crop it is greatly important that the plants shall make a vigorous growth the first season.

In some instances alfalfa will not grow well when the first attempts are made to grow it, even on soils that have the requisite physical and chemical conditions for growing the crop. The cause is found in the absence of the requisite bacteria in the soil for the successful growth of alfalfa. Where these are not present in the soil alfalfa cannot be grown with complete success. The absence of the bacteria in a season of normal rainfall may be known: (1) by the lack of growth in the plants, especially in the latter part of the summer; (2) by the pale color of the leaves, and (3) by the lack of production in the plants, even though they should survive the rigors of the winter.

When it is apparent that the bacteria are lacking in the soil, the part of wisdom is to introduce them. This may be done: (1) by securing the culture known as nitragin and soaking the seed in it before sowing; (2) by securing, say, 200 pounds of earth, preferably from an old alfalfa field, and scattering it over each acre of land on which alfalfa is to be sown before or after the sowing of the seed; (3) by the liberal application of farmyard manure at the outset on land that is to be sown to alfalfa. The first method is not always reliable, as the germs may have lost vitality before they are used. The second method is reliable, and the same may be said of the third, but the reasons therefor are not as yet well understood. Happily such inoculation is not usually needed when alfalfa is sown on western soils.

Care of the crop.—In some instances, on some soils heavy rain falling on newly sown seed packs the ground to the extent of preventing the plants from reaching the



THE DEERE ALFALFA CULTIVATOR.

Courtesy Deere & Webber Co., Minneapolis, Minn.

surface. This crust should be broken, preferably by a weeder. In some instances it may be necessary to resow the crop.

On some soils it will pay well to harrow the crop, but not usually until the plants reach the height of, say, 3 to 5 inches. On other soils this may not be admissible. Where the harrow can be thus used, it aids in cleaning the land, and frequently it may be used again, once or twice, at a later period.

The crop should be clipped when, say, 8 to 10 inches high, by running the mower over it and set so high that it will not cut off the crowns of the plants. Should the tops of the plants show any indication of lack of moisture, by assuming a yellowish tint, the mower should be at once sent into the field. The clipping cuts off weeds that may be present, and it tends to strengthen the alfalfa plants by causing renewed growth in the roots. What is thus mown may usually be left to mulch the land. The plants should then be allowed to make a good growth, so that they may go through the winter in good condition. The top growth will tend to hold snow and to break the force of the wind. It should not be pastured the first season.

After the plants have reached the age of two years, discing will be found profitable in the early spring, also carefully stirring the soil with an alfalfa renovator (see p. 154). The discing should be done in the early spring, also the stirring of the soil, as soon as either can be done without harm to the soil. The discing may be severe, but the discs should not be set at too much of an angle, or they may cut the plants. After the discing the harrow should be run over the ground to smooth it. The renovator stirs the ground deeply and does not cut the plants or split the crowns. Such stirring of the soil helps to kill weeds and insect life, aerates the ground, conserves moisture and makes plant food available.

Harvesting for hay.—For hay, alfalfa should be cut for swine just before any blooms open; for sheep, dairy and beef cows, just after the blooms begin to open, and

for horses still later. It is raked as soon as the rake will readily do the work. It is drawn into small winrows and lifted from these onto the wagon when cured, or it is stacked by the aid of other machinery of modern construction, as the bull rake and stacker. In other instances the winrows are put up in small cocks to complete the curing. In dry areas the first cutting may sometimes be injured by rain, but this will seldom happen with the second cutting.

Harvesting for seed.—Dry land conditions frequently show high adaptation for the production of alfalfa seed. Excessive rankness in the growth of the plants and wet weather when the plants are in bloom are adverse to the growth of alfalfa seed. The same is true of plants that grow too thickly on the ground. The best seed crops are obtained from plants young and strong and growing well apart. Because of the influence which ample space has on the production of seed, the practise of growing seed in dry areas that is obtained from plants grown in rows and cultivated is meeting with much favor. This method of growing the seed, however, has not as yet been carried beyond the tentative stage, but much is expected from it.

The following are among the indications of a probable shortage in the seed crop: (1) blooms not numerous, and light in color; (2) blooms that do not fertilize, but fall off from the plants; (3) the production of only one or two weak and small pods in a flower truss. When these and some other indications that may be given are present, the crop should be cut for hay. In areas north of the latitude of Denver, the first cutting frequently furnishes the best seed crop, but this does not always follow. The crop should be cut for seed when a majority of the seeds have turned brown. The stems, notwithstanding, will still be green. If allowed to stand too long, there will be much loss through shattering of the pods, and this condition is intensified by rain. When

the seed crop is cultivated, the danger is present that there may be an excessive thickening of the crop from volunteer seed. The fertilization of alfalfa is partly accomplished by bees and other insects, and partly through self-fertilization, a property that inheres in the plants.

More commonly the seed is harvested by using the self-rake machine. The aim should be to thresh the seed from the sheaves, a method which is seldom hindered



DRY LAND ALFALFA, TWO YEARS OLD, HARNEY CO., OREGON.

Courtesy Northern Pacific Railway Co.

by rainfall, in areas where much alfalfa seed is produced. When thus threshed, it should be stacked, and much care should be exercised to have the crop sufficiently dry before stacking, otherwise the seed may be injured by heating.

The seed is threshed in best form by the clover huller, but it may also be threshed with the grain sepa-

rator, but that method of threshing is more or less wasteful of seed. The yields of seed vary. As many as 15 to 18 bushels per acre have been obtained, but 4 to 5 bushels are considered a good crop.

Good alfalfa seed is a bright golden yellow color, but it may have a slightly greenish tinge. It should be plump and free from shrivelled seed, and also from the gray-like seeds of dodder and other noxious weeds. Before planting, it should always be tested as to its vitality.

Duration of the crop.—The duration of the crop in semi-arid areas varies greatly with the conditions. It seldom fails from lack of moisture. Should it get weedy or grassy, it is usually wise to break up the crop. On the bench lands it has not yet been fully determined as to the time that alfalfa will continue to produce well, but it will last, in most instances, for several years. Where it is easily grown it may be broken up at the end of 3, 4 or 5 years to improve the soil for other crops.

Breaking alfalfa sod.—Alfalfa does not make a stiff sod, nevertheless it is very difficult to plow, because of the size of the roots. It is not easy to cut them all off with the plow and thus prevent future growth. To aid in this work, a share more or less notched on the cutting edge is sometimes used. In some instances the land is plowed shallow, and again more deeply, before the crop that follows is sown.

MISCELLANEOUS FACTS

1. The seed of alfalfa is sometimes mixed with the seed of sweet clover. The resemblance between them is so close that the presence of the clover seed can only be detected by the sense of smell. There is no way of separating these.

2. When alfalfa fields have been broken up and sown to grain, the plants that have escaped the plow usu-

ally become prolific producers of good seed. This is threshed with the grain and separated subsequently.

3. Should a crop of alfalfa be injured by such influences as drought, frost, hail or insects, when the growth is at all advanced, it should be at once cut, as it will make more growth subsequently, and of superior value, than if it were not so treated.

4. The objections to pasturing alfalfa under dry conditions are: (1) that in some instances it may cause bloat in cattle and sheep; (2) that in others it may unduly pack the land; (3) it may prove fatal to plants late in the season in northern latitudes, and (4) it may tend to spread disease among the plants. When pastured with swine, which is one of the best uses to which it can be devoted, it will not live so long as when grown only for hay.

5. The leaves of alfalfa that break off in the curing, the stubs of stems below the cut portions which later fall off, and the stubbles, in addition to the roots, bring much enrichment to the land and also much vegetable matter.

GROWING CLOVERS

The place for clovers in dry areas will never equal in importance the place that will be assigned to alfalfa. The part that clovers will play, relatively, in such areas will not be one of great significance, judged by the present indications. This arises from the fact that clover must have considerable moisture in order to make its growth profitable. Where the rainfall is 15 to 20 inches, clover may be grown with some success. This means that it may be grown in certain portions of the semi-arid country, especially those portions of the same that border on humid areas and certain other areas near the foothills of the mountains. On nearly all areas to which irrigating waters are applied clover may be grown with great success. But where the rainfall is less than 15 inches per

year, the wisdom of sowing much clover is certainly to be questioned.

The kinds of clover that furnish food prized for live stock, and that may be sown with some success in certain portions of the semi-arid belt are the common red, the mammoth, the Alsike and the small white. Far southward the Japan variety will probably be the most valuable variety to grow. Sweet clover (see p. 335) may also be grown for certain uses.

Soils.—Clover will grow well on all soils that are suitable for alfalfa. It will also grow on soils that are much more shallow, as in none of its classes or varieties does it root so deeply. The Alsike variety is best adapted to low, damp soils. Clovers will grow well on soils very low in fertility. Japan clover is better adapted for such a condition than the other clovers.

Place in the rotation.—The clovers follow naturally where grain crops have been grown for a longer or shorter term of years. The best place for clovers, viewed from the standpoint of securing a good stand of the clovers, is on land that has been summer-fallowed after a grain crop or after a crop that has been cultivated. Such land is clean and it usually contains sufficient moisture to insure a stand of the clover when it is sown. The clovers should be followed by corn, flax and the small grains. The best succession is probably corn followed by grain, but good crops of flax may usually be grown on clover sod.

Preparing the land.—The preparation of the land that is suitable for the small grains (see p. 218) is also suitable for clover. The seed bed that will grow these in best form is also the seed bed that will grow clovers in best form. A clean seed bed is important when these crops are sown in dry areas, and the summer-fallow and the cultivated crop which precede the small grains put the land in such a condition.

Sowing.—The leading classes of clover, which also may be looked upon as varieties, have already been referred to (see p. 323). To what is there said, it may be added that the most important of the clovers is the common red, since, when moisture is present in ample supply, it produces two cuttings in a year. The mammoth is of stronger growth and, therefore, may prove more satisfactory on light lands. The Alsike is pre-eminently adapted to low lying lands, but will grow well on higher lands, especially when these are strongly impregnated with lime. The small white, which is only adapted to pasture production, or at least mainly so, gives the best account of itself under moist conditions. Japan clover will grow on very poor soils, but the growth will be less vigorous proportionately than when it is grown on good soils.

All the clovers should be sown early in the season except the crimson, and that variety is not well adapted to dry areas. As a rule, the clovers should be sown as early in the season as the land is in suitable condition to receive them. In areas southward, it may answer to sow clovers early in the autumn. This method, however, is not applicable to northern areas, as the plants in these are unable to stand the rigors of the winter when sown thus late. They may be sown with the grain drill. More commonly they are sown with an attachment to the grain drill which allows the seed to fall before the grain tubes. It is much better, however, to have the seed feed into the grain tubes, which bury it with the grain, or, what is still better, running the seeder over the ground subsequent to the sowing of the grain. It may then be buried at a proper depth. On winter rye ground it may be sown broadcast in the early spring and covered with the harrow, or it may be sown with a drill such as has been referred to above.

Clovers should usually be sown with a nurse crop. They may grow better, in some instances, without a nurse crop, but if clovers cannot be grown successfully without starting them with a nurse crop, it is questionable if it will pay to grow them, since they are short lived. The nurse crops which would seem best adapted to their growth in the order named are: Speltz, barley, rye, wheat and oats. Oats are ill adapted as a nurse crop for



DRY LAND CLOVER AND TIMOTHY, NEAR REDMOND, OREGON.

Courtesy Great Northern Railway Co.

clovers, because of the abundance of the leaf growth, which produces an excessive shade, and draws heavily on the moisture in the soil. If clovers are sown along with oats, not more than 2 pecks per acre of the latter should be sown, and the crop should be cut for hay when it has reached the heading stage. They should be sown to the depth of 1 to 2 inches, on soil that is not stiff. It will not

answer to sow clover on the surface, as in humid climates, for then it would not germinate. On very light soils it should be sown more deeply even than 2 inches.

When red clover of either the medium or mammoth varietes is sown, about 6 pounds per acre should suffice. When Alsike is sown, about 4 pounds should be enough, and of the small white or the Japan even 3 pounds should answer.

Care of the crop.—If clover is sown in cold areas, it will not answer to pasture it down in the autumn of the year in which it is sown. Where the winters are mild, such pasturing is legitimate. If seed only is to be obtained, the crop may sometimes be pastured with advantage in the early spring. It is questionable whether any form of cultivation that could be given to the crop after it has become established would be of much service to the crop. In cold areas the shelter furnished by the stubbles is proportionate to the length of the same.

Harvesting for hay.—Clover of all kinds is ready for being harvested when it is in full bloom. It is, of course, cut with the mower. In a very short time in dry areas, it will be dry enough to rake. If not raked with some promptness, there will be loss of leaves and also injury to the crop from becoming overdry. In such areas curing may generally be completed in the winrow. The crop may be stored in the same way as alfalfa (see p. 318).

Harvesting for seed.—In the absence of experience the discussion of this question cannot be definite or specific. There are good reasons, however, for believing that clover will produce seed more abundantly relatively than hay. Whether in the case of medium red clover it would not be better to take seed from the first crop than to try to grow a second crop is at least an open question. From the mammoth and the Alsike, the seed must come from the first and only crop produced.

The seed crop is ready for harvesting when the heads have nearly all assumed a reddish brown hue. They are so ripe when they become black that they are much liable to break off in the curing process. The seed crop is harvested in much the same way as alfalfa (see p. 319). If the huller cannot be had for threshing clover it should be run through the separator twice in order to get all the seed. The probable yields of seed in the dry areas cannot be given definitely yet.

GROWING SAINFOIN

Experience in growing sainfoin in the semi-arid areas of the west is somewhat limited, so much so that facts regarding its growth under dry conditions are almost entirely wanting. It would seem probable, however, that sainfoin will fill a not unimportant place in providing food for live stock, both as hay and pasture in the semi-arid west. Sainfoin is a plant of the clover family. It is more branched in habit of growth than clover and attains a greater height. It furnishes two cuttings of hay in humid areas or one cutting of hay and one of seed, but under dry conditions it may not probably furnish more than one cutting. It is a good pasture plant, since it does not produce bloat as alfalfa does. It furnishes pasture quite as early as alfalfa and is probably as continuous and persistent in its habit of growth. It has a pink blossom which deepens into a crimson, so that a field of sainfoin has a beautiful appearance when it is in early blossom. One of the greatest difficulties encountered in growing sainfoin is the relatively low vitality of the seed. Because of this the stands obtained from sainfoin seed are not as complete as could be desired. To prevent such an occurrence large quantities of seed should be sown.

Soils.—While sainfoin will grow on a variety of soils, it has pre-eminent adaptation for soils that are rich in

lime and somewhat dry in character. This means that it should possess relatively high adaptation for many of the soils of the west, which, as a rule, are unusually well supplied with lime. This plant should, therefore, give a good account of itself on the volcanic ash soils of the far west. On soils saturated from seepage water or water from other sources, it should not be sown.

Place in the rotation.—Sainfoin, like the clovers, should follow a cleaning crop. As it should remain in the soil from year to year for several years when a stand is once obtained, it ought to be sown only on well cleaned land. It should, therefore, follow summer-fallow, or a cultivated crop. It may be followed with much of fitness by flax or other small grain, or by a crop of corn. The enrichment which it brings to land should increase crop production in a marked degree.

Preparing the soil.—The preparation of the soil for sainfoin is much the same as for alfalfa (see p. 314). It is especially important that sainfoin shall be sown on clean land, as intimated above, for the reason, first, that it is to remain in the soil for several years, and, second, that like alfalfa it is not well able to contend with weeds.

Sowing.—The best methods of sowing sainfoin under the conditions that obtain in the semi-arid west have not been worked out as yet. It would seem correct to say, however, that the crop should be sown in the early spring, without a nurse crop. The question of varieties has not yet been raised in this country.

The seed is sometimes sown in the hulled form, but it would seem correct to say that more commonly it is sown while yet unhulled. When thus sown it may be readily put into the soil with the ordinary grain drill. When sown in the hulled form, it may be necessary to mix it with some substance, as meal or road dust.

It is buried about as deeply as alfalfa. Somewhat shallow planting is best, when moisture is ample, but, of course, in order to insure good germination, it must be put down to the moisture. The germination is slow at the best.

The amount of seed called for under dry land conditions, has not been well worked out. European practise sows very large amounts of seed. It calls for about 40 pounds of clean and hulled seed per acre, and 3 to 5 bushels of unhulled seed. A bushel of unhulled seed weighs about 26 pounds. These amounts would seem to be excessive for western conditions, but this question has yet to be worked out.

Care of the crop.—The treatment of the crop under western conditions is yet in the tentative stage. It would seem probable, however, that the treatment for sainfoin the first season would be about the same as for alfalfa (see p. 317). Where the winters are mild it should endure moderate pasturing the first season without injury. Subsequently it may be grazed through the whole season or for only a part of it, hay or seed being furnished by it later. It is an excellent pasture crop. Whether it will endure discing like alfalfa does has not yet been proved, but it is not probable that it will endure treatment quite so harsh without suffering injury. As in the case of alfalfa, it will eventually be crowded out more or less by grass and some forms of weed life.

Harvesting for hay.—The harvesting of this crop for hay is about the same as the harvesting of alfalfa (see p. 318). The same precautions must be observed to prevent the shedding of the leaves and to insure the drying of the stems before storing the hay. The average yields of hay that may be looked for cannot be given in the present state of our knowledge. The quality of the hay is not quite equal to that of alfalfa, being a little more woody.

Harvesting for seed.—The conditions in the semi-arid west would seem to be especially favorable for growing seed, for the same reasons that they favor the production of good seed of grains and other seed-producing products. If seed can be produced with superior germinating power, it will mean much for the future of this plant. Information regarding the methods of handling the seed crop under dry land conditions is wholly wanting, and the same may be said regarding the yields of the seed. But the method followed when harvesting alfalfa seed should answer also for sainfoin (see p. 319). As the seed shatters very easily, the seed crop must be handled with much care.

GROWING VETCHES

The exact place that the vetch will occupy in the production of the semi-arid regions cannot be forecasted with precision at the present time. It would seem probable that it is only in areas that are favored with a considerable amount of moisture and temperatures that are reasonably cool, that it will grow in best form. The classes of vetch that are commonly grown include the common vetch and the sand vetch, frequently known as the hairy vetch. The latter is the more hardy of the two, not only in its power to endure cold but also to endure drought and hard conditions generally.

The common vetch is chiefly grown for hay, but may be grown for pasture also. The sand vetch is frequently grown for pasture, but may also be grown for hay. In the drier and hotter regions of the semi-arid west, the vetch will not fill an important place in the economy of production.

Soils.—The common vetch will grow well on any kind of soil that is possessed of a fairly abundant supply of plant food, and that has in it a reasonable amount of friability. It will grow on stiff clay soils, but not nearly

so well as on those that are of open texture. The sand vetch, as the name implies, is best adapted to a soil of open texture which may be easily penetrated by the roots. It has more power to grow in soils low in fertility than the common vetch, but it will, of course, grow much better on soils that are well stored with plant food.

Place in the rotation.—The common vetch may be given any place in the rotation, but, of course, not with equal adaptation. It comes naturally after a crop of small grain, to make amends for the depletion of fertility when growing the grain. But more frequently it will probably be sown along with some kind of grain to provide forage. The sand vetch is usually sown with some kind of small grain to provide forage or pasture, whether sown in the spring or in the autumn.

Preparing the soil.—The preparation of the soil for vetches will be the same usually as the preparation of the same for the grain crop amid which it is sown. This means that the crop will very frequently be sown on summer-fallowed land when sown in the autumn, and on similar land when sown in the spring, or on land that has been cultivated.

Sowing.—The common vetch is sometimes sown in the spring only, and in other instances both in the spring and fall, whether sown alone or with other grain. But it cannot be sown in the fall save where the winters are mild. The sand vetch is in some instances sown in the spring along with small grain and again it is sown similarly in the fall. More experimentation is wanted to determine conclusively the best time for sowing vetches. They are sown with the ordinary grain drill. The depth that will be most suitable for the grain will also answer for the vetches, hence the seeds may be mixed and sown with one cast rather than at different times. When the common vetch is sown alone, which is done

in some instances, the seed is usually buried about 2 to 3 inches.

Three to 4 pecks of the vetch will usually suffice per acre. When the common vetch is sown in the spring, it furnishes excellent hay when sown with bald barley, but it may be also sown with oats. About 2 pecks of vetch seed are sown per acre, and the usual amount of other grain sown is reduced by that much. About the same amount of the sand vetch ought to be sown. In the spring it may be sown with almost any kind of grain, reducing the amount of the same by only one peck. The vetch may add in a considerable degree to the value of the forage furnished by the grain. It will also grow on after the grain is harvested and furnish pasture both in the fall and spring, especially the latter. In the autumn the seed may be sown with winter wheat or rye, sowing about 2 pecks of vetch per acre and reducing the usual amount of grain by that much. The crop thus grown should usually be grown for hay.

Care of the crop.—About the only care of the crop that can be given is the use of the harrow at certain times. The vetch will probably stand about the same amount of harrowing without injury as would be suitable for the grain with which it is sown. When the sand vetch is sown with spring grain, harrowing or even discing after the grain crop has been removed, may prove helpful. In mild areas the pasturing of the vetch may be continued through much of the winter, but care must be taken in such instances not to injure the land by poaching.

Harvesting for hay.—When the crop is cut for hay, if sown alone the common vetch should be harvested by the aid of the field mower with an attachment in the same way as peas (see p. 266). The sand vetch grown alone cannot be harvested thus because of the tangling of the

vines. When these are grown with other grain crops, they may be harvested for hay with the binder or the mower. They should be cut for hay while yet a little short of full maturity.

Harvesting for seed.—The common vetch may be harvested for seed when grown alone as peas are harvested. It may also be threshed similarly (see p. 266). When seed is wanted from the sand vetch, it is best obtained by sowing it with grain as described above. Grown alone it would be almost impossible to harvest the crop owing to its recumbent and tangling habit of growth. When grown with grain such tangling is prevented, insomuch that the combined crop can be cut with the binder. When threshed the seeds are separated. Information as to yields of hay or seed are not yet obtainable.

GROWING THE COW PEA

The cow pea is not specially adapted for being grown in dry areas and yet it may be grown with profit under conditions where the rainfall is considerably less than what is considered normal in humid regions. This plant has marked adaptation for conditions in which the temperatures are higher than would be suitable for the successful growth of the Canadian field pea. In the dry area, therefore, one of these is in a sense the complement of the other, for where the temperatures become too warm for growing the Canada field pea at its best, they seem to have special adaptation for the successful growth of the cow pea. In the semi-arid areas, therefore, the cow pea will have a mission south of the parallel 45. North of the latitude named the Canada field pea will give results more satisfactory than can be obtained from the cow pea.

Soils.—Cow peas may be grown on any kind of good soil. They are grown for the purpose, first, of providing

hay, and, second, of enriching the land. Although this crop can be grown on soils low in fertility, it will grow much better on those that are well supplied with plant food. The best soils for cow peas, therefore, as for nearly all other crops, are loams varying from clay to sand in their composition. Nearly all the soils of the semi-arid region have abundant plant food for the successful growth of cow peas.

Place in the rotation.—As the cow pea is usually grown for hay or for the purpose of bringing plant food and humus to the land, it is more commonly sown after a grain crop. This means that it is more commonly sown after a crop of small grain and on land that has been specially prepared by correct cultivation autumn and spring. When cow peas are grown for a green crop that will be buried, any kind of a grain crop may follow the next season that is suitable to the locality. The same will be true of it when sown in rows and cultivated. In the latter instance more moisture will have been conserved as a rule than in the former. It is not possible to sow cow peas in dry areas the same season after a crop of grain as it is in humid areas.

Preparing the soil.—When cow peas follow grain the land may be prepared in essentially the same way as for peas (see p. 266), with the difference that more time is given for working the soil on the surface before sowing the cow pea than would be possible to secure in the case of peas. Should the crop be sown on spring plowed land, which may be admissible in some instances, it should be plowed early and at once packed.

Sowing.—Cow peas are of many varieties. The Wonderful is one of the best of these for average conditions. The Whippoorwill and the Black are also good, but these should not be sown save in warm latitudes. The time for sowing is not earlier than the close of the usual corn planting season. The cow pea will

not germinate in cold soil. Under dry conditions the seed should invariably be sown with the drill. As a rule the rows should be far enough apart to admit of easy cultivation. As the varieties named are vigorous growers, the vines will almost meet under many conditions of growth. The amount of seed to sow will seldom exceed one peck per acre. The seed should be buried about 2 inches or lower if moisture is farther down.

Care of the crop.—It may be harrowed before the crop is above the surface. In some instances the plants may be harrowed after they are above the ground, but more safely with the weeder. The cultivation should be about the same as that given to corn (see p. 280).

Harvesting for hay.—The cow pea furnishes excellent hay, but it is slow in curing. The hay may be cut with the mower, but better with the pea harvester. It is best cured in small coils. Dry areas are particularly favorable to the curing of the hay. When cured as described it is particularly valuable for feeding purposes, being unusually palatable and nutritious. As the vines tangle some, the hay is not always easy to handle.

Harvesting for seed.—As the cow pea ripens its seed very unevenly, the common method adopted to secure seed was that of hand-picking. The process is slow and costly. Another method is to harvest the crop when ripe, and thresh it as the common pea is threshed.

GROWING SWEET CLOVER

In northern areas sweet clover has never been given that attention which its good qualities should give to it. In several of the states, this comparatively harmless plant is proscribed as a noxious weed. Notwithstanding, the following may be said in regard to this much despised and much maligned plant: (1) It will grow on soils too low in the elements of fertility for the successful growth of many other plants. (2) It will grow on soils strong-

ly impregnated with alkali, and in its growth on these soils much of the alkali is removed, thus preparing the way for crops possessed of higher economic food value. (3) It will grow well at high altitudes, which means that the area in which it may be successfully grown is very wide. (4) It is one of the most valuable of the nitrogen gathering of the legumes. Its ability to draw nitrogen from the atmosphere and to deposit the same in the soil is in a sense unrivaled. (5) The nodules that live on the roots are essentially the same as those which feed alfalfa plants, hence sweet clover may be made the fore-runner of alfalfa. (6) It will produce a large amount of green manure for being buried in the soil. On soils that are strongly impregnated with alkali this production is simply beneficent. (7) Stock, which may not eat it at first, will at length become fond of it, notwithstanding the bitter principle which it contains, and will thrive on it. (8) It is most persistent in its habit of growth, more so, probably, than any other plant grown in dry areas.

The prejudice that has led this plant to be regarded as a weed is not well founded. It has arisen, doubtless, from the fact that, because of a bitter principle which it contains, live stock do not relish it, but they may be trained to feed upon it with satisfaction. The place that may yet be assigned to it is a large one in dry areas, not only in providing food for live stock under hard conditions, but also in removing an excess of alkali from the soil. This plant is also one of the best honey plants that can be grown.

Soils.—Sweet clover will thrive on soils that are low in the elements of plant food and that are firm in texture. In fact it seems to thrive better on soils that are firm in texture than on those that are loose and spongy. It is a plant that would seem to thrive best under hard conditions, notwithstanding the violence which such a state-

ment may represent with reference to ordinary plant growth. Sweet clover will thrive on barren, gravelly and sandy soils, and when grown it may be made to increase their fertility by the nitrogen which it has brought to them, and to improve their mechanical texture by burying the growth that has been made in the soil.

Place in the rotation.—As sweet clover is a plant that grows under hard conditions it may be given almost any place in the rotation. It may be grown with much propriety on lands that are low in the elements of plant food, and that are lacking in friability, also on lands that are impregnated so strongly with alkali as to preclude the growing of crops on the same. The burial of the sweet clover in the same will have an effect that is simply beneficent in the amelioration of such soils.

Preparing the soil.—The preparing of the soil for sweet clover is by no means an elaborate process. In some instances, the scattering of the seed on sandy or gravelly soil will result in a stand of the plants, even in the absence of harrowing. But this does not mean that sweet clover will not do relatively better on well prepared land. It is a fact nevertheless that sweet clover does not grow well on land that is possessed of a marked degree of friability.

Sowing.—Information regarding the best methods of sowing sweet clover is much lacking. That the seed may be sown in the early spring and along with a nurse crop is doubtless feasible. The clover should not seriously interfere with the growth of the nurse crop. The next year the clover should furnish a crop of hay or of pasture as may be desired. The fact, however, that sweet clover will sow itself makes it quite apparent that it would be possible to obtain a stand of sweet clover by sowing it in the autumn, either alone or with a nurse crop. When sown with a nurse crop, the seed may be put in by mixing it with the grain, or by sowing it with

an attachment of the grain drill. It is better to sow the seed shallow. This will be at once apparent from the fact that the crop is self-sown in so many instances, the seeds falling on the surface. But when spring-sown, the seeds cannot usually germinate without a certain amount of covering. The amount of seed that will suffice is not large, probably not more than 6 to 8 pounds per acre. But information on this point is very meagre, because of the slight extent to which it has been sown in dry areas.

Care of the crop.—When sown with a nurse crop, sweet clover does not require any other attention than what will be called for by the nurse crop. When sown alone it may profit by harrowing more or less. Should the crop ever prove troublesome, as is sometimes the case, by volunteering to grow where it is not wanted, it may soon be removed by simply preventing it from going to seed. It is a biennial, hence the plants can only persist in growing for two years. Should it grow in alfalfa fields, the frequent cutting of the alfalfa will soon cause it to disappear. Should it grow on the sides that line the irrigating ditches, it may soon be removed from these by persistent cutting, and it may be readily sup-planted by alfalfa, if the seed is sown at the proper season.

Harvesting for hay.—When this crop is harvested for hay it is greatly important that it shall be cut at an early stage of growth, as early as the stage of the first appearance of bloom. If allowed to grow longer, the stems become woody. Because of a bitter principle which the plants contain, they are not relished by live stock, but in dry areas where other grazing plants and other forage may not be present in much variety, they soon learn to relish the plants, as pasture or as forage. It is managed like alfalfa when harvested for hay (see p. 318).

Harvesting for seed.—But little information can be given with reference to the growing of seed, as it is not much grown. The plants, however, seed plentifully. It may be harvested for seed about the same as alfalfa and threshed in the same way. No figures can be given with reference to the yields of hay or of seed that will be of any special value.

As a green manure.—Sweet clover should furnish vegetable matter to the soil by sowing it with grain in the spring and by burying the plants the next season when the land is to be summer-fallowed. When sown on gumbo land the plants when buried should have a disintegrating effect on the hard soil.

CHAPTER XIV

GROWING HAY AND PASTURE CROPS IN DRY AREAS

The hay crop in dry areas is obtained from three sources. These are legumes, the grasses proper and certain of the grain crops. Of these the most important source by far is the legumes which have been discussed in chapter XIII. The cultivated grasses which will furnish hay in dry areas are not numerous. Of these the three that are most important are timothy, western rye grass and brome grass. Hay from grains is relatively far more important in dry areas than in those that are humid.

In many sections of the dry country, pastures are obtainable from rugged lands that never can be tilled, and yet they are in close proximity to arable farms. The owners of arable farms who can utilize such pastures are fortunate, as they are in proximity to cheap pastures furnished by nature from rugged lands that never can be tilled. In many instances, however, the tillable areas are not in proximity to such lands, hence, the necessity for obtaining pastures from other sources. The pasture problem in dry areas is confessedly difficult. This is owing to the fact that the grasses grown cannot usually be cultivated during the period of growth, as the grains are cultivated, hence the conservation of moisture in growing of grasses is difficult. The chief cultivated grasses grown for pastures in dry areas are virtually the same as those grown for hay, but for pasture they are more frequently grown in combination than for hay. The growing of pasture is the most difficult problem that confronts the farmer in dry areas.

Growing timothy.—While timothy is the best grass for furnishing hay for horses that has yet been introduced

in many portions of the dry areas, it does not grow so well as either western rye or brome grass. It does not stand dry conditions so well as either of these grasses, hence when grown it should be in favored situations, as near the foothills of the mountains where the seepage waters furnish moisture from subterranean sources, or where the rainfall is more than normal for dry areas.

Soils.—Loam soils are the best for timothy, more especially those that are rich in vegetable matter. Timothy will not grow well on sandy or gravelly soils when these are not plentifully supplied with moisture.

Place in the rotation.—In the rotation, timothy should come after summer-fallow or after a cultivated crop. Unless it is sown on land reasonably well-stored with moisture, the plants may die even after they have germinated. Among the best crops to follow timothy are flax and corn.

Preparing the land.—The preparation that is suitable for the crop along with which timothy is sown is also suitable for timothy. It should not be sown on rough or cloddy ground, hence where a good stand of timothy is expected the soil should be made fine near the surface. A seed so small as timothy will not prove satisfactory in cloddy land.

Sowing.—When timothy is sown alone, it may be sown fall or spring, preferably the former, as when thus sown it is much less liable to fail from drought than when sown in the spring. When sown in the fall, it is usually sown along with a crop of winter wheat, also in certain areas with winter barley. Such sowing is surer to secure a stand than spring sowing, as the plants have time to become firmly rooted before the arrival of dry weather.

The seed is sown with a nurse crop, preferably winter rye, winter wheat, and southward winter barley, but it may also be sown in the spring, especially in such areas

as the Upper Flathead valley where the rainfall is much distributed throughout the year. The seed is usually sown with a seeder of the wheelbarrow type, and covered with the harrow. At other times it is sown with the seeder attachment to the grain drill. Again it is sown on very light and loose soils by mixing it with the grain. On firm soils such burial would be quite too deep. Ordinarily one inch of a covering will be ample, providing moisture comes thus near to the surface. When sown alone, from 8 to 10 pounds of seed will usually be found ample for an acre.

Care of the crop.—But little can be done by way of caring for the crop after it has been sown. When sown with winter grain and well rooted, it may be quite possible to harrow the grain in the spring without dislodging many of the timothy plants, but this work will have to be done with a prudent caution, as timothy is a shallow rooted plant. To harrow the grain crop when the timothy is sown in the spring after the timothy has appeared above ground would mean the destruction of the young plants quite as effectively as it would cause the destruction of weeds. The greatest hazard to the young timothy crop comes when the nurse crop is maturing and subsequently. The maturing of the crop draws heavily on soil moisture. This drain, with the warm, dry period that follows, is hazardous to the stand. The hazard is much lessened when the nurse crop is cut for hay soon after the heading stage.

Harvesting.—Timothy is cut with the mower when cut for hay. It is raked when partially cured, and in dry areas the curing is usually completed in the winrows, from which the crop is lifted with forks, by a hay loader or otherwise. It cures readily and quickly. The yields run from about 1 to 2 tons per acre.

When cut for seed, it is harvested and cured like grain. It is threshed with the ordinary separator from

the shock or stack, as may be found convenient. The yields of seed run ordinarily from, say, 6 to 10 bushels per acre.

Combinations.—While timothy may be sown with various other grasses, the best combination is that of timothy and common red clover on average soil, and timothy and alsike clover on low land. The amounts to sow may be put at, say, 5 to 6 pounds each of timothy and common red clover per acre, and 5 to 6 pounds of timothy and 3 pounds of alsike clover.

Growing western rye grass.—Western rye grass, frequently designated slender wheat grass, is probably the best grass, all things considered, for dry conditions that can be grown. The seed has good germinating power. The grass is very hardy in standing heat, cold and drought, and it is abiding. It makes reasonably good hay and pasture, but for either use it does not rank very high among the grasses. It tends to grow more or less in bunches but not so much so as orchard grass. It is indigenous to the prairies of the west and it grows in highest perfection in those of the northwest.

Soils.—This grass will grow on nearly all soils found in western areas, but of course in best form on those that are reasonably friable, rich and moist. It will not grow on alkali lands. It will grow better relatively on soils lacking in moisture than any other useful grass that has yet been introduced. Its adaptation for wet soils is low rather than high.

Place in the rotation.—Western rye grass will be surer to make a stand when it is sown after the bare-fallow, or after a cultivated crop. But since it has much power to grow, in areas where the rainfall is more than 15 inches per year it may answer under some conditions to sow it on other land. Usually it is sown with some kind of a nurse crop. When the sod of this grass is broken it may with much fitness be followed with flax or

corn or even potatoes as the first crop and small grain as the second, unless where the rainfall is more than ordinarily deficient.

Preparing the land.—The preparation of the land is the same as would be suitable for the nurse crop. As for all other grass seeds, the seed bed should be fine and moist up near to the surface and, of course, firm below.



DRY LAND WESTERN RYE GRASS, WESTERN MONTANA

Courtesy Northern Pacific Railway Co.

Viewed from the standpoint of the needs of the grass only, the surface cannot be too well pulverized.

Sowing.—As in the case of timothy, this grass may be sown fall or spring. If sown in the autumn, it should be along with winter rye or winter wheat. In areas of low winter temperatures, it should be sown in the early autumn. If sown in the spring, this hardy grass cannot well be sown too early. As with timothy, in some in-

stances, it will answer to mix the seed with the grain and sow it thus. It feeds out more evenly when sown thus than timothy, but under average conditions, it is safer to sow it by running the drill a second time over the land at right angles to the rows that were made when the nurse crop was sown. If sown alone, which may in some instances be a good plan, it may answer simply to broadcast and harrow the seed where a grain drill is not available. The seed may be buried between 1 and 2 inches, but should it be necessary to bury it even more deeply on loose soils, it will come up from a greater depth. When sown alone from 8 to 10 pounds of seed should suffice per acre under dry land conditions.

Care of the crop.—When sown in the early autumn, this grass may be so far advanced that it will not interfere with the harrowing that should be given to the grain crop at that season, but there are instances when such harrowing would do harm. In the spring neither the grass nor the nurse crop will be harmed by judicious harrowing when the first blade points of the grain begin to show. Under some conditions it may answer to sow the grain just before such harrowing is given to the crop. If sown alone, the grass may be pastured the first season, but care must be taken not to graze too closely.

Harvesting.—Western rye grass should be harvested for hay soon after it is fully out in head. The hay soon becomes woody if not cut promptly and when it does much has been lost in palatability. The hay is firm, like that made by timothy, and the yields are usually better under dry conditions. The cutting and curing are done in the same way as when handling timothy (see p. 342). This grass should seldom yield less than a ton per acre and in some instances it will yield considerably more.

It is cut for seed with the binder, cured in the shock and threshed with the grain thresher from the shock, or stack. The winnowing is easily accomplished by the aid

of the fanning mill. It yields seed profusely, frequently as much as 300 to 400 pounds per acre.

Combinations for western rye grass.—This grass is frequently sown with brome grass. The combination is particularly good when these grasses are grown for pasture. The brome aids in filling in the spaces between the rye grass plants. The plan is good which sows the combined crop along with a thin seeding of grain in the early spring, and cutting the same for hay at the heading stage or grazing it. When thus sown about 2 pecks of grain will suffice. About 5 pounds each of these two grasses will prove ample.

GROWING BROME GRASS

Brome grass (*Bromus inermis*) is, next to western rye grass, the highest in its adaptation for areas with but limited rainfall. It should be remembered, however, that the strength and vigor of this grass increase with increase in the amount of moisture present. In moist areas and on alluvial lands difficulty is found in removing this grass from the soil when the ground is plowed on which it grew, but no such difficulty exists where moisture is lacking. It would seem quite safe to say that brome stands at the head of all the grasses in providing pasture under hard conditions. Northern areas have relatively higher adaptation for the growth of this grass than those that lie to the southward.

Soils.—This grass grows best on alluvial soils that have much power to hold moisture. It also grows relatively well on the brown loam soils of the benches distributed over the Plains region. It will grow reasonably well on high soils, too light for the growth of timothy, but on these the roots do not spread as in rich, moist soils, nor do the plants thicken to the same extent. It has no special adaptation for gumbo lands.

Place in the rotation.—The rotation for brome grass is but little different from the rotation for timothy and western rye grass referred to above. It comes after fallow or cultivated land and before corn, flax or potatoes. It remains longer in the soil than most other grasses, should such prolongation be desired. In instances somewhat numerous, experience has shown that small grains do not succeed well as the first crop after brome, and probably for the reason that the roots do not decay quickly enough to afford nourishment for the roots of the plants. Corn, therefore, is one of the safest crops to follow brome grass.

Preparing the soil.—The young brome grass plants grow delicately and slowly for a time, hence the importance of having the soil in a good condition as to tilth and moisture when the seed is sown. Fine pulverization after fallow or a cultivated crop furnishes a very desirable condition, but it is possible to obtain stands of this grass on stubble land that has been disced in seasons of considerable moisture.

Sowing.—Brome grass may be sown during almost any month of the growing season, hence it is better to sow it in the early spring than at other times. It is not easily sown because of the relative lightness of the seed. When it is sown by hand, even a light wind may result in an uneven stand of the grass. When sown with the grain drill, it does not feed out readily unless mixed with some substance that is heavier. When sown on light soils, it may be mixed with a light seeding of oats, but the oats should be cut while yet green and made into hay. Even when sown on heavy soils, this method of seeding may answer, but in such instances the burial given should be very light. In mild latitudes, and where much of the precipitation falls in the winter, the seed may be sown in the autumn. As a rule, however, it should not be buried so deeply as the grain amid which

it is sown. In northern areas, it is sometimes sown in the late autumn without a nurse crop. In such instances, it is usually sown by hand and harrowed in, but of course it may be sown otherwise.

Shallow sowing is preferred, not deeper than 1 to 2 inches on average soils. The amount of seed varies much with the object sought in sowing. When sown alone to provide pasture, where the rainfall is limited, from 10 to 12 pounds of seed should be enough. When sown to provide hay, 8 to 10 pounds should suffice, and this quantity may be still further reduced when seed is sought. The tendency in this grass is to thicken continually or at least up to a certain limit, hence the quantities of seed sown need not be relatively large.

Care of the crop.—It is usually hazardous to use a harrow on a nurse crop amid which brome grass has been sown, or the feeble young plants of brome may be destroyed. When sown with a light nurse crop of oats or other grain in the spring, the crop may in many instances be pastured with profit to the same, but not at an early period of growth. Should the grass thicken so as to hinder abundant growth, it may be renewed by double discing followed by the harrow, the work being done in the early spring. In other instances shallow plowing in the late autumn or early spring will effect the same end. The growth of the grass may also be greatly stimulated by top-dressings of farmyard manure, preferably applied in the late autumn or during the winter.

Harvesting.—Brome grass is ready to harvest for hay soon after coming into head. It is harvested in the same way as timothy (see p. 342). The feeding quality of the hay is not far different from that of timothy, but because of its soft and somewhat fluffy character it will never take the place of timothy in the market. In the semi-arid country one ton should be looked upon as a fairly average yield of hay from an acre.

It is ready to cut for seed in about three weeks after coming into head, or when the seeds are full of meat, but not more advanced in growth than the dough stage. More commonly the crop is harvested with the binder set so high in some instances as to take only the seed stems, thus leaving a leafy residue that may be cut for hay. The seed is threshed with the ordinary thresher but owing to its lightness the wind must be shut off from the machine, or the seed will be blown away. From 300 to 400 pounds of seed are frequently produced per acre from the first cutting of the crop, but as a rule the yields grow less with advancing age in the growth of the plants.

Combinations for brome grass.—In humid areas these are many. In dry areas one of the best combinations for brome is western rye grass (see p. 343). The presence of the brome tends to thicken the stand. The yield of the combined mixture is, therefore, greater, for hay or for pasture than either grown alone. But in dry areas yields must not be looked for so large as those furnished in humid areas.

GROWING HAY FROM GRAINS

In dry areas hay from grains is sought for to a much greater extent than in humid areas. This is owing (1) to the larger relative yields that may be obtained; (2) to the fact that the hay is frequently fed without first threshing the crop, and (3) because a more complete ration may be obtained by feeding it thus. The larger relative yields result chiefly from cultivation given to the grain while it is growing. In the newer areas, it is more convenient to feed the crops than to thresh them, as it may not be easily possible to secure a machine to do the work. When grown in combination, it is possible to produce a ration suited to the needs of different classes of stock. The chief of the grain crops thus grown are rye of the

winter and spring varieties, wheat, barley, oats, peas and vetches.

Grown alone for hay.—The chief of these crops grown alone for hay are rye, wheat, barley and oats. The beards of the speltz lower its value greatly for hay, and the recumbent growth of peas and vetches increases much the labor of harvesting when these crops are grown alone. Although rye may be grown under climatic and soil conditions so rigid as to prevent the successful growth of other grains, its woody character gives it a much lower place as a hay plant than would otherwise be assigned to it. Wheat makes excellent hay for horses but the value of the grain renders it too costly to feed thus in a large way. Barley is in high favor in many areas, especially in those of the far west and southwest. For such use the beardless varieties are the most popular. Oats are grown to furnish food for cows more than for other uses.

Grown in combination for hay.—The combinations that will prove the most suitable will vary with the soil and climatic conditions. The favorite combinations are: (1) oats and peas; (2) barley and peas, and (3) barley and the common vetch. When thus grown in proper combination, the peas and vetches are sustained so that they may be harvested with a grain binder should this be desired. Oats and peas, barley and peas, and barley and vetches furnish most excellent hay for milch cows. Nearly mature and fed with alfalfa hay, the ration would be complete in itself. In areas where the precipitation falls chiefly in the winter, hay furnished by the sand vetch and winter wheat or winter rye may yet become popular.

Soils.—It would not be possible to state with exact precision the soils that will best meet the needs of these combinations, but, since bulk is an important consideration when growing hay, the aim should be to grow them

on good soil. Winter rye and the sand vetch will grow better on soils low in fertility than the other crops.

Place in the rotation.—The place in the rotation for these crops is virtually the same as when they are grown separately for the grain. They come most fittingly on land that has been made clean and in which moisture has been conserved by correct processes of cultivation. In a normal season, they will usually do well also on breaking if sown early. They are best followed by corn or fallow, but where the normal rainfall is 15 inches or more they may be followed by grain if the soil has been judiciously prepared.

Preparing the land.—The land should be prepared as for crops sown for the grain. Although a clean seed bed is very desirable, these crops will take less injury from the presence of weeds than grain crops, as they may be cut, if necessary, considerably short of maturity. The weeds may thus be prevented from forming seed.

Sowing.—When sowing grain alone to furnish hay, the procedure is much the same as when sowing it to mature seed but some additional seed may be used to improve the quality of the hay by making it less coarse than it would otherwise be. In combinations, the chief differences arise from the determination of the amounts of seed to sow, and some modifications as to the method of sowing which are referred to below.

Grain for hay should be sown as soon as the land is in good condition for being tilled. Early sowing will usually have an important influence on the yield. But should it not be possible to sow the crop early, such grain will take less harm than if it were to ripen, because of the fact that it may be harvested when considerably short of maturity.

The seed is best sown with the grain drill. The depth will vary with the kind or kinds, but usually not greatly. When mixtures are sown, in many instances, it

will answer quite well to mix them before sowing. In the case of peas and other grain, the plan is good which drills in the peas deeply and then about two weeks later drills in the other grain less deeply. The aim should be to sow varieties that ripen nearly at the same time. It will not be possible to state the amounts that it will always be most suitable to sow, but the following amounts will be approximate: For sowing alone, rye 6 pecks, wheat 5, barley 5, oats 5; for sowing in mixtures, oats and peas 2 and 3 pecks respectively, barley and peas 2 and 3 pecks, and barley and vetches 2 and 3 pecks.

Care of the crop.—Usually the grain may be harrowed when the points begin to appear. It may also be harrowed once again or oftener, but in the case of peas and vetches, the harrowing should be given with much care after the crop is up. Should the grain be too thick it may be beneficial to the crop to harrow out some of the grain.

Harvesting.—Grain for hay may be cut at any time from the earing stage until it is nearly ripe, according to the kind and the use that is to be made of it. It is possessed of maximum nutrition when cut with the grain in the dough stage.

When grain is cut for hay, the aim should be to cut it with the binder when practicable and cure it in the shock. The labor of handling is thus much reduced, but the cost of the binding twine must not be overlooked. When cut while yet quite green, the binding should not be tight, lest some mold be engendered beneath the bands. The aim should be to cure it in long shocks, and to stack as soon as ready, to prevent over-curing. Of course, whenever the grain is cut, it may be cut with the mower and raked and cured like other hay, but there is always more or less waste in handling it thus.

GROWING HAY FROM THE MILLETS

Millet, at least in several of its varieties, may be fairly classed as a dry land plant. In some instances it is grown for the grain, but more commonly it is grown for the hay. It has relatively higher adaptation for southern than for northern latitudes, and for low rather than high elevations. It is readily injured by frost both in the spring and in the autumn.

Soils.—The best soils for growing millet in the absence of irrigation are loams well capable of retaining moisture. The more humus which they contain, the higher is their relative adaptation. The plants have but little power to struggle on soils leachy and light and practically destitute of humus. To sow them on pronouncedly alkali soil is to throw the seed away.

Place in the rotation.—The place in the rotation will depend somewhat on the method of sowing. If the seed is broadcasted, a method of sowing which should be avoided, it will not succeed well after a grain crop in a normal season, save where the rainfall is considerably above 15 inches. Nor can the growth be considered safe when it is sown on such land with the grain drill, all the grain tubes being in use. If sown in spaced rows and cultivated like corn, it may do reasonably well. On new breaking, fairly good yields are obtained from drilling in like grain and even from broadcast sowing but the plan is attended with some hazard. Ground cultivated or summer tilled cannot well be spared for this crop. A cultivated crop on the summer-fallow naturally follows millet, but when the millet crop has been cultivated a small grain crop may follow.

Preparing the land.—While the preparation of the land for millet should be fine and clean, it is specially important that the moisture shall be retained sufficiently to germinate the seed when it is sown. The late season

at which the seed is sown gives ample time to prepare the land thus. As millet draws heavily on the moisture in the soil, it will not make a satisfactory growth on weedy land.

Sowing.—It would seem safe to say that the best dry land millet, all things considered, is the broom corn variety, although some other varieties, as the Hungarian, German and Japanese, may have higher adaptation for sectional areas. Pearl millet is valuable for southern areas.

Millet should not be sown until the ground and weather have become reasonably warm. Even though safe germination should follow early sowing, the growth subsequently is not likely to be so satisfactory as when the seed is sown later. About the best time to sow millet is at the close of the corn planting season or about the same time as would be suitable for field beans (see p. 298). When the seed is sown with the drill, all the tubes in use, not more than $1\frac{1}{2}$ pecks of seed should be used per acre. When sown in rows and cultivated, from, say, 4 to 8 quarts of seed should suffice, according to the spacing of the rows. These may be from, say, 24 to 36 inches apart, the wide spacing giving the better opportunity for cultivating the crop. The seed is buried from 1 to 2 inches or even to a greater depth, according to the soil conditions.

Care of the crop.—If millet is harrowed before the crop is up the aim should be to stir the ground as shallow as such work can be done. When the crop is 3 to 4 inches high, harrowing may only in some instances be given with profit. The later cultivation given to the crop grown in rows should be much the same as that given to a corn crop (see p. 280).

Harvesting.—Millet is ready to harvest for hay when all the plants are fully out in head, and for seed when all have assumed a golden tint, except in varieties the seeds

of which are some other tint. When harvested for hay, the millet may be cut with the mower or the binder, preferably the latter, when the crop stands up well and the land is smooth. The binder should be set low. If mown, the completion of the curing should take place in the cock. If cut and bound it should take place in long shocks. The yield should average a ton or somewhat more per acre. When harvested for seed the crop should always be handled like small grain. The yields of seed vary greatly. Broom corn millet should average about 20 bushels per acre.

Combination for millet.—In dry areas millet is but little grown in combination for hay. It may, however, be drilled in with sorghum or even Kafir corn, but the advantage from growing it in combinations is to be questioned.

GROWING PASTURE CROPS FROM GRASS

The term "grass" as used here includes clovers and alfalfa. To grow these pasture crops is one of the most difficult problems that confronts the dry land farmer. This is owing to the fact, first, that grass crops draw heavily on the moisture in the soil, and, second, that a dust mulch cannot be maintained on them to anything like the same extent as on a grain crop. The native grasses furnish a relatively small amount of pasture, and the same is true of the prickly pear in far southern areas, and the amount decreases with close and continued pasturing. It is the estimate of many ranchmen that from 10 to 15 acres are called for of native pasture in dry areas to maintain a cattle beast of nearly mature or mature age for one year. The dry land farmer cannot afford to use any large proportion of his arable land in that way, so small is the return from it, hence the necessity for growing other and relatively more productive pastures.

Pasture plants grown alone.—The grass plants that will prove the most satisfactory in furnishing pastures under arable conditions cannot be stated with absolute precision at the present time, because of the lack of experience in growing these. It is probable, however, that when grown alone, brome grass (*Bromus inermis*) will furnish more grazing over a wide area than any other grass. Next to brome grass in general adaptation is western rye grass (*Agropyrum tenerum*) but it will not furnish as much pasture nor does the period of growth cover nearly so large a portion of the growing season. There will be a more limited place for tall oat grass and meadow fescue. Timothy may also be grown under the more moist conditions. For certain kinds of grazing, alfalfa will also have an important place. The importance of this plant for pasture is found, first, in the large growth which it produces; second, in the long period covered by its growth, and, third, in the fact that a soil mulch may to a certain extent be maintained in the crop. The value of sainfoin in thus providing pasture has yet to be determined under dry conditions.

Pasture plants grown in combination.—It is probable that the most valuable pastures in dry areas, as in other areas, will be those that are grown in certain combinations. Here, also, the grasses that will furnish the best pastures cannot be stated with precision from lack of experience in growing them. In the northern portions of the semi-arid belt, a mixture of brome, western rye and alfalfa will probably furnish more pasture than any other grass combination that can be grown. Farther south, tall oat grass or meadow fescue will probably take the place of brome grass. In the more moist areas, as where the annual rainfall is near 20 inches, the old-time pasture, timothy and clover, will probably best serve the end sought.

Soils.—Since on the arable farms, the aim should be to rotate the pastures more or less with other crops, the fact remains that these will grow best on moist soils. The aim should be, therefore, to grow them to a greater extent on the more moist soils of the farm. On the drier lands, grain pastures may serve the purpose relatively better.

Place in the rotation.—The aim should be to start pastures on clean land, hence they should be sown as a rule on fallowed or cultivated land. Whether it would answer to sow them after small grain, and pasture them the season that they are sown in order to keep down weeds and to firm the land by the treading has not been ascertained as yet. Nor has it been determined as to how long the land should be kept in pasture. The indications at present are, however, that, all things considered, short rotations will prove the most satisfactory. The crops that follow pastures will be the same as those that follow newly broken prairie, that is, such crops as winter wheat on fallow land, or such crops as flax, corn or potatoes on sod land that has been broken in the spring.

Preparing the land.—While it is important that the soil shall be fine, firm below and clean, that is to be sown to grass, it may be very difficult to provide for it a clean seed bed. This may arise, first, from the fact that in a dry season weed seeds may not germinate though near the surface, on fallow or on cultivated land, but may germinate the next season after the grasses have been sown. It may arise, second, from the large amount of weed seed that may be carried to clean land and strewn over the same. These contingencies may prove a real difficulty in the way of getting a clean stand of grass. Because of this, it may be wise to sow some of these grasses with a nurse crop sown early in the season.

Sowing.—At the present time it would not be possible to state positively the very best method of sowing

grasses in combination under all conditions. The methods of sowing these singly have already been discussed. It would seem reasonable, however, to expect that one of the best combinations that can be sown will consist of brome grass, western rye grass and alfalfa. The seed may be mixed before sowing it. It would seem safe to say that the best method of sowing the mixture would be with the grain drill and along with a nurse crop of, say, 2 pecks of oats or some other grain. It should be sown to the depth of about 2 inches in average soil, but due allowance must be made for the characteristics of soil where the mixture is sown. About 4 pounds each of the mixture should prove enough for an acre. Under some conditions the crop may be grazed the first season, but not until the plants have become firmly rooted in the soil. In other instances it may be better to cut the nurse crop for hay and to defer the grazing until the second season.

Grazing the pastures.—One great advantage resulting from growing alfalfa in the mixture is the large amount relatively of the pasture which it will furnish. A second benefit arises from the safe nature of the pasture. When alfalfa is thus grazed along with other grass pastures the danger from bloat is virtually eliminated. But when thus grazed the alfalfa would probably be the first of these grasses to fail. The brome would probably be the most enduring because it is the most aggressive. In time it would practically take possession of the land.

The grazing should not be too close. When grass is grazed down too closely the hot sun saps the moisture from the unprotected land, and it may also result in the partial destruction of the stand of grass. It may not be easy, however, to regulate the closeness of the depasturing, because of the great variations in the seasons. These pastures may usually be much benefited by top

dressings of farmyard manure, more especially when these may be applied in the winter season. They may be also helped by discing in the spring and following the disc with the harrow.

The duration of those pastures will vary with the conditions. There may be conditions in which it will be desirable to prolong them for a long term of years. Again there may be conditions when they should be maintained for not more than 2 or 3 years. Pastures of relatively short duration will usually prove the most satisfactory in semi-arid areas, because, first, of the more abundant grazing obtained from the fresh pastures, and, second, from the benefit resulting from the frequent burial of humus in the soil.

GROWING PASTURE CROPS FROM GRAIN

Many of the farmers in the semi-arid country will obtain pasture from three sources. They will obtain it, first, from the rental of rugged and un tillable lands in proximity to their holdings; second, from grass pastures grown upon their farms, and, third, from the grain pastures grown to supplant the grass pastures. It would seem correct to say that the more dry the conditions are, the greater is the necessity for growing grass pastures, and the greater relatively will be the benefits obtained from growing them.

Pasture from grain grown alone.—Winter rye stands at the head of the grain crops that may be grown in dry areas for furnishing grazing. For such a use it would probably be no exaggeration to say that it is more valuable than all other cereal grains. When sown early it may be grazed in the autumn, and again in the spring. Winter wheat when sown early may be grazed in the autumn when sufficiently strong, but in the spring it will not stand grazing as rye does, especially when a crop of grain is to be obtained from it the same season. It would

seem reasonable to suppose that the sand vetch has an important mission in supplying pasture in dry areas, but the value of this plant for such a mission has not been fully determined. But any of the spring grains may be thus used in providing grazing, more especially when the weather is adverse to profitable production in the crop if allowed to mature. In such instances it may be more profitable to graze the crop and then to summer-fallow the land to prepare it for a crop that will follow. This method of procedure would be vastly ahead of that which allows the crop to continue to sap moisture from the soil as soon as it is certain that the crop has failed from lack of moisture, or for other reasons.

Pasture from grains grown in combination.—More pasture will be obtained from grains grown in combination than from grains grown alone. This follows from the fact that the maximum periods for best growth in the various grains differ. When several are grown together the period of good grazing is, therefore, more prolonged than if these were grown separately for the purpose of providing pasture. This will hold true of autumn and also of spring grains, but these should not be sown together in order to provide pasture.

The best combination of autumn-sown grains to provide pasture is probably winter rye and the sand vetch. Next to this would probably be winter wheat and the sand vetch. The value of this combination will depend in a considerable degree on the behavior of the sand vetch when thus grown and this has not been fully determined in many areas of the dry region. The spring-sown grains will probably furnish increased grazing in proportion as the number of various classes of grains are used in the admixture. But when determining the mixtures that shall be grown, the market values should be considered. As a rule the policy will be wise that selects the grains

that are cheap to grow in the combination rather than those that are dear.

Soils.—The soils for these crops include any soil that will furnish a good crop of any of the small grains that will furnish good pasture. These have already been discussed when showing how to grow the various grains used in providing pasture when these are grown to provide grain. The only real differences in the methods of growing them are such as arise from the different amount of seed required. The soils that will grow grains at their best for seed in dry areas will also as a rule grow them best for pasture. Any productive clay or sandy loam soil will grow good pasture crops.

Place in the rotation.—Since pasture crops from grain are usually grazed down early in the season, they may generally follow with much propriety a small-grain crop and in turn be followed by the bare-fallow. After the bulk of the grazing has been completed there will still be time to summer-fallow the soil the same season. Especially is this true of the grains that have been sown the previous summer or autumn.

Preparing the soil.—The soil for grain pastures is prepared virtually the same for the grains that provide the pastures as when these are grown to provide grain rather than pasture. The more clean and moist and friable near the surface, and the more firm that it is below, the higher is the adaptation of the soil for grain pastures. But cleanliness in the soil is not nearly so essential as when growing these crops for grain, as the grazing prevents the major portion of the weeds from going to seed, and the residue that may escape the grazing are buried in the summer-fallowing process that usually follows.

Sowing.—The best time for sowing a combination of winter rye and the sand vetch or winter wheat and the sand vetch, in order to provide grazing in dry areas, is probably the month of June. The seed will then ger-

minate readily where the bulk of the precipitation comes in the growing season. The grazing should be close until the autumn to lessen the draft on soil moisture. In areas where the precipitation comes largely in the autumn and winter months, these grains may be best sown on the arrival of the autumn rains. When grains are sown to provide pasture in the spring, as a rule the earlier they are sown the more valuable will be the pastures which they furnish.

When winter rye or winter wheat are sown to provide grazing, it is not improbable that the largest amount of grazing will be obtained from these grains if sown in June and kept closely grazed until sometime in the autumn, the grazing being made to cease in time to allow the grains to make more or less top to furnish some winter protection. The grazing may begin again early in the spring unless the crop is to be grown for fodder or for the grain. When grains are sown in the spring to provide pasture, the aim should be to sow them early.

When the grains are sown separately or in combinations, the aim should be to sow them with the drill and to put them so far down that they will germinate readily. When sown alone, about 50 per cent. more seed may be sown for pasture than is sown for grain. When sown in combinations not less usually than 6 pecks of the mixture should be sown in the autumn and in some instances 8 pecks would be better. The proportion of the sand or other vetch that may be sown can only be fully determined by experiment. It is probable, however, that in but few instances, if indeed any, should less than 2 pecks of the vetch be sown per acre. When grains are sown in combination in the spring not less than 6 to 8 pecks should be sown. The thicker seeding is called for to furnish more plants for grazing. As they are usually grazed down so as to prevent high top growth, they draw

less heavily on moisture than plants pushing on toward maturity.

Grazing the pastures.—The grazing of the summer or autumn sown pastures should be close until the dry season is about over. The amount of grazing obtained may not be very large in very dry seasons, but the close grazing lessens the drain on the moisture in the soil. Spring grains will probably furnish more grazing if allowed to make a good start before the grazing begins. Should the grazing not be wanted the grain should be buried at the proper season for plowing fallow land, taking care not to let it get so far advanced before plowing it as to retard quick decay in the plants when buried.

CHAPTER XV

GROWING TREES AND FRUITS IN DRY AREAS

The absence of trees on the prairie and bench lands of the west gives to it something of the appearance of a land that may not be inhabited, in the sense that it will become a land of permanent homes. There is a lonesome look about it that does not attract, and in the winter season the lack of trees around the dwelling certainly adds much to the discomfort of its inmates. The apathy shown by many of the dwellers on the prairies in areas where farm crops have been grown for several years is in a sense almost unexplainable. Many dwellings may be found on northwestern prairies where the farms on which they stand have been cultivated for a score of years, and yet not a single tree or shrub has been planted on the farm during all that time. This course, which is greatly to be deplored, may arise, in many instances, from the too commonly cherished view that the farmer will get all he can for a term of years from the land which he tills, and he will then remove to other lands which he regards as more congenial.

Can trees and fruits be grown.—The answer to this question is of great moment to those who dwell on the newly occupied lands of the dry area and also to those who are seeking homes on the same. On the answer will depend the permanency of the farming in much of the dry area, for one cannot imagine indefinite continuity in the tilling of the soil in an exposed country in the entire absence of trees. But why should the ability to grow trees be doubted? For the same reason that the successful tillage of the soil was doubted for many years. The fact had not been demonstrated, just as the fact has not been demonstrated on wide areas in the dry region as to whether trees can be grown. On the dry bench lands

of Montana, for instance, it is scarcely possible to find a windbreak or a grove at the present time. Notwithstanding, the following may be said meanwhile with safety: (1) Windbreaks and trees may be grown with success without the aid of applied water; (2) that the success in growing them will vary greatly with the conditions, and (3) there are instances in which the aid of applied water is essential to success.



DRY LAND YOUNG APPLE ORCHARD.

On Shore of Flathead Lake, Montana.

Courtesy Great Northern Railway Co.

That windbreaks and trees may be grown on nearly all the tillable land of the semi-arid area may be safely assumed from the following: (1) Certain forms of trees, or at least of shrub life, grow on much of the unbroken area without the aid of man, as witnessed in the sage brush and other forms of tree life that maintain an existence in areas where even grass cannot maintain a foothold. In some areas where the precipitation is in the neighborhood of 10 inches, as for instance central Oregon,

much of the land is covered with sage brush of more or less vigor in its growth. Where shrub life can maintain its hold upon the soil unaided under such conditions, there would seem to be no hazard in assuming that higher forms of shrub and even of tree life can be produced under judicious cultivation. Under very dry conditions cedars maintain an existence in the Great Basin and the mesquite in Arizona under conditions equally dry. (2) In the very few instances in which attempts have been made to grow trees and shrubs, a fair measure of success has followed where the work has been judiciously done. (3) It would seem safe to claim that wherever grain crops may be grown successfully the measure of the precipitation that will grow grain will make it possible also to grow certain forms of trees and shrubs, where the land has been properly prepared before planting the trees, and where proper care is given after the planting.

That the results from growing trees and fruits over so wide an area will differ greatly is in no way surprising. They are the outcome of a difference in soil, in the amount of the precipitation and in temperature. Nearly all of the soil in the entire dry area is well adapted to the growing of fruit. Especially where the real volcanic ash soils prevail is the adaptation superlative. The tendency to fruiting in the trees grown on these soils is remarkable. Of course where the precipitation is the highest, trees and fruits are the most easily grown in the absence of irrigation. For instance, in the upper valleys of the Columbia and its branches, fruit may be readily grown in the absence of irrigation, but it cannot be thus grown in the lower valleys of the same. West of the Rocky Mountains only the more hardy fruits can be grown, whereas east of the same, varieties much less hardy are quite easily grown.

In many of the dry states there are areas where trees and fruits cannot be grown with much or even with any success in the absence of irrigating waters. The areas are many, however, where they cannot be thus grown, in which the additional water called for is so little that for the needs of the home it may be supplied by a windmill and the accompanying tank.

What should be sought in trees.—Trees should be grown primarily: (1) to furnish protection for the home; (2) to furnish protection for the fruits grown, and (3) to furnish posts for fencing. Whether the growing of trees for timber will ever become at all general cannot be forecasted with certainty at the present time. Meanwhile it has little or no place in connection with dry land farming.

That homes are benefited by the protection furnished by windbreaks and groves under nearly all conditions, will not be questioned. Even in sheltered nooks and valleys where the annoying winds are not greatly prevalent, the shade furnished by trees around the dwelling is very grateful. On the prairie and bench lands the need of trees for shelter is in a sense imperative. Of course, life may be lived in their absence, but when thus lived it is in more senses than one a life of privation.

In wind-swept areas, as for instance in much of the Great Plains country, windbreaks and groves are a great protection to the trees planted inside of them, or at least on the leeward side. The wind currents will cause fruit trees and shrubs exposed to them to lean too much in one direction. The fruit will also in the case of the larger trees be blown off before it has reached maturity, because of the swaying of the limbs. In many areas, in the absence of such protection, fruit raising cannot be made a success, even when the other conditions are present that would lead to a successful issue. Some small fruits,

as currants or gooseberries, may be grown without such protection, but even these will profit by its presence.

When live stock is kept on the farms of the semi-arid region, as it will be in the near future, to some extent at least, fences will be necessary. The posts will be one of the most costly items of the expense where they have to be purchased. This at least will hold good in the Great Plains region, where the long distance of the transportation will prove costly. Where these may be grown, the cost will not be nearly so much. One acre devoted to growing posts should furnish several thousands of posts, varying, of course, with the kind. As several years are called for to grow trees large enough for posts, the homesteader should not defer planting longer than may be absolutely necessary. The same may be said of trees that are to furnish groves.

What should be sought in fruits.—When growing fruits the aim should be (1) to grow only such fruits as are likely to succeed; (2) to grow them mainly for the home; (3) to have some water in reserve to aid in the proper maturing of the crop, and (4) to defer planting no longer than may be necessary.

It may not be possible at present to determine the fruits that will grow best in the various portions of the dry area, for the reason that this has not been proved, either with reference to species or to variety, at least in very many areas. It is known, however, (1) that only hardy fruits will succeed west of the Rocky Mountains, save in the southern portions of the same; (2) that varieties less hardy, but possessed of more valuable qualities, may be grown east of the same; (3) that in southern areas species will succeed that it would be unwise to try to grow in northern areas. It is possible, therefore, to select varieties to grow in a tentative way that will not prove disappointing when grown.

In dry areas, as intimated previously, fruits should be grown mainly for the home. This at least should be the rule where the hazard is present that they may be injured during the ripening period by a shortage in the moisture supply. This idea, however, must not be pressed too far, as in certain areas of the semi-arid country fruits are being grown with much profit without irrigating waters where the rainfall is less than 18 inches. Parsons, of Colorado, has grown, with much profit, apples, plums and cherries, with a rainfall annually of about 14 inches. Nevertheless, the fact remains that where the rainfall is less than 15 inches per year many fruits cannot be grown so cheaply as to compete successfully in the general market with the same fruits grown with a rainfall of not less than, say, 18 inches, or by the aid of irrigation. This, however, does not justify neglecting to grow them for the home, even where much care must be exercised to insure successful work.

The amount called for to supply the needs of the home is not large in any instance, hence the land devoted to such use need not cover more than a small area, the care of which will not involve great labor. The limited area thus involved will make it quite practicable in many instances to furnish enough water from a well and tank to insure safe maturing in the fruit, should such aid be called for. Many seasons it may not be needed, but even in very dry seasons the farmer thus prepared may secure a full supply of fruit.

The wisdom of planting some fruits until a wind-break has been started that will furnish some protection for the fruits is to be questioned, but only under conditions of extreme exposure. A windbreak, however, will usually furnish some protection within one year of the time of planting. Consequently fruits that are favored by protection, may be planted on the lee side of a wind-break one year after the planting of the same. The

windbreak will thus make two years' growth before the fruits planted contiguous to it will enter the first winter after planting. This would mean, therefore, that the homesteader may be ready to plant such fruits as need protection in exposed situations, in, say, two years from the time of breaking the sod where the windbreak is to be planted.

Trees suitable for dry areas.—The trees that may be grown in dry areas may be divided into the three classes: (1) for windbreaks; (2) for groves, and (3) for fence posts. It should be remembered that suitability for any of these uses will vary with the conditions, insomuch that what is best suited to one locality may be quite unsuited to another.

For windbreaks, all things considered, the common white or gray willow will best serve the purpose when a windbreak is to be grown, and especially in northern areas. It is hardy, of quick growth, and the branches will grow very closely together. Moreover, although it has highest adaptation for moist conditions and humid climates, it will grow reasonably well on the bench lands of dry areas. It would seem correct to say that no other tree will furnish protection within so short a time. Windbreaks may also be made by growing box-elder trees in a way that will cause them to branch from the ground upward, as has been so well exemplified by Mr. Angus Mackay in growing them thus at the experiment station at Indian Head, Sask. In some areas it is practicable to grow evergreen windbreaks by the judicious planting of and caring for the trees. Black Hills spruce of far western South Dakota, the jack pine and the bull pine (*Pinus ponderosa*)—all these are now being grown under nursery-conditions.

For groves, the green ash, the elm, the oak in more than one of its varieties, the box-elder, the catalpa, the black walnut, the black locust, the silverleaf poplar and

the cedar and yellow pine may be grown. The oak, cedar and yellow pine are all of slow growth. Poplar trees grow quickly but are not usually long lived. The catalpa and black locust grow quickly and the box-elder fairly so, but these are not long lived. The green ash grows somewhat slowly, but all in all it is one of the most satisfactory trees that can be grown. The catalpa and the black locust are not to be relied on in the Great Plains area north of the parallel 43 north latitude.

For fence posts, the white willow, the diamond willow, the catalpa, the black locust and the green ash may all be grown, also the cedar, but the latter is of very slow growth. The white willow will furnish posts more quickly and in greater number than any of the other trees mentioned. They are not durable if cut and set at once, but will last for several years if the bark is removed and the posts are dried before planting them. If treated with creosote it would seem safe to infer that they would last still longer, and that the same would be true of all posts. The diamond willow is very durable as a post, but it does not grow so quickly nor so erectly and straight as the white willow. Moreover, it has higher adaptation for damp ground, hence the aim should be to grow it with the aid of applied water, or at least on land with more than the usual amount of moisture. The catalpa and the black locust are both durable, especially the latter, and both grow well in the central and southern areas of the dry belt. The green ash will grow straight and tall if put in between other trees, as the poplar, the branches of which crowd it, as it were. If the posts are peeled and dried before planting, they will last for several years.

It will doubtless be found quite practicable to grow ornamental hedges when the time comes for such planting. The Caragana and the Russian olive have much adaptation for furnishing such hedges. There are also

certain shrubs adapted to dry areas. These include lilacs, spireas and certain kinds of roses. In view of these facts, the hope may be cherished that, ere many years shall pass, the transformations in the appearance of the dry country will be marked.

Fruits suitable for dry areas.—For the purposes of this discussion, fruits may be divided into three classes, viz., small, medium and large. In addition are vines such as grapes. Small fruits are usually grown more safely and more successfully than large ones, and chiefly for the reason that the latter mature their fruit later, when, generally speaking, moisture is less plentiful. Nearly all varieties of small fruits mature somewhat early in the season.

Among the small fruits that may be grown with more or less success in nearly all parts of the dry area, are currants, gooseberries, raspberries, strawberries and the sand cherry. The varieties will vary with location, hence it will avail but little to name varieties, but as hardiness is a matter of much importance in fruits grown in the Great Plains region, it may be in place to mention some varieties of proved hardiness. Among these are the common red currant, the Downing gooseberry, the Turner and the Cuthbert raspberry, and the Bederwood and Senator Dunlap strawberry. The sand cherry and the wild black currant are among the very hardiest of the small fruits. All, or nearly all, of these mature their fruits before the period of greatest drought.

Among the intermediate fruits are the cherry, the plum, the peach, the apricot and the date. These, except the two classes first named, cannot be grown profitably in dry areas west of the Rocky Mountains. The hardy varieties of cherries include the Early Richmond, the Early May, the Montmorency and the English Morello. Sweet cherries may be grown in many areas in the Inter-mountain region. The plum has special adapta-

tion for being grown under hard conditions in at least several of its varieties. Some of these are native, even to areas of the Great Plains region, where the climate is severe. Hardy varieties include the Wild Goose, the Weaver, the Minor, and the Wolf and many others. In the milder latitudes, varieties of superior merit may be grown.

Among the large fruits, the apple will always have first place, but pears and quinces are not unimportant.



DRY LAND APPLE ORCHARD, NEAR KALISPELL, MONTANA.

Courtesy Great Northern Railway Co.

Pears cannot be successfully grown in many localities in the dry area west of the Rocky Mountains, but this is not true of them eastward from the same. Apples of some varieties may be grown in even the coldest areas of the Great Plains, but in some localities to grow them with any considerable success calls for much care in furnishing for them adequate protection. Among the varieties with adaptation for those areas are the Transcendent Crab, Duchess of Oldenburg, Hibernal and Ben

Davis. Varieties with adaptation for areas west of the Rocky Mountains include Yellow Transparent, Winesap, Wealthy, Gano, Alexander, Jonathan and Rome Beauty.

The Russian Mulberry, which produces a large tree relatively, bears small fruit and much of it, which is of some value. It is drought-resistant in a marked degree. Grapes will not succeed in the northern areas of the Great Plains region, but they will succeed in portions of the Great Basin and in some other areas. There is no tree probably that will stand drought better than the olive. In Arizona olive trees have succeeded where the average rainfall is not more than 10 inches. This would seem to indicate an important place for the cultivation of this fruit in southern areas of the dry belt in the not distant future. Other fruits, as the Chinese date and certain varieties of the fig, may yet come to be grown in the same areas.

Making ready for planting.—When preparing for planting trees and fruits, careful thought should be given to the general plan to be followed, and also to the specific details of the same. While in the general plan much will depend on the location of the steading, that is of the buildings, and also on the aspect of the land, the aim should be to place them as nearly as possible at the centre of the farm in order to avoid unnecessary travelling while doing the work of the farm.

In general outline, the plan for the windbreak and grove should be so made that the trees will protect the buildings on the three most exposed sides, thus forming three sides of a rectangle. Another way would be to have the trees surround the buildings in the form of a circle, one part of the circle being without trees on the leeward side. Some are content with planting trees on two sides of the steading, thus forming the two sides of a right angle on the two sides that are most exposed. Care should be taken not to plant the trees too close

to the buildings, as they may interfere with future plans about the buildings, and in areas where snow is much liable to drift it will pile up on the buildings and in the yards, having been carried right over the trees, especially in the early stages of their growth.

The trees best suited for a windbreak should be planted on the outside, with one to two or three rods between them and the trees of the grove, as the snow that lifts over the windbreak will then fall in a considerable degree before it reaches the trees of the grove. In some instances it is advisable to have two rows of windbreak trees, with, say, two rods between. In these spaces grasses, clovers, or alfalfa may be grown, but not too close to the trees, the snow that blows into them furnishing a goodly supply of moisture.

Some fruits may be planted along the rows and in between the trees, with the understanding that later they will be removed, as the shade of the trees will soon make this necessary. Plums and some small fruits may be thus grown. The abiding place, however, for the fruits, is inside of the grove. Though planted simultaneously with the grove, protection will soon be furnished by the windbreak and forest trees in their upward growth.

If trees for protection and for orchard uses are to be planted on breaking, the ground should be broken deeply one year in advance of the planting. It should be carefully worked on the summer-fallow plan. The objects sought are, first, the subduing of the sod, and, second, securing a supply of moisture for the subsoil. If the ground has been cropped previously, it should by all means be summer-fallowed before it is planted. At the end of, say, three years from the time of planting, trees planted thus will be quite ahead of those planted out for four years, but on land not thus prepared at the outset.

In dry areas, trees and fruits should be planted out in the spring. They may live though planted in the autumn, but in such areas the winter is a more critical season for trees than the summer, hence they should be given the benefit of the most favorable season in which to make a start. The aim should be, except in the case of some evergreens, to plant as early in the season as the ground can be worked in good condition.

The aim should be to secure the trees and fruits from nurseries where the trees and fruits have been grown under climatic conditions not differing greatly from those that prevail where they are to be planted. This is greatly important, as if brought from a milder climate they will not be possessed of sufficient hardihood to produce the best results.

Planting and caring for trees.—Windbreaks may be planted by opening a straight furrow where the willow cuttings are to go. In this furrow they are placed about 3 feet apart, taking care to start them at something of an angle, the tops all leaning in the same direction and along the line of the furrow. The cuttings should be fresh and not more than, say, 12 inches long, and about the thickness of the finger. About 2 inches should project above the surface after the earth has been firmly filled in around the cuttings.

Evergreen windbreaks involve more labor and outlay. The trees should be purchased when young. The nurseryman should pack them with much care. As soon as unpacked for planting, the roots should be kept submerged in what may be termed a solution of soft mud until each is to be taken for planting. The ground is first marked off where the trees are to be set. When marking it the continuity of the squares should be broken in each alternate row, which will make a more perfect windbreak, but it will confine the cultivation to but one direction. They should have 8 feet between the

rows, and a similar distance between the same in the line of the row. The roots are carefully spread on moist earth at a proper depth, and the hole is then filled and the earth firmed while being filled to within 2 or 3 inches of the surface. The top soil should be left loose to form a dry mulch and should slant a little downward toward the tree, which should be set about 2 inches lower than it was previously. In very dry areas the aim should be



DRY LAND SIX YEAR WAGNER APPLE TREES.

Near Bonner's Ferry, Idaho.

Courtesy Great Northern Railway Co.

at the first to provide windbreaks that will grow more quickly than evergreens.

When securing a windbreak from box-elder the procedure is about as follows: Secure the seed before the time of frost in the autumn. When the danger to the young plants from frost is over, draw a straight furrow

but not deeply, with the plow, scatter the seed along this by hand and cover to the depth of 2 inches with the hoe. The furrow may be made with the hoe and beside a stretched line if desired. The harrow should be used more than once until the young trees are an inch or two high, and then cultivation should follow as in the case of corn. Practically no other pruning is needed than to cut the young trees back a little at the end of the first year.

The trees for the grove should be planted in rows, and, of course, inside the windbreak. The rows should be not closer probably than 10 feet, and the distance between the trees in the line of the row will vary with the conditions. If a quick-growing tree, as the Norway poplar, is planted between slow-growing trees, as the ash, it should be done with the intention of removing the quick-growing tree in due time, and allowing the more durable one to remain. The distance between each in the line of the row may be, say, 5 feet. But the distance both ways will vary with the normal precipitation and the combinations when planting. The number of the rows should be determined by the time that may be given to caring for them. Ample protection and shade are of great price in a dry country. The planting may be done in about the same manner as described above for evergreens. Trees not to exceed the age of two years should be preferred for planting.

The white willow may be grown for posts as for windbreaks, and when cut will grow again. When growing the diamond willow, proceed about as follows: Mark off the land, say, in squares, and plant the cuttings in these squares. They will make posts more quickly if trimmed to one limb, but in some instances 2 to 3 are left. The cultivation given may be made in both directions. One acre planted thus should furnish from 3,000 to 4,000 posts.

For areas south from the parallel 43, the black locust and some of the hardy catalpas will probably best supply the need when posts are to be home grown. In moist areas they are planted about 4 feet each way, but in dry areas it would seem safer to leave them more distant, say in squares 5 feet each way. Both are relatively quick-growing trees, and both will grow up again when cut. The posts from both are durable.

The Caragana and Russian wild olive hedges may be made by sowing the seeds or by planting young trees obtained from the nursery. These may be planted 2 to 3 feet apart, and may be made to grow close and stocky by severe pruning. Ornamental hedges may be grown from almost any of the willows when properly pruned.

The surface cultivation given to all of these trees for whatsoever purpose given should be enough to keep a clean dust mulch continuously on the soil until the trees are large enough to mulch the ground with their leaves. This will entail cultivation for several years, according to the kind of trees and the growth made by them. It is vain to expect trees to grow in dry areas if neglected after they are planted. The growth of grass in their midst will rob them of the moisture that they need.

Planting and caring for fruits.—When planting large fruits in dry areas they should be given ample room. The necessity for this does not arise so much from the large size of the tree as from the need for ample root space in which to gather moisture. The fruit trees in semi-arid regions, like the grains, are more or less dwarfish in their habit of growth. But in addition to the root space required, there must be room to drive between the rows when cultivating and gathering the fruit. The apple trees in the orchard of E. R. Parsons, at Parkers, Col., are 40 feet apart, which is a greater distance than

is followed, as a rule, when planting the apple trees of the East, which grow so much larger. Where the rainfall is more than 15 inches per year the trees may be planted closer, as close, probably, as 30 feet. For a time, crops that call for cultivation during the period of growth may be grown between the trees, but these should not come near to the tree, lest they draw upon the moisture that it should have.

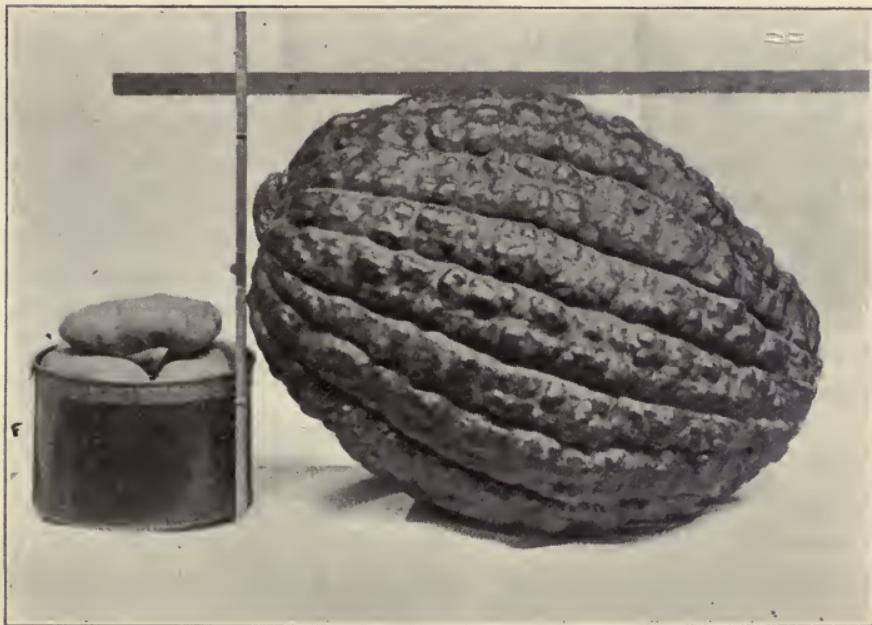
Medium fruits, as plums, prunes and cherries, may be planted in squares 20 feet apart. This will give ample room for proper cultivation and gathering the fruit. The practise is sometimes followed of planting these intermediate fruits midway between the apple trees in the line of the row, when the latter are planted far apart. Where irrigating water can be applied, the practise has merit, as the trees thus planted intermediate may be removed when they begin to encroach on the needs of the larger trees, but they should not be planted thus in areas of scant rainfall without good reasons for the step. Under such conditions every facility should be given for the proper cultivating of the trees by driving in several directions.

Small fruits, as currants and gooseberries, when grown in such areas, should be not less than 8 to 10 feet apart each way. This will insure room to give them the cultivation which they need. They are one of the surest fruit crops that can be grown in dry areas. Strawberries may have from 6 to 8 feet between the rows. If grown on the matted row plan the runners should not be allowed to root indiscriminately, as the plants will then become too numerous for the moisture.

Of the large and intermediate fruits only young trees should be planted, not older probably than one to two years. This reduces the percentage of the trees that may fail to grow, and it gives the grower the opportunity to head them low, which is of great advantage

when picking the fruit, and the hazard to it is less from the blowing of strong winds.

The cultivation must be enough to keep the ground clean, to keep a dust mulch on it, and to break up any undercrust that may form. This work may be done almost entirely with the harrow and disc. Owing to the enormous fruitage of trees in the West, due attention must be given to the thinning of the fruit, if high quality



DRY LAND SQUASH, YELLOWSTONE COUNTY, MONTANA..

Courtesy Great Northern Railway Co.

is to be maintained. This is especially important where the moisture is not plentiful. In some localities fertilization may be called for to maintain heavy and successful cropping, because of the great drain on the elements of the soil. Due attention must also be given to pruning and spraying the orchards, but these and other details must be omitted from this discussion for want of space.

Whether vegetables should or should not be grown in orchards and between small fruits will depend entirely on the conditions present. When fruits are first planted out it would not appear to be necessary or advantageous to leave all the ground unoccupied. On the other hand, they must not be grown to the extent of drawing upon the moisture that the trees or shrubs should have.

As elsewhere intimated (see p. 453), a reserve supply of water may render great service to the small garden in the perfecting of such fruits and vegetables as do not mature early in the season. One application may be enough in many instances to mature the crop. In the case of orchards where irrigating waters are chiefly used for the irrigation of alfalfa and kindred crops, it is quite practicable in some instances to apply the surplus waters to the orchard after the fruit has been removed. Enough water may be thus stored in the soil and subsoil to insure a crop the next year, where otherwise it would not succeed without the provision thus made through the storage of needed moisture.

CHAPTER XVI

ROTATION IN DRY AREAS

Rotation means an interchange in the succession of the crops grown with a view to the better maintenance and improvement of the soil with reference to chemical and physical conditions.

The nature of the interchange will depend more or less on the kinds of the crops that it is desired to grow, and on the adaptation of the natural conditions for growing them. Any interchange in the succession constitutes rotation in a sense, but such interchange does not of necessity result in either the maintenance or improvement of the conditions that govern production. Rotation in non-leguminous cereals only may tend to some extent to lessen weed production, but it does not in any way increase the plant food in the land. When cultivated crops are grown in interchange with this class of cereals, the cleaning of the land is much facilitated, but the depletion of the plant food goes on unless one or more of the crops grown is a legume. Increase in production is best secured in the absence of the use of commercial fertilizers when the rotation is of a character that will improve the tilth of the soil and its moisture-holding power, and will also increase the increment of plant food in it. To secure all of these benefits calls for the introduction of a grass or clover crop into the rotation, preferably the latter, which in itself meets all the requisites sought as stated above.

Positive reasons for rotations in humid areas.—It is necessary in these for the following reasons, among others, that may be given: To maintain an equilibrium, (1) in plant food; (2) in the humus supply; (3) in the mechanical condition of the soil, and (4) in the food products grown.

When one crop is grown for successive years on the same land in the absence of commercial fertilizers, the plant food in the soil gets out of balance. The crop grown will draw more heavily on one element of plant food than on another, consequently the supply of that element becomes too much reduced for profitable production. The result will not be changed though the other elements of plant food in the soil are present in sufficient quantity. For instance, should successive wheat crops reduce the nitrogen in the soil below a given quantity, full crops of wheat will not be obtained, though the supply of phosphoric acid and potash should still be ample. To maintain the equilibrium it becomes necessary to add nitrogen. This can be most cheaply and effectively done by introducing a legume into the rotation, as clover or alfalfa. These crops may also be made to add to the supply of phosphoric acid and potash in the cultivated portion of the soil, when they are fed to animals and the manure is applied to the land that grew them, but such increase is at the expense of these products in the subsoil.

When cereals or cultivated crops only are grown on land the supply of the humus gradually decreases. Such decrease results in the loss of that mechanical condition which is most favorable to production. Such loss of condition may take various forms. Heavy soils become more and more impacted, insomuch that they are not easily plowed. When dry they become cloddy and call for the exercise of much labor to pulverize them when preparing a seed bed. On the other hand, light lands become lighter to the extent frequently of lifting with the winds. These conditions are the immediate outcome of too great a reduction in the humus supply, and the best remedy is to introduce into the rotation a grass or clover crop, the roots and stubbles of which will supply the need.

The humus thus introduced prevents heavy clays with their fine soil components from adhering too closely, consequently they are much more easily tilled. They are more completely aerated, and because of their more friable condition the roots of plants can penetrate them more readily. Plants that furnish humus tend to bind together the particles in soils so light as to drift, by the many rootlets that they furnish. In this way they aid in preventing soil lifting. Humus furnishes food in some instances at least in a readily available form, as when the vegetable matter that furnishes it is in process of decay. But one of the most important, if not the most important benefits resulting from it is the influence which it exerts on moisture in the soil. It tends to absorb and hold moisture, whether in its upward or downward movement, to the great advantage of the crops that are growing.

Where rotation is not practised, the labor called for is too much congested at certain seasons, and at other seasons it is too little congested. The preparation of the land for sowing, to be in season, must be done within a limited time. The same is true of the seeding and harvesting of the crop, subsequently. Because of this the outlay for labor is larger than would otherwise be necessary in order to get the work done. The difficulty of getting the work done properly and in season would also be greatly increased. In proportion as it is done not in good form and out of season, the hazard of low yields would be present. Farming is usually safe and profitable in proportion as the farmer is able to do his own work within his own household, or at least when the necessity for hiring much labor is not present.

Negative reasons for rotation in humid areas.—Rotation is called for in humid areas: (1) to prevent the undue accumulation of weeds; (2) to prevent the undue increase of insect pests; (3) to prevent an increase of

fungous diseases, and (4) to prevent the shifting of soils by water and winds. Other reasons may be added to these but not of equal importance.

Where but one crop is grown through successive years, there is an increase in the growth of many kinds of weeds, especially those which mature their seeds before this can be prevented by any of the ordinary processes followed in the cultivation of the land. Especially annuals and perennials may be thus allowed to multiply until their number becomes a menace to the growth of any kind of crop that may be sown. Summer-fallowing the land every few years may bring some relief, but in each instance where it is practised no crop is reaped that year from the land. An interchange in the succession of cereals may bring a small measure of relief, since some of these occupy the land at a somewhat different season from others. The most effective remedy for such weed intrusion is a rotation that includes cultivated crops, grass crops, and in some instances an occasional summer-fallow. The cultivated crops are to be relied on chiefly for cleaning the land. The grass crops, especially if of long duration, as in the case of alfalfa, favor the decay of weed seeds of many kinds in the soil, and the summer-fallow aids effectively in destroying perennials that might not otherwise yield to less heroic methods of eradication.

Insect life peculiar to certain crops cannot be easily mastered, in some instances at least, without an interchange of crops. Such interchange leads to their destruction by starving them through cutting off their food supply. The Hessian fly, for instance, which preys chiefly on winter wheat, may be banished, if not exterminated in the locality, by dropping that crop out of the rotation for a time. Chinch bugs, which prey ravenously on spring wheat, may be kept at bay, at least in a considerable degree, by ceasing to grow spring

wheat for a time, and by substituting for it certain crops that call for cultivation. Variations in the crops grown in rotations tend to variations in the time and methods of the cultivative processes, and these in turn have a most disturbing influence on insect life, both in the embryo and subsequently.

Rotation exercises a far reaching influence on the reduction of the hazard incurred by the presence of certain fungous diseases. In the northwestern states, as shown by Bolley, the continued growth of wheat on the same land for many years has led to the extensive prevalence of a fungous disease which preys upon the roots. The remedy proposed is an interchange in the crops grown. When flax wilt reaches a certain soil, in order to remove it flax should not be grown on the soil for a term of years. Likewise when potato scab is introduced into land, it can only be removed by refraining from growing potatoes on the same for at least a limited term of years. What is best, therefore, for keeping fungous diseases at bay, is best also, as has been shown, for maintaining a proper equilibrium in the land.

The shifting of soils by water and winds is in some instances very serious. The removal of soil by water is facilitated by fineness in the soil particles, by the absence of humus in the soil, by shallowness in the cultivated area, and by the violence and quantity of the rainfall. The soils in the semi-arid belt, especially such as are flocculated in character, shift the most readily because of fineness, especially when visited by torrential downpours. Next to these probably are loam soils light in texture. Humus in the soil, especially in the form of vegetation not yet decayed, as previously shown, binds soils. The binding power of vegetation is most strikingly illustrated in the presence of such grasses as Russian brome (*Bromus inermis*). Shallowness in the cultiva-

tion may be remedied by man, and also the lack of humus, but the original texture of the soil and torrential rains cannot be controlled by the character of the rotation.

The shifting of the soils by winds is much influenced by the nature of the soil, by the character of the cultivation and by the extent to which high winds prevail. Light sandy soils, in which the particles are fine, shift most readily with the winds. After these are the light spongy loams of the prairie. Clay soils are much resistant to such lifting. Soils that are much liable to shifting should not be given more cultivation than will absolutely suffice to produce a given result. Where high winds prevail in the spring while crops are being planted, the soil is frequently removed in areas with soils that lift to the extent of leaving the seed entirely bare. The best remedy is a rotation that keeps vegetation of some kind growing on these to the greatest extent practicable, and of a character that will add to the vegetable matter in the soil by the root growth.

Incidental benefits from rotation.—Among the incidental benefits which rotation brings are the following: (1) reducing the hazard from crop failure; (2) the more complete character of the maintenance for the household; (3) a wider diversity in the production of live stock, and (4) a salutary influence on markets and marketing.

Rotations may be broadly classed as wide and narrow. They are wide when they embrace a wide diversity in production, and narrow when they embrace but few lines of production. The wider the rotation, that is, the larger the number of the products grown within a certain limit, the less is the hazard from crop failure. Of course, it would be possible to make diversity so wide that the concentration of the energies would be diffused to the extent of putting the stamp of low attainment on

all efforts, but this mistake is of less frequent occurrence than the opposite. When but one crop is grown, the stake for the year is all centered in that crop. Should failure be complete, the stake is lost. Should it be partial, the farmer is proportionately crippled. The more the diversity in the grain production, the more safe is the farming, and if the production is extended to live stock the farming is still safer. Such widening of the rotation is not inconsistent with centering the effort mainly on the production of one leading staple. The story of the one-crop system indefinitely continued is the same in the main in all the states. If continued long enough it ends in disaster.

The maintenance furnished to the home from a wide rotation is very much more complete than from a narrow one. It makes it easily possible for the farmer to grow nearly all the food products which he needs, thus reducing proportionately the outlay. The influence on the accumulation is thus very marked. The person who centers all on the production of one crop or but a few crops, incurs large outlay for the support of his table. His profits are by that much reduced.

A wide diversity in crop production makes possible a wider diversity in the production of live stock, as it furnishes the food called for by each class. The farming is thus made doubly sure, as a season that may be unfavorable to the production of marketable cereals may be favorable to the growth of fodders which may be turned to good account by live stock when fed to them. The farmer who thus diversifies is certainly pursuing the safest line of farming. Let the season be what it may, he is sure to get returns from some line or lines of his work.

With increasing wideness in production comes increasing stability in the markets. This may not apply so much to a product of world-wide use and of easy

transportation as to one more limited in use and of costly transportation, because of its bulkiness. It may not be easy to glut the wheat market, but the potato market, for instance, may be glutted in a single season. The same is true of the market for certain kinds of perishable fruits. When all the people center on the production of one commodity, the tendency in the outcome is to disturb the market and adversely to the interests of the farmer. The equilibrium in marketing is also disturbed.

Additional reasons for rotation in dry areas.—In dry areas the reasons for rotating the crops in addition to those given include the following: (1) to prevent the loss of moisture that does not enter the soil; (2) to prevent the loss of moisture in the soil; (3) to increase the moisture content in the same, and (4) to make farming possible and profitable.

In such areas it is greatly important, as previously shown, that the precipitation which comes, whether in the form of snow or rain, shall in due time enter the soil rather than run away over the surface. The various methods which may be resorted to in order to accomplish this have already been discussed (see p. 123). The great importance of preventing waste from this source is emphasized at this time. All the operations relating to tillage should, therefore, be conducted with this thought in mind. In humid areas it is different. In these there are times when the removal of the waters of precipitation is more important than their retention, as, for instance, when they are present in excess, but even when thus present removal through drainage beneath the surface is much preferable to removal through open drains. Rotation facilitates the entrance of water into the soil in dry areas by the necessity which exists for introducing into it frequently crops that call for frequent stirring of the surface soil, and an occasional deep stir-

ring of the same, that the water that falls may enter it readily, even though it should fall in large volume. Grass crops are the least favorable to the entrance of water into the soil from above. Alfalfa is in some degree an exception, because of the discing that is given to the crop in the springtime.

The character of the rotation exerts a very marked influence on the retention of moisture in the soil that is already present in the same. When the small cereals follow each other in close succession they not only draw proportionately on the soil moisture to perfect their growth, but there is no means of preventing the sub-soil moisture from escaping into the air subsequent to the cessation of the use of the harrow on the crop. The more frequently that a fallow or a cultivated crop, therefore, can be introduced into the rotation, the more perfectly will the moisture be conserved in the soil. Because of the increase in the power in the soil to hold moisture as a result of putting humus into it, the introduction of humus occasionally in some form should never be lost sight of. The ability of the soil, therefore, to hold moisture in these areas will be proportionate: (1) to the infrequency with which the cereal crops are grown; (2) to the frequency with which cultivated crops are grown, and (3) to the increase in the humus content in the soil.

These agencies will also have an influence on the increase or decrease of the moisture content in the soil. The summer-fallow is probably the most potent agency that can be introduced in the line of cultivation to increase the moisture content of the soil. The increase which it may thus exert may be in itself a sufficient reason for introducing the summer-fallow. Next in potency in this respect is probably deep plowing and subsoiling. The alfalfa crop calls for such deep plowing when preparing the seed bed for it, and when the ground is broken

up on which it grew, the percolation following in the line of the decayed roots adds to the moisture content of the soil. A rotation, therefore, that will bring about such a result should be the aim. The more that it calls for the judicious stirring of the surface soil, the more is the moisture likely to be increased in the soil.

In dry areas, rotation of some kind is absolutely necessary to make farming profitable. Under all conditions this may not be absolutely necessary in humid areas. In these the farmer may begin with virgin soil. He may grow successive crops of the same kind on the same, for a term of years, at a profit. The duration of such profitable production will depend on the original fertility of the land and on the skill or lack of skill which he shows in taking fertility out quickly or slowly by the large or small crops which he grows. It is different with the farmer in the semi-arid region. He must have regard also to the moisture content in the soil. Without some kind of a rotation he cannot adequately retain moisture enough to enable him to grow crops. At the very outset, therefore, he must have some regard to rotation.

Rotation by alternating fallow and grain.—The discussion of this question will ask: (1) how such rotation is conducted; (2) the benefit emanating therefrom; (3) the area for the same, and (4) the objections that may be offered to it.

This rotation grows grain each alternate year, and summer-fallows the land in each of the years that intervene. Any kind of cereal may be thus grown which it may be desired to grow. Such a rotation is especially well adapted to growing winter wheat, since it virtually insures the germination of the seed even in a dry year and at the season when the crop may be best sown. No other kind of preparation can be given to the land that will so well secure this end. A cultivated crop should

not be alternated with the summer-fallow, since the moisture that has been stored by the fallowing process is more needed by the cereal crops that are grown in the rotation. A crop of any of the cereals is not assured in the absence of stored moisture, whereas a cultivated crop, as corn, is much more certain under such conditions.

The benefits from such a rotation include the following: (1) It makes it possible to grow good yielding grain crops in areas where the moisture is so low that these could not be obtained in any other way; (2) it makes it easily possible to maintain cleanliness in the land; (3) it makes it possible to furnish supplemental forage where it could not otherwise be obtained. In some areas the precipitation is so light that grain crops could not be grown by any other system of farming that could be followed. The choice in these is between no grain crop and the summer-fallow. Where this rotation is practised land may be kept absolutely clean. True, grain may volunteer, but the summer-fallow makes it possible to destroy it (see p. 119). In some areas where the seasons are very short, so short that grain may not be depended on to ripen, it may be devoted to forage uses.

This rotation may be necessary in many portions of the dry belt. If grain is to be grown it may be necessary where the rainfall is too little to grow a crop of grain after a cultivated crop. The difference in the degree of the precipitation that will make grain succeed on fallow land and fail when sown after cultivated land has not been well worked out, but such a difference does doubtless exist. As expressed in inches, however, the difference may not be very great. Where the precipitation is less than, say, 8 inches on the average, the summer-fallow would seem to be a necessity where crops of any kind of grain are to be grown. This rotation is practised where the rainfall is considerably greater than

has been stated, even where it is as high as 15 inches and more per year. It is not absolutely necessary, however, to adhere to such a rotation as a rule, in order to grow good grain crops with a rainfall above 10 inches, providing the climatic conditions will admit of growing cultivated crops.

The objections that may be urged against this rotation are: (1) that it reduces the fertility of the land; (2) that it leads to the depletion of the humus supply, and (3) that it encourages blowing in light soils. That it does lower the supply of plant food in the soil cannot be questioned. It lowers it by the amount that is taken out by the crop grown, for this system gives nothing back in return. That it lowers the amount of available fertility would also seem true, for, as the gross amount of fertility in the soil becomes reduced, it would seem reasonable to conclude that the relative amount released would become less and less from year to year. The store of plant food, however, in some of those western soils is so great that in some instances they have produced crops thus covering a period of not less than 40 years, without any diminution in the yields. Because of this some farmers have concluded that so it will be always, but the end will inevitably be reached. The day will come when the yields will wane.

What has been said about waning fertility will apply equally to the depletion in humus. It will probably apply even in a greater degree, since the supply of humus in these soils was less bountiful at the first than the supply of plant food. This system only puts back the humus furnished by the stubbles, and it consumes humus rapidly while the fallowing is being done. With decrease in humus comes proportionate decrease in the moisture-holding power of the soil, and this in semi-arid regions will in time work serious harm.

This system facilitates the blowing of soils where they are so light as to lift with the winds, because of the loose condition in which they keep them on the surface, for so large a part of the season. Owing to the fine condition in which the particles are kept they are carried away more readily by torrential rains, should they come. It is so far fortunate, however, that the average far western soil does not lift so readily with the wind as the soils that cover areas of the prairie that lie farther eastward.

Rotation by alternating cultivated crops and grain.—This method of growing crops substitutes a cultivated crop for the summer-fallow. It will be observed that it does not widen the rotation. The discussion will consider: (1) how such a rotation is conducted; (2) the benefits resulting therefrom; (3) the area where it is to be practised and the objections to such a rotation.

Any kind of a grain crop may be grown in this rotation that may be desired, providing it can be produced under the climatic conditions. The cultivated crop may be of any character that will involve a sufficiency of cultivation while it is growing to result in the retention of soil moisture to the greatest extent practicable. The crops thus grown more commonly include corn, potatoes, field beans and field roots. Of these corn will be grown to a greater extent, probably, than all the others combined, a result which arises, first, from the relatively small amount of hand labor involved in growing it, from the large return in proportion to the labor, and from the fact that it furnishes food for live stock larger in quantity from a given area as a rule than can be obtained from any other plant. Of course, the cultivated crop is grown one year in the rotation and is followed by the grain crop the next season.

The benefits from such a rotation include, first, a return from the land every year, which, under normal

conditions, will yield some profit to the grower, and, second, the furnishing of food for animals that may be kept upon the farm, such as can be obtained from no other source. The bare-fallow alternating with grain can only give one crop in two years, whereas by this system, as intimated, a crop is obtained every year.

The area where this system of cropping may be practised covers a very large amount of the semi-arid belt, but it cannot be practised everywhere, because of the shortage that may be present in the moisture. This system of cropping will probably conserve moisture about as effectively as the bare-fallow, but it draws more heavily on the moisture content in the soil, since it draws on it every year, where, by the other system, it is drawn upon only once in two years. It is clear, therefore, that more moisture will be used when the alternation in the cropping includes a cultivated crop. But how much more moisture will be called for in the one rotation as compared with the other, has not been worked out as yet. It would seem safe to say, however, that on average soils such a rotation could be conducted where the annual rainfall was not less than, say, 12 to 15 inches.

To this system two objections may be urged. First, it draws heavily on the plant food and humus in the soil, and, second, it draws so heavily on moisture that the grain crops grown must soon suffer from a shortage in plant food and also in moisture. The first objection is valid. The second is only partially so. In time such a rotation would deplete the plant food in the soil to the extent of reducing crop yields. Whether reduction would follow from a shortage in moisture will depend, first, on the total amount of the precipitation, and, second, on the proportion of this that it is possible to conserve. A crop of corn, for instance, will use as much moisture in many instances as a crop of wheat, but it does not

follow that it leaves the soil as much lacking in moisture as the wheat. It draws more of the moisture used in growing it from a deeper area than wheat, hence it draws less heavily on moisture near the surface. Moisture is also conserved when growing the corn, whereas it is not so conserved when growing wheat. Nothing can be done further to conserve it after the last harrowing has been given to the wheat. Moreover, the broad leaves of the corn furnish shade to the ground, and in doing so reduce the evaporation. It follows, therefore, that corn will leave much more moisture in the soil than small grain, as experiment has shown, but it will be less than the bare-fallow by the amount that it has taken to grow it. In areas where humus is abundantly present and the rainfall is fairly liberal, larger yields of grain may usually be expected after grain than after the bare-fallow, as an excess of straw is more liable to be present after the cultivated crop. Such excess in the straw, however, is less liable to occur on the soils of the far west than on the prairies of the eastern portion of the dry belt. But where the rainfall is not quite enough to grow a crop each year as outlined, one crop only should be sought in two years.

Rotation which combines fallow and cultivated crops.—The discussion of this rotation will also consider: (1) how it is conducted; (2) the benefits resulting therefrom; (3) the area where it is to be sought, and (4) the objections thereto.

The fallow and cultivated crop in each instance is followed by a crop of small grain, and these crops alternate. The rotation, therefore, covers four years. The order in the same is as follows: Summer-fallow, small grain, cultivated crop and small grain. This rotation grows three crops in the four years. Where it can be adopted, therefore, it is more profitable than the rotation which gives but one crop in two years. It is easily

feasible to so divide any farm, large or small, that the succession involved in this rotation may be conducted on it. Suppose, for instance, that the farm has in it 160 acres. If 40 acres are set aside for hay or pasture, 120 acres will be left for cropping. If the 120 acres are divided into four equal parts, the rotation may be introduced as outlined. In this rotation 60 acres will be cultivated each year by the fallow or by the cultivated crop, and the remaining 60 acres will be devoted to the growing of cereal crops. On one-half of the cultivated area a crop will also be grown, hence but one-fourth of the land that is cultivated from year to year will be idle.

This rotation is attended with the following benefits: (1) it keeps the land in a clean condition; (2) it makes practicable the growing of fodder on the farm, as corn for instance; (3) it is not only not antagonistic to a wider rotation, but is helpful to the same, since it makes provision for the growing of hay and pasture, and to any extent that may be desired, as the rotation is practicable on any residue of the land left after the hay and pasture land is set aside, providing the said residue is divided into four parts.

This rotation will probably be extensively adopted in the semi-arid country, since it favors the introduction of live stock onto the farms. It cannot be successfully practised on so small an amount of precipitation as will bring a crop of small grain once in two years, on the summer-fallow plan, but it can be practised on a rainfall somewhat less than will suffice to grow corn or the other cultivated crop in combination with small grain each alternate year. In this rotation, where winter wheat may be successfully grown, it should be made to come after the bare-fallow, and other spring crops after the cultivated crop.

The objections to it include the following: (1) it makes no provision directly for putting back on the land

plant food or humus removed by the successive crops that are grown; (2) it involves a considerable amount of labor in cultivating so large a proportion of the land each year; (3) it involves the fencing of at least that portion of the land devoted to the growing of pasture. In reply to these objections it may be answered: (1) that the system can be easily so modified as to bring fertility and humus to the land. This can be accomplished by changing at intervals the portions devoted to the growing of hay and pasture. These may be devoted to the crops of the rotation, and hay and pasture may be grown for a time on the other portion of the land. The ends thus sought will be most completely realized when the hay and pasture plants are of the leguminous order. (3) The fencing to be erected cannot be avoided where live stock are to be kept on the arable farm, whatsoever may be the rotation.

Rotations which include grass crops.—As in the preceding rotations, there will be discussed the following under this sub-head: (1) how these may be conducted; (2) the benefits from so conducting them; (3) the area for the same, and (4) the objections to these methods.

It will be observed that this rotation includes one or more grass crops, of course including the clovers where they may be grown with success and also alfalfa. The various clover crops cannot be grown at their best in semi-arid areas, as already intimated, hence it is not probable that they will ever be given an important place in the rotation in these areas unless under exceptionally favorable conditions. The grass rotation plants will include brome grass, western rye, and, in some places that are exceptionally favored with moisture, timothy and red top. It is almost certain, however, that alfalfa will be grown to a greater extent as the grass crop of the rotation than any other plant.

It is not possible to fix definitely the order of such a rotation where the conditions vary so much. The grass crop may be added to each of the rotations given above, but in none of them will it fit in so well as with the rotation that combines fallow with a cultivated crop. The order would be summer-fallow, small grain, a cultivated crop, small grain and the grass crop. The term of years that the land should thus be laid down to grass or alfalfa will vary with the conditions. It is preferably long rather than short, because of the hazard of failure in getting a stand of grasses in years that are unusually dry. When the grass or alfalfa crop is broken up, the cropping to small grains in alternation with cultivation may be prolonged as desired.

The benefits from such a rotation are unquestioned. It insures the maintenance of a supply of humus which is so necessary to high production, more especially in dry areas. It cannot be so well supplied in any other way. It also opens up the way for the maintenance of live stock on the farm. It is not to be expected that the grazing in dry areas will be so much as in those that are moist, and yet a certain amount of pasture land is necessary where much live stock is kept. When alfalfa is the grass crop grown, it will also furnish nitrogen to the soil in liberal degree, and will in this way contribute beneficially to the maintenance of fertility.

The area for such a rotation will virtually embrace all the semi-arid country, but the necessity for it will not be so great in all parts. In much of the arid region rugged lands are contiguous to the farm lands. These may be made to furnish all the pasture called for. Notwithstanding, the necessity for hay still continues, and it cannot be better supplied than by growing alfalfa as a rotation crop. This means that this crop may be made not only to furnish hay, but that it may also be made

to furnish humus and nitrogen in addition in all parts of the dry area.

But few objections can be offered to this rotation. When the virgin lands of the prairie are first broken up the grass roots are present in the soil to the extent of hindering production. The hindrance is felt in the slow decay of the vegetable matter. This means that in a dry year less production will be obtained from such lands than from the same when the original grasses have reached a more advanced stage of decay. Because of this it may be wise, and usually it is wise, to try to secure several crops of small grain from these lands before they are laid down to grass in any form. The objection that introducing grasses involves the introduction of fencing, is not well taken, for live stock cannot be so well kept in the arid country, or indeed in any country, in the absence of a certain amount of fencing.

Rotation that should not be followed.—The discussion of this question will consider: (1) growing small grains in succession; (2) growing pastures for many successive years; (3) growing alfalfa for many successive years, and (4) growing small grains in any rotation which does not bring them after a cultivated crop.

The mistake of growing small grains in succession in dry areas should be avoided. This does not mean that the method of growing them thus will not succeed in some instances, as when the precipitation is unusually large. But an abnormally large precipitation can never be forecasted. The Montana Experiment Station has shown conclusively that a good crop is never assured under such conditions of growth, and that a limited term of years of such cropping will result in the production of crops that are not worth harvesting. Adherence to this method of crop production, especially along the eastern side of the semi-arid belt, has unquestionably

involved the several states concerned in a loss of several millions of dollars annually.

Many farmers are apparently imbued with the idea that it is impossible to secure as large profits from one cereal crop grown every alternate year as from annual crops of the same grown every year. Whether this can or cannot be done depends entirely on the yields. Experience has shown that where the rainfall is not more than 15 inches annually more bushels of small grain will be obtained in a term of years by taking one crop from the soil in two years than from cropping the land every year. Though the yields should be the same the profits from growing the one crop in two years will be greater because of the less expense involved in growing it.

Where the rainfall is more than 15 inches annually, and less than 20 inches, it may be legitimate to grow several grain crops in succession on land when broken from the virgin prairie. But even in these areas the process should not be long continued because of the drain that such a system involves on the fertility and also on the humus supply in the land.

While pastures should as a rule be continued for a longer period than two years, they should seldom be made permanent in dry areas. The objections to such permanency are: (1) the necessity that exists for renewing the humus supply in the land; (2) the difficulty found in maintaining high relative production in such pastures, and (3) the tendency in such a system to lessen the store of moisture in the soil and especially in the subsoil. It is important, therefore, that such pastures will not be grazed for too long a term of years.

On arable farms the aim should be to avoid maintaining alfalfa crops during a long term of years. This does not follow from any real difficulty in maintaining maximum production in the alfalfa crops, but rather

from the advantage that comes to the grain crops that follow the alfalfa through the supply of plant food and humus which it brings to the land. To this rule, however, there may be many exceptions. The wisdom of growing small-grain crops as a rule only after cultivated crops, or fallow, has been amply justified by experience. To this, however, there are some exceptions. Flax, as has been shown, may come after grass with reasonable certainty in the results when properly grown. Should the autumn rains be heavy, an occurrence that may happen, although it is rare in the semi-arid country, in some areas but not in all, it would be legitimate to follow small grain with small grain.

CHAPTER XVII

MAINTAINING FERTILITY AND HUMUS IN DRY AREAS

When the settler locates on western soils, the thought which dominates his mind and directs his efforts is how to get marketable crops to grow. As long as he is able to accomplish this it is difficult to impress him with the thought that the time will surely come when such a system of cropping will lead to the impoverishment of the land. That such a result will follow if crops are taken from the land and sold in successive years for an indefinite period cannot be questioned. The land will stand such cropping for a much longer period in dry than in humid areas, because of the greater store of plant food in the soil, and because of the less loss of the same in crop production. The farmer, therefore, in dry areas, must give careful attention to the maintenance of fertility in the soil, if he is to maintain maximum production. He must also give equally careful attention to the maintenance of the humus supply in the soil, in order to maintain it in a proper physical condition, and to increase its moisture-holding power. The system of alternate cropping and summer-fallowing so commonly advocated is decidedly unfavorable to the maintenance of either in the absence of the renewal of fertility and humus.

In the present discussion, fertility, of course, means plant food, and especially the three essential elements of plant food. No time will be spent in discussing the question as to what fertility in the abstract means. The author who claims that "fertility is not something that inheres in the soil" is welcome to all the comfort he can get out of so stupid a definition. Likewise the scientist who claims that "fertility is what the soil is capable of

doing under the best possible conditions" is welcome to all the comfort he can get from making fertility a thing so intangible. If the elements of fertility—phosphate, potash and lime—are not a part of the soil, what are they a part of? Humus in the discussion, of course, means organic, that is, vegetable matter, whatever may be its stage of decay.

The soils are usually fertile.—The richness of the soils in dry areas in all the essential elements of plant food is owing chiefly: (1) to the inherent richness of the soil particles; (2) to the similarity of the subsoil to the soil in its essential constituents; (3) to the little loss of fertility by leaching, and (4) to the extent to which the soil has been moved by rodents.

The richness of the soil particles is owing chiefly to the source from which they have come (see p. 62). This inherent richness applies largely to food that is not yet available. This reserve food is unlocked gradually by the cultivation given and through other agencies, hence the ability of these soils to maintain an undiminished production for a long term of years.

It cannot be said, of course, that the subsoil is in all instances similar to the surface soil, but in many instances it is. Because of this the beneficial descent and ascent of soil moisture is facilitated, the feeding ground for the roots of plants is relatively enlarged and the removal of plant food to the surface soil from below is made very easy and sure. This explains why it is possible to grow grain on lands for long periods which increase rather than decrease in their producing power.

On nearly all soils in dry areas the loss from leaching is so small that it is not to be considered. The exceptions to this are rare. There is, therefore, virtually no loss of fertility from this source, which is a never-ending source of loss in humid areas. This means that inert fertility is made available slowly and that it is

not removed from the soil save as it is taken up by the crops where proper methods of cultivation are followed. In humid areas, the loss from the leaching of fertility down through the soil in the form of nitrates is present more or less every season. This loss is proportionate to the abundance of the nitrates, and to the superabundance of the water in the soil. Some fertility may be removed through the washing of the soil. The loss from this source may be felt more or less on soils that have much slope, providing these are cultivated. On fairly level lands this may be almost entirely prevented by a judicious system of tillage (see p. 91).

Rodents have doubtless exercised an important influence on the increase of the available fertility in dry areas by the extent to which they have burrowed into the soil and carried it to the surface. The channels thus made in the process of burrowing were followed by air and moisture and these have aided in the reduction of the soil. The combined influence of sun and rain furthered decay in the soil that was brought to the surface. This decay was favorable to the growth of plants, which in turn added to the available fertility. This process has been going on for long centuries, hence the influence of these toilers has doubtless been material in the liberation of soil fertility.

The loss of fertility.—Many claim that the supply of fertility in dry areas will never be lost. This view is doubtless based on the observation that grain crops have been grown on the same land for periods of, say, 25 to nearly 50 years without any diminution in the yields, and in the absence of any form of fertilization other than that furnished by the straw of the grain crop or crops that were grown upon the land. These results have been obtained in Utah and also in some other parts of the semi-arid belt. This, however, only demon-

strates that the supply of fertility in these soils is very great rather than that it is inexhaustible.

Every non-leguminous crop grown upon the soil and sold from it carries away from the soil a certain proportion of the elements of fertility essential to plant growth. This means that the residue left in the soil and subsoil is reduced by the amount removed in the crop grown. It follows, therefore, by logical sequence, that in time the elements of fertility in the soil will be so reduced that it will be rendered incapable of producing a profitable return. The time when this result will be reached will depend, first, upon the crop grown, and, second, upon the abundance of the crop yields. The more abundant the crop yields, the more rapid will be the depletion in the fertility. It has been found that to grow a bushel of wheat and the straw that it takes to produce it, removes $1\frac{3}{4}$ pounds of nitrogen from the soil, 1 pound of phosphoric acid and 1 4-5 pounds of potash. To grow a 20-bushel crop will remove twenty times as much of these elements; hence, if both straw and grain are removed, the fertility left in the soil is reduced by the amounts as calculated. Such a heavy drain on soil fertility in the absence of any fertilization must in time so deplete the store of plant food in any soil, howsoever rich it may be in plant food originally, that it will cease to grow profitable crops. In certain areas in California where grain crops were profitably grown for a generation, during recent years they have fallen below the limit of profitable production in the absence of fertilization. Even though production by such a system should be profitable for two or even three generations, the day of reckoning will assuredly come because of the low yields obtained.

The loss of plant food is less rapid in dry than in humid areas. This arises, first, from the smaller growth of straw produced by semi-arid soils; second, by the

almost entire absence of loss by leaching, and, third, because when moisture is absent the liberation of fertility practically ceases. In humid areas the fertility is continually drawn upon during the period of growth, if not in growing crops in growing weeds. In dry areas growth is practically at a standstill during a considerable portion of the growing season. The less rapid loss of plant food in the soil in such dry areas is strikingly shown in the longer period during which the effects of farmyard manure are traceable when applied to the soil. In many instances these are not traceable in humid areas beyond three years, whereas they are traceable in dry areas for at least twice as long.

The restoration of fertility in dry areas is much more difficult than in humid areas. This follows: (1) From the relatively small growth of vegetable matters produced for burial in the soil. In humid areas, weed growth is more constant, and two or three crops of green substance may be grown and buried in one season. Such production in dry areas is much less. (2) From the less extent to which legumes may be grown on a given piece of land. These, of course, are the most important restorers of fertility. (3) From the more limited supply of the farm fertilizers that are on hand, resulting from the less bulky crop production. (4) From the slower action of applied commercial fertilizers. These facts should be carefully weighed by those engaged in dry farming.

Sources of fertility.—The sources of fertility in dry areas include: (1) Food furnished directly by the soil; (2) food carried up by the subsoil; (3) food liberated by cultivation, and (4) food furnished by legumes. No one of these sources is unimportant.

The soil is beyond all comparison one of the most important sources of plant food. The larger portion of the food exists in the soil in the inert form, and is

slowly unlocked or made available by the processes of cultivation. This is one reason why judicious cultivation is so important in dry areas. The difference between poor soils and soils that are rich, is mainly a difference in the food elements that these soils contain and chiefly in the inert form. It is fortunate that these stores are made available chiefly through the processes of cultivation. Were it otherwise, there would be a great waste of fertility before it could be utilized. But there are certain forms of bacteria in the soil that have the power of gathering nitrogen from the air, and converting it into forms suitable for the needs of plants. According to Widtsoe these bacteria utilize for their life processes the organic matter of the soil. To work effectively they require a soil rich in lime, fairly dry and warm and well aerated. Fortunately these conditions are all met on the dry farms of the semi-arid west.

The food carried up from the subsoil exercises an important influence on fertility in semi-arid areas. The soluble materials in arid areas go down to the lower limit of moisture penetration. The soil and subsoil are thus made of equal porosity. Because of the facility with which air may penetrate the soil and subsoil mass, the subsoils are in a sense weathered and made suitable for furnishing available plant nutrition to great depths. In some instances in the semi-arid region, the soil and subsoil are not very different from the surface soil down to the distance of many feet, hence in these deep plowing does not bring up unweathered soil as it does in dry areas, and it enlarges at the same time the reservoir for storing water. It has been claimed, and probably correctly, that the relative fertility of different areas in the semi-arid belt depends more on the nature of the subsoil than of the surface soil. In semi-arid regions the roots of plants go to stored water, and the latter does not need to be brought to the surface.

The limit of root penetration in the crop, therefore, is an important factor when conducting experiments in dry areas. But the upward movement of the natural precipitation in the soil is also an important factor in determining its producing power. The plant food dissolved in the downward movement of soil moisture is again carried upward to the domain where it may be utilized by growing plants. In this way the fertility of the surface soil is continually reinforced by plant food carried up from the subsoil. In humid areas much of the food thus dissolved and carried down to the surface soil goes out in the drainage water.

The proper cultivation of the soil tends to liberate plant food in the same. The frequency with which the soil is stirred in the summer-fallow and in growing a cultivated crop favors such liberation of fertility. It greatly facilitates growth in the crop sown on such land, but this influence is secondary to that exerted by the moisture conserved. In humid areas much of the fertility thus liberated may be carried down and out into the drainage water, but in dry areas this very seldom occurs.

The growing of legumes is one of the most effective methods by which fertility may be increased in dry soils. The supply of available fertility may be increased by cultivation, by the amount carried in solution through capillarity, and from the action of certain bacteria working in the organic matter in the soil, but such increase relates almost entirely to temporary increase, which means a reduction of the total amount left in the soil. The increase through growing legumes is a positive addition to the fertility of the soil, at least with reference to its nitrogen content.

How to increase fertility.—Fertility in dry areas may be increased: (1) by growing legumes; (2) by applying farm manures, and (3) by applying artificial fer-

tilizers. Fertility already in the soil may be made available by various processes.

Soils in dry areas are usually rich in mineral matters, hence they do not meanwhile call for additional supplies of phosphate and potash, but they are frequently deficient in nitrogen and humus. These may be best supplied by legumes (see chapter XIII). They take nitrogen from the air in the process of growth, and much of what has been stored in the soil feeds the crops that follow, at least for a time, usually for 2 or 3 years in humid climates, and frequently it may be for a longer term in dry areas. If the crops are not buried but are harvested and fed or grazed off, such enrichment is without cost to the grower of these crops. Whether the entire crop should be buried will depend more on the extent to which the soil needs vegetable matter than on the extent to which it needs fertilization. Humus may frequently be supplied more cheaply by non-leguminous plants. In areas where the header is used in harvesting wheat grown on fallowed land in alternate years, the humus thus supplied does not cost anything. Grazing off the crop grown, especially when leguminous in nature, brings enrichment to the land in a very effective form. The pea crop properly grown is one of the best for such a use.

Farmyard manure is very beneficial to arid soils when properly applied, but it may be so applied as to do harm, as when, for instance, large quantities are buried in the soil at one time. When dry weather follows, such a soil is kept too open and will not sufficiently hold moisture. It should, therefore, be applied in quantities quite moderate, not more usually than ten tons to the acre, and frequently considerably less will be better. It should be applied when practicable with the manure spreader. If the manure is disced in before the land is plowed, its action will usually be quicker

than when not so managed. Farm manure not only brings plant food to the soil, but it increases the vegetable mold in the same, and it facilitates the liberation of fertility through chemical agency. The beneficial effects of manure on the soil and crops are present for a much longer period in dry than in humid areas, because of its slower decay in the soil. When live stock are kept in any considerable number on dry farms, the maintenance of fertility on these will not be a very serious question.

The use of artificial fertilizers in dry areas will not assume large proportions for many years to come, and for the reason that the expense incurred would probably be greater than the benefit accruing. There may be instances in which such nitrogenous fertilizers as nitrate of soda may be applied with advantage and profit, but usually nitrogen may be brought to the soil more cheaply by growing legumes. Phosphoric acid and potash will not be much needed for many years, in some instances for an indefinite period.

In various ways the available supply of fertility may be increased without adding fertilizer to the soil directly. Among these are the following: (1) Cultivating the soil so as to expose it more effectively to those weathering agencies which unlock inert plant foods. These include sun, air, frost and rain. (2) Supplying the soil with vegetable matters which in process of decay produce various acid substances which act upon the soil grains so as to set free more or less of the plant food which they contain. Such action is present in degree in the decay of all kinds of plant food in the soil, whether it has been produced above or below the surface of the same. (3) Keeping the soil in a condition so that water will move through it freely. Plant food is thus dissolved to feed the plants, and though carried downward it is again carried in dry areas to the

upper soil, that is, the soil which may be regarded as the domain of root-growth.

The supply of humus in dry areas.—The supply of humus in dry areas is much less than in humid areas. The difference in the relative proportions cannot be stated, as the humus supply does not increase in all instances as humidity increases, nor is the supply limited in proportion to the dryness of the climate. The character of the soil exercises a potent influence.

The supply of humus in dry areas is low because: (1) The proportion of the sandy soils in these is greater than in humid areas. Especially is this true of the Inter-mountain areas of the west. These do not produce a strong vegetation in the absence of irrigating waters. (2) The plants are bunched, as it were, in their habit of growth, hence the number of the plants on a given area is relatively small. In dry areas a tough, dense sod is rarely found, though of common occurrence in humid areas. The proportion of organic matter thus produced is much less than in the latter. (3) The growth in dry areas is less luxuriant than in humid areas. It is in a sense dwarfish in its nature. The hay or straw taken from a piece of land in dry areas is relatively small. The trees show the same characteristics. (4) Much of the growth in dry areas has been burned through long centuries, and this has greatly reduced the humus supply in the soil. (5) The extent to which alkali prevails on western soils has interfered adversely with the growth of vegetation, in many instances to its entire exclusion.

From what has been said it will be apparent that it is more difficult to increase humus in dry than in humid areas. In the latter, when soils are left untilled for a time, they will produce, as it were, spontaneously, a luxuriant growth of weeds. Later these will be succeeded by native grasses which will dislodge the weeds,

and where the humidity is marked trees will eventually take possession and crowd out the grasses. In arid areas under such conditions the weed growth would be much less strong. The possession of the soil by grasses would be much less complete, and forest trees would not grow at all. In humid areas germination from good seed is sure, but in dry areas such is not always true. Even though crops should be grown specially to increase the supply of humus, dry conditions may prevail to such an extent that they may not furnish very much vegetation.

Fortunately humus is not lost so readily in dry areas as in moist areas of equal temperature. Organic matter buried in the soil does not decay in the absence of moisture. Should a heavy coating of stubble be buried in the soil in dry areas, say in the spring season, and a crop be sown on the land, the crop will fail because the undecayed stubble cuts off the moisture supply from below. Should dry weather prevail through the entire season, the stubble will be turned up by the plow in a condition showing but little decay, whereas had rain fallen copiously the stubble would have been all decayed. This explains why the effects of farmyard manure are discernible for a period much longer than in humid areas. This fact tends much to even up, as it were, the difference resulting from the different quantities of humus possessed by soils in dry and humid areas respectively. It is less needed in dry soils to keep them in mechanical condition, and because of their dryness. Moreover it is claimed that humus in dry areas contains much more nitrogen than in humid areas. But because of the greatly increased power which humus gives to the soil to hold moisture when judiciously supplied to it in dry areas, the aim should be to maintain at all times an adequate supply in the same.

Sources of humus.—The sources of humus in dry areas includes: (1) organic matter that decays on the surface of the soil; (2) the roots and stubbles of plants; (3) green crops grown and buried, and (4) farmyard manures.

The supply of organic matter from the decay of plants on the surface of the ground is inconsiderable, for the reason, first, that the growth of these is relatively small, and, second, that what is produced is in a great measure consumed by animals when grazing. This was true to a very considerable degree, even before the introduction of domesticated animals. The comparatively small extent to which vegetable soils occur in dry areas in thus accounted for.

The roots and stubbles of plants are one of the most important sources of humus in dry areas. The plants grown on these are possessed of a relatively long and deep root system. The roots are encouraged to go down because they may secure moisture thereby and also additional food. The opposite is true of plants grown under irrigation. The proportional weight of the roots of plants differs greatly, and the same also holds true of the weight that the roots bear to the stems and leaves. The weight of the roots of clover is about the same as that of the portion grown above ground. The weight of the roots of alfalfa is probably much greater than the weight of any single crop of the hay. The roots of brome grass are about the same weight as that of the stems and leaves. The roots of oats are about 40 per cent. of the stems and leaves, whereas the roots of peas are only about 9 per cent. of the portion above ground. It would seem correct to say that no plant grown in dry areas will equal alfalfa in the quantity of the organic matter which it brings to the soil in its roots, or in the deep distribution of the same.

The stubbles of plants likewise differ greatly in the amount of the humus which they bring to the land. The amount thus brought is proportional to the density of the stubbles and to the length of the same. Because of their density the stubbles of grasses rank high in furnishing organic matter. Wheat, when headed in harvesting the crop, may also be assigned a high place, not because of its density, but because of the length of the stubble that is thus left for burial. Peas furnish very little stubble when the crop is harvested and the same is true of vetches.

In the future much attention will probably be given to the growth of plants for burial in dry areas. The quantity thus added in a single crop will enable the farmer to furnish organic matter to the soil more quickly than it can be furnished in any other way, but in many instances it will not be possible to get any return from the land the same season that a crop is buried for such a use. This loss may be avoided in some instances by burying the crop in conjunction with the summer-fallow, as is shown in the division that follows. The value of plants for such burial differs greatly. Legumes hold first rank for such a use, because of the nitrogen they bring to the soil, and because of their quick decay. Some are more suitable than others, because of the season at which they can be buried. Such is winter rye that may be buried early in the season. Others have the recommendation that they grow quickly. Such is buckwheat.

Some time in the future farmyard manures will be an important source of humus in dry areas. That, however, will not follow for many years to come, as the farmers will center their efforts on growing grain crops for sale rather than on growing crops for feeding uses. Manure buried in the soil in suitable quantities and at

the proper time adds greatly to the productiveness of soils in dry areas.

The benefits from humus.—Prominent among the benefits from the application of organic matter to the soil are: (1) that it improves the physical structure of soils; (2) that it adds to their moisture-holding power; (3) that it furnishes food to plants in a readily available form, and (4) that it lessens the lifting of soil by winds.

Organic matter improves the physical texture of soils by preventing them from lying too compactly. The evils resulting from over-impaction are: (1) the baking of soils, which is adverse to aeration and to the entrance of rain into the soil when it falls; (2) adding greatly to the labor of tillage, and (3) it is proportionally adverse to successful growth in the crops. When the organic matter in soils is practically exhausted, which is certain to follow long-continued cropping with small grains, soils run together and become impacted in many instances. There is virtually no organic matter between the soil particles to keep them asunder. This adhesive condition prevents the rain that falls in the form of heavy showers from entering the soil as it otherwise would, and because of this much of the moisture that falls may run away over the surface and be lost to the soil. That the soil may be kept in such physical condition that the moisture that falls shall have an opportunity to enter the soil to the greatest extent possible is greatly important in dry areas, and indeed in all areas. The baking of the soil proportionally excludes air, and as it does, it proportionally lessens the activity of bacterial life, thus reducing the beneficent influences that flow therefrom. The difference in the labor involved in plowing a soil in a baked condition as compared with the same in the unbaked form, will be readily apparent, and the increased labor involved in the pulverization of the same will be relatively greater than

the labor involved in plowing it. When the soil gets thus impacted successful growth therefrom is simply impossible.

Organic matter judiciously applied to the soil adds greatly to its moisture-holding power. It is applied judiciously when it is added in quantities that will not, because of their excess, keep them lying too loose and open, and when it is buried in a condition that will facilitate quick decay as far as this may be possible. When excessive in quantity, impaction is so little present, that the air removes too much moisture from the soil. It does not lie sufficiently close to the seeds when they are planted to promote vigorous germination, and the roots of the plants cannot feed properly because of lack of moisture. It is easily possible in a dry season to produce failure in a crop that would otherwise prove successful through the injudicious application of organic matter. This means that when manures are buried in the soil they should be applied only in moderate quantity at one time, and that when a green crop is buried it should be so buried before it reaches too advanced a stage of maturity, otherwise it will decay too slowly.

Organic matter in its decay adds much to the moisture-holding power in the soil. It does so by absorbing water that is going downward in the soil and holding it much as it is taken up and held by a sponge. Of course it will not hold it for an indefinite period in the absence of rain, but it will in very many instances hold it sufficiently long to enable it to be taken up by the roots of plants which penetrate the soil much more readily because of the presence of organic matter. It has been claimed that in dry areas the presence of a sufficient supply of organic matter in the soil in a suitable stage of decay will increase its moisture-holding power by fully 50 per cent.

But the opposite result will follow when it lies in the soil without decaying, as it does sometimes when buried in the form of stubble, of dry grass on sod land or of strawy manure. Because of such burial and the adverse results that have followed, the prejudice has arisen which prevails to a very considerable extent in dry areas against the application of farm manures. If straw must be buried, as when strong stubbles are plowed under, the aim should be to disc the soil before it is plowed, that the stubbles may be mixed with the soil before they are buried, and then to pack the soil where it will stand such packing after it is plowed. The direct burial of heavy stubble by covering it in a shallow furrow, in the eastern portions of the semi-arid area, where heavy stubble is frequently produced, has led to the ruin of many a grain crop. The stubble thus lying in the bottom of the furrow has prevented the ascent of soil moisture and also the downward penetration of the roots. Why, then, does the plan of burying the straw of grain that has been headed meet with so much favor? Because (1) its deep burial is usually followed by the bare-fallow, which gives it time to decay; (2) because in its decay it encourages all the processes of bacterial life which are so helpful to crop production; (3) because of the plant food which it furnishes in its decay, much of which is brought up from the subsoil while the crop that produced the straw has been in process of growth, and (4) it makes the soil more porous and therefore more easily and effectively worked for the prevention of evaporation. The burning of stubble, like the burning of straw, is a most baneful process.

Organic matter in the soil furnishes food to plants in a readily available form. The plants that are buried have gathered food from the soil through the wide distribution of their roots, and by processes that have been slow in their action. When the organic matter thus

produced is buried in the soil, as in the form of green crops, this substance in its decay readily furnishes food for the crops that follow, providing the decay of the green crops thus grown is sufficiently rapid. Thus it is that crops that are less valuable are made to gather food for crops that are of greater value relatively.

The burial of organic matter in the soil materially lessens the tendency to the shifting of soils through the action of the wind. In sandy loam soils, and to a greater extent in sandy soils, the shifting of soils through the action of strong winds that are much liable to prevail at certain seasons of the year, is becoming a serious handicap to the farmer in the prosecution of his work. Where this occurs, the more labor that is put upon the seed bed by discing and harrowing, the more will be the loss through the drifting of the soil. In some instances the seed is laid bare, and the soil that covers it is carried to other areas. A plentiful supply of organic matter in the soil, whether in the form of plant roots in the soil or of stubbles incorporated in the surface soil in the process of discing the same, will tend very much to lessen the shifting of soil through the action of the wind.

How to increase humus.—Since the presence of humus in soils in dry areas produces results so beneficial, it is greatly important that the supply of the same shall be abundantly present. How to maintain such a supply is certainly a question of much moment. The following are some of the ways in which it may be applied: (1) by growing and burying non-leguminous plants; (2) by growing alfalfa; (3) by growing and burying the Canadian field pea; (4) by growing and burying the cow pea; (5) by growing and burying the sand vetch, and (6) by growing and burying sweet clover.

Any of the non-leguminous plants may be grown for such burial. Some of these, however, are so valuable for other uses, as wheat, for instance, that it would not

seem profitable to grow them for such a use. Prominent among the non-leguminous crops that are grown for burial are winter rye, buckwheat and Dwarf Essex rape. Winter rye has peculiar adaptation for such growth, since it can be sown in the autumn and buried in the late spring without losing a crop the season that it has been buried. It may be drilled in amid the stubbles and without discing them in the autumn. It may be buried in the spring in time to follow with a crop of corn or to summer-fallow the land as may be desired. Buckwheat and rape may be grown for such a use on summer-fallowed land. When thus grown the late season at which the crop is buried may to some extent prove adverse to the retention of soil moisture, but this will be probably more than offset by the benefits that will result from the burial of one or the other of these crops. Winter rye should be buried usually not later than the earing stage, buckwheat at the stage of full bloom, and rape when it has reached maximum growth.

Alfalfa furnishes large supplies of organic matter in the decay of its roots when the crop is broken by the plow. The roots not only increase the plant food content in the soil and subsoil, but they add greatly to the moisture-holding power of the soil by the absorbing power of the roots in their decay, and also by the many small channels which they open up in the subsoil for the downward passage of ground water. So beneficial is the mission of alfalfa in this respect, that in dry areas it may be wise to grow it in somewhat short, rather than in long, rotations, so that the benefits resulting from the humus which it supplies may be accelerated and increased.

The Canadian field pea is a most excellent humus-supplying plant when buried in the soil; but to the burial of a crop of peas there is the same objection that applies to the burial of a crop of alfalfa, viz., that the pea crop,

like the alfalfa crop, is too valuable for such burial. There is the further objection that the price paid for the seed of peas makes such feeding costly. But when peas are thus buried the available nitrogen thus brought to the land is very considerable and much of it has been obtained from the air.

The results from growing and burying the cow pea are quite as significant as the results from growing the Canadian field pea, but the domain for the cow pea is, of course, in latitudes that would be too warm for growing the Canadian field pea at its best. The objection also applies to the cow pea, that its food value is such as to preclude the advisability of growing it for burial, save in certain instances that are more or less exceptional in character.

The area in which the sand vetch will grow with sufficient success to justify growing it in the dry area has not been sufficiently determined as yet. If it should prove true that the sand vetch may be sown with a spring crop without detriment to the same, and that it will grow on subsequently and furnish a large amount of organic matter for burial the following season, then it will follow that the mission of the sand vetch in furnishing humus in dry areas will be one of much significance, as (1) it would start in its growth without detriment to other crops; (2) it would furnish humus for burial without necessitating the loss of a crop, which would be true of it even when buried on land that is to be summer-fallowed, for such land would not in any case furnish a crop that season, and (3) it would furnish nitrogen from the air in plentiful supply.

The place for the growing and the burial of sweet clover as for the growing and burial of sand vetch has not been well worked out, but especially under hard conditions the place for the growth of this plant in order to supply humus would seem to be a large one. As

in the case of the sand vetch, it would seem to be quite feasible to sow the seed in conjunction with spring grain without detriment to the grain, and to bury the clover crop the following season, preferably in conjunction with the summer-fallowing of the land. The sweet clover produces a large tonnage relatively for burial, and it gathers and stores in the soil relatively large amounts of nitrogen. Moreover, it will succeed on soils so strongly impregnated with alkali as to preclude the possibility of growing on them the more valuable plants with any measure of success. In this way such soils may be improved by the removal of considerable quantities of the alkali, should the crop be removed, and by the favorable influence exerted on the soil mechanically should it be buried. Ordinarily the cow pea, the sand vetch and sweet clover should be buried when in full bloom.

CHAPTER XVIII

LIVE STOCK ON DRY FARMS

When the homesteader locates on the dry farm, his efforts are usually concentrated, and properly so, on the production of grain, but he makes a serious mistake if he entirely neglects the keeping of live stock, for the presence of the cow and the brood-sow are about as essential to the farm home in dry areas as the presence of the breaking plow. It is true, nevertheless, that live stock on the dry farm should not be introduced with undue haste, for at the outset the furnishing of food for winter may prove a costly problem in seasons that are unusually dry.

That the production of grain for sale should be the principal object of the dry farmer during the first years of his farming is undoubtedly true, but in time more or less of live stock should be grown upon his farm. This should be done to the extent of using practically all the coarse grains that he will grow and also the hay and straw produced as well as the pasture areas that are accessible on the farm or on the unoccupied lands that may be adjacent thereto.

The lament that the tillage of the arable areas of the open range is going to destroy the live stock industry in dry areas is not well founded. Even on the arable farm devoted largely to the growing of grain, more live stock can be kept in addition than were formerly kept on a similar area. This results from the greatly increased production that follows the proper tillage of the soil in fodder and also in pasture. It would seem safe to say that the food nutrients in the straw grown on an acre of well tilled land in dry areas will be more than the food nutrients from an acre of the same before the land has been broken. The food nutrients produced by an acre

of well planned pasture from grasses grown under cultivation, should be from two to three times as much as from grasses produced from the native prairie. The production of live stock on the arable farms will therefore, in time, greatly increase the production of beef and mutton, to say nothing of the production of pork and poultry, which was impossible under old-time range conditions.

Why live stock should be kept.—Live stock should be kept on the arable farm for the following reasons among others that may be given: (1) to prevent waste on the farm; (2) to prevent waste on the range; (3) to increase diversity in production; (4) to maintain fertility in the land; (5) to furnish food for the home, and (6) to increase the revenues from the farm.

In the absence of live stock on the arable farm other than the work horses that till the land, serious waste is unavoidable; (1) there will be more or less waste in the uneaten grasses of untilled portions; (2) in the straw, much or all of which will probably be burned; (3) in the grain heads that are lost amid the stubbles because un gleaned; (4) in the uneaten food that grows up amid the stubbles, and (5) in the unconsumed grain that is unavoidably wasted where threshing is done in the open air. Such waste is unavoidable in areas where live stock is not maintained.

In newly settled areas, there are usually more or less range pastures contiguous to the individual farms. This may be entirely wasted in the absence of live stock to consume it. In some instances these pastures are so ample as to justify the homesteader in making the growing of live stock the dominant feature of his work, until the adjacent lands are taken up as homesteads.

The growing of live stock encourages diversity in production. It encourages the growth of forage and root crops. While they are being grown the land is being

prepared for the successful growth of grain crops the following year. The larger, therefore, that the area of such crops is, up to the limit of the ability of the farmer to properly care for them without undue outlay for hired help, the larger should be his profits from the ground thus tilled, as, to the extent that he grows these crops, he avoids the necessity for the cropless bare-fallow.

The introduction of live stock makes it possible to maintain virtually undiminished production in the land. The waning fertility in lands where such production has been long deferred, as in some parts of the Dakotas, California and other states, should serve as a warning. Some lands, and especially the volcanic ash soils of the west, may stand continued cropping for many years, but ultimately they must fail. Beyond all question, the fertilizing material produced by live stock will add greatly to production in all its various lines.

Live stock may be made to furnish a large part of the living of the farmer, and with but little cost. The cow, for instance, can turn the free grasses of the prairie into the best food that man may get. The brood-sow and her progeny will manufacture the same grasses with waste from the grain fields into meat for the winter. Fowls with a moderate grain supplement will turn grasshoppers and other insects into valuable food. Such live stock, therefore, should be introduced the first season where there is a family on the ranch, but, of course, in very limited numbers.

At the very outset, therefore, the revenues of the farm may be increased by reducing the outlay for food. The farmer with a family who fails to try to grow a large part of his living on his own farm is not true to himself. As time goes on the live stock will become a source of considerable revenue, although for several years it is not likely to become the chief source of revenue on the arable farm.

The kinds of live stock to grow.—Because of the varying conditions, the discussion of this question is not easy. These are such as relate to the character of the production, the location and its surroundings and the predilections of the individual. It will be manifest that in some areas the production of grasses will be relatively easy, in others relatively difficult. In one location pasture land may be cheap and relatively plentiful. In other instances it may not be possible to secure it outside of the home. One man may succeed best in handling dairy stock, and another will succeed best with sheep. — All these and other factors must be considered.

Among the determining factors are the following: (1) the climate; (2) the precipitation, and (3) the market. The climate has an important bearing on the shelter called for and also on the production. Fortunately, in much of the dry area of the west, shelter is not so much needed as in corresponding latitudes in the east, but some shelter is called for, and more for some classes of live stock than for others, and all shelter is more or less costly. The precipitation has an important bearing on the production. For instance, in the upper Flathead valley, 15 inches of rainfall produces more pasture and more succulent than a similar rainfall in the same latitude west of the mountains, hence dairying may be more readily conducted in the former than in the latter. The market demands alone may determine the character of the live stock that ought to be chiefly grown, and the facilities for marketing should also be carefully considered. The farmer with a good local market near at hand has a great advantage over the one whose market is not local and distant.

All farmers, whether married or single, must have horses. That question does not admit of discussion. Beyond that much will depend on the presence or absence of a family in the home. Where it is present, it

is, in a sense, imperative to have enough live stock to supply the needs of the family. This means that the farmers must, in a sense, have some cows, swine and poultry, and it will be all the more to their interest to have some sheep, especially after the farm is fenced. The farmer thus equipped, who at the same time grows his own vegetables and small fruits, has but little additional outlay for his living. To furnish this he does not need to maintain a large number of any of these classes of animals.

Under some conditions it may be wise to extend the growing of live stock so as to make it the dominant industry, even at an early day in the work of the homesteader, as, for instance, where free or very cheap pastures are easily accessible. Such extension may apply to horses, cattle or sheep, according to the conditions that may be present.

Stocking the dry farm.—As a rule, the live stock on a dry farm should be introduced very gradually. For this several reasons may be given. First, there has not been time to make suitable preparation to care for them in a large way. The outbuildings are not ready. Fences have not been built. It may be that winter water supplies have not been secured. There has not been time to make sure of winter supplies of food, as the bulk of the ground broken is usually wanted for grain. The introduction of much stock by purchase is costly. It is much better, as a rule, for the dry land farmer whose operations must be confined to his own farm, to begin with a small amount, and to grow much or all of the subsequent increase. When increase is made in this way, all the operations of the farm may be kept in due balance. Such increase is thus obtained at a minimum of cost. The experience while making it has been obtained under the attendant conditions, and is, therefore,

doubly valuable. The protection wanted may also be furnished at a minimum cost.

The amount of live stock that a dry land farm will sustain cannot be stated. It cannot be even approximated, owing to the very great difference in the conditions. It will be at once manifest that where the rainfall is 18 inches, much more live stock can be kept than where it is but 12, or even 15 inches. It will also be apparent that where bulky foods may be readily grown, as corn and the sorghums, more live stock relatively may be kept than in areas where these do not succeed well because of low temperatures. It would seem safe to say, that the amount of live stock that a dry farm will sustain will increase with increase in the precipitation. The relative number that such a farm will sustain is not high, not so high as in humid areas. Such farming where the farmer has no access to outside grazing lands is usually a mixed farming proposition in which the growing of grain for sale will probably be a dominant factor for many years to come. It would be unwise, therefore, for one situated thus to make the growing of live stock a dominant factor in his work at the outset, but this may be done by the farmer who has access to pastures that are cheap or free.

Great care should be exercised not to overstock the dry farm. Under the most favored conditions, such a mistake is very costly, as it forces the sale of the animals, whether in good condition or lean, and at such a time it is almost certain that they will be lean. When a very dry season comes, and it may come at any time, there may be a serious shortage in both pasture and fodder, hence some reserve kept over from a season more bountiful may be a wise provision. While the hazard mentioned may occur, it does not furnish a fitting excuse for the exclusion of live stock from any farm.

Growing horses.—On the dry farm horses will always be necessary in order to do a large part of the work. This statement does not mean that other kinds of power, as steam and gasoline, may not be extensively used, especially in breaking up the stubborn soils of the prairie. The horse will always be in evidence not only on the dry farm, but on all farms.

Usually from three to four horses are called for when breaking up the stubborn soils of the prairie. There would seem to be no good reasons why two at least should not be brood mares. These may produce foals while aiding in doing the work of the farm, providing they are carefully worked. As much work should not be exacted of them as if they were not suckling foals, but they will still do a large amount of work and also rear foals if well fed. It will, furthermore, be a decided advantage if such foals come in the autumn, for then the dams can suckle them at that season of the year when they are not worked, as they are in the summer. Experience has shown that brood mares worked in moderation will rear foals more surely and in better form than those that are not worked at all. The young horses, if of the draught types, may be made to aid in the light work of the farm when from 2 to 3 years of age, and when they have reached the latter age, they will sell readily for a good price.

Horses reared in the dry country call for but little shelter at any season of the year. When allowed liberty, they can secure food where other classes of live stock would not be able to do so, as when, for instance, the ground is covered with snow. The habit of pawing to remove the snow makes it possible for them to live and flourish where other classes of live stock would not survive under similar conditions. In the winter they will utilize such foods as straw to better advantage

than most other live stock. Relatively, therefore, they may be grown cheaply.

The return is also large, for the numbers kept. Where the farmer devotes his attention mainly to the growing of this class of stock, he does not need to have many of them on the place at one time, hence there is but little hazard of loss in a season of drought. Where range of rough pastures is accessible, in the larger portion of the dry country, horses will come through the winter in good form without the necessity of very much supplemental food.

The supplemental foods for the feeding of growing foals include alfalfa, fodder corn fed in the bundle, and straw, in northern areas. For idle work horses, straw will suffice for much of the winter. In southern areas, alfalfa, Milo maize, Kaffir corn and sorghum will best answer the purpose. Milo maize is also much esteemed for feeding work horses in these areas. It is usually fed to them as grain food in the head, which not only obviates the necessity for threshing the grain, but it also insures a more complete digestion of the naturally hard grain, since it is more thoroughly masticated.

Growing dairy cattle.—That the dry farm is not nearly so well adapted for dairying as the irrigated farm cannot be gainsaid. The creamery, therefore, will not probably be much in evidence where dry farming is followed for many years subsequent to the settlement of the land. But this does not mean that home dairying may not be practised in a moderate way, even at the outset of the farming. It may even be wise in some instances for a farmer to give considerable attention to dairying at the outset, where free pasture is plentiful, but when the stock must be confined to the limits of the arable farm, the number of cows kept should not usually be large.

Where the cows are to be kept within the limits of the farm, the grazing problem is more difficult than the furnishing of winter foods. The pastures that may be grown are discussed elsewhere (see p. 355). These, however, may be supplemented by such soiling foods as alfalfa, corn and field roots in the north, and by alfalfa, the sorghums, Milo maize and stock melons in the south.

The winter food in the north may be made up almost entirely of alfalfa hay and corn fodder fed in the bundle, and supplemented by a very small amount of rye, barley or speltz fed in the ground form. The ration may also consist of alfalfa and grain cut underripe and fed unthreshed. A mixture of Canada field peas and beardless barley grown together is excellent. This also is true of millet grown in rows and cultivated. In southern areas the winter food may consist mainly of alfalfa hay, sorghum and Milo maize fodder, and a supplement of Milo or sorghum meal, or of ground speltz. The Milo maize may be fed as seed and heads ground together.

The cows should drop their calves in the fall rather than the spring, as the calves can be fed with more care and success in the winter season. The cows will then be dry in those months of the late summer when the pastures are dry. When thus managed, the milk flow will be better sustained, and the lactation period more or less prolonged.

As such cows will, of course, be hand-milked, the skim milk and the buttermilk should be fed to calves and swine. The butter or the cheese product, as the case may be, will usually find its way to private customers, as it will be too restricted in quantity for a wholesale market.

Growing beef cattle.—In dry areas the field for growing beef is probably wider than that for growing

dairy products, owing to the fact that it may be grown largely, in many instances, on rugged and broken pastures in proximity to the arable farm or forming a part of it. During the milk period, beef will be produced by methods that are radically different. On the strictly arable farm, the calves will be hand-fed, while on the arable and rugged farm, they will be suckled by their dams.

When reared by hand, the calves should be progeny of dual cows, and the aim should be to have them come in the fall. If the progeny of dairy cows, they should be sired by a beef bull. They should be reared essentially on skim milk and adjuncts after the age of two weeks. They should have good grazing, as rye or rape, sown especially for them, and they should, as a rule, be put on the market at the age of not more than 18 months. While taking milk, and subsequently, such meals as bran, ground oats, barley or Milo maize should be fed to them freely, also a nice quality of alfalfa hay. During the second winter they should be fed on such fodders as alfalfa, corn and sorghum, and should get a few pounds daily of such meal as barley, speltz or Milo maize. The aim should be to force growth with a prudent haste and thus shorten the period of pasturing and effect a substantial saving in the food of maintenance.

When reared on the dams during the milk period, it may not always be the best plan to have the calves come in the fall, as when they come in the spring the cows may oftentimes graze much of the winter on the rugged pastures. Provision should be made for saving such pasture by keeping the stock from grazing on that portion in summer. The first winter the calves should be given a moderate amount of grain along with the fodders named above. The second summer they will be on the pastures without grain. The second winter they may be fed similarly to the hand-reared calves when

preparing them for market, and they ought to be sold when two years old. Some western farmers head their wheat and feed it thus to cattle that are being fattened. The wisdom of doing so is to be questioned. They should then weigh about 1,200 to 1,300 pounds, while those hand-fed would weigh about 1,000 pounds.

Such animals should find a ready market wherever high-class meat is wanted. Grown thus it will be high-class meat, and should command the highest price. When growing such meat, it should never be allowed to become lean.

Sheep on the dry farm.—When sheep are reared on the dry farm the number so reared should not be very large. The production on the same when mixed in character would not justify the maintenance of numbers so large relatively as in humid areas. In the latter, sown pastures may be grown in succession through all the season, but only to a limited extent in the former. The numbers, however, should be enough to consume all the forage that would otherwise go to waste, as, for instance, grazing in the lanes and amid the stubbles in the fields and on summer-fallow land. On every farm the pasture from such a source is ample to sustain a small flock of sheep, which may be thus grazed virtually in most localities for three-fourths of the year without cost. The benefit thus rendered will be marked in the destruction of weeds, and in distributing more or less fertilizer over the land.

When rough pasture areas are contiguous to or form a part of the dry arable farm, sheep can be grazed on them about in the same way as cattle are grazed as described above. The breeding portion of the flock may be wintered on food grown on the arable portion of the farm. The part of the flock to be disposed of may be finished on pastures grown for the purpose. These may comprise Dwarf Essex rape grown in rows and culti-

vated as a rule, some dwarfish kind of corn or peas and white hulless barley. These will be grazed where they grew, and, if necessary, they may be supplemented by more grain grown on the farm, as, for instance, barley in the north and Milo maize threshed or in the head in the south.



SHEEP ON RANGE PASTURES, MALHEUR COUNTY, OREGON.

Courtesy Great Northern Railway Co.

When simply fattened on the farm the supplies for fattening will be purchased and they will be finished on foods such as have been referred to in the preceding paragraph. In the San Luis valley of Colorado the fattening of sheep mainly on peas has grown into a large industry. There are no reasons for concluding that this industry may not be extended to many other areas.

The opportunity to fatten sheep on Squaw corn or some other small variety grown for the purpose in the

dry area, is thus virtually without limit. The growing of the corn stores moisture in the soil for the next crop, and feeding it off thus furnishes readily available fertility. Such grazing is not well adapted to areas in which considerable rain or snow falls in the autumn months.

The market for the surplus of the small flock should be found chiefly on the farm itself. It should furnish an important source from which the home supply of meat may be obtained, especially in the winter season. When finished in a wholesale way, as on crops that are grazed, they will be in condition to meet the needs of any market that may be accessible to them.

Swine on the dry farm.—The place for swine on the dry farm will always be one of considerable importance. From this source, more than any other, must come the supply of farm meats. To purchase meat for the home on the dry farm that may be all grown upon it would be a grave mistake, owing to the fact that pork may be slaughtered at almost any age should necessity call for it. Complications which sometimes arise with other animals from over-stocking may be prevented. Where a few cows are kept, the milk will aid greatly in giving the swine a good start in growth at an early age.

But even in the absence of cows, swine may be grown with much profit. The young pigs should remain on the dams until they become self-weaned, and the farmer should be content, as a rule, with but one litter from each dam in one year. With the aid of skim milk, two litters may be grown save where the winters are quite cold. The dry land farmer is not in a position to grow swine as cheaply or as numerously as the farmer who grows the same in irrigated areas. In summer alfalfa is the basic pasture for swine in the larger portion of the dry country. But other pasture, as Dwarf Essex rape, beardless and hulless barley, is good. In the south

the sorghums may be made to add to the grazing; northward swine may be finished in the fields, as on peas or some small kind of corn. In the south peanuts and also corn furnish good fattening foods. If Milo maize is fed it should not be fed alone, as the swine do not thrive when fed thus.

On the dry farm the needs of the family must first be supplied. If there is a surplus beyond this, it will



SWINE GROWN ON DRY LAND FARM, NEAR HOBSON, MONTANA
Courtesy Great Northern Railway Co.

usually find a market without the need for shipping it. This is one of the few food commodities that will never glut the market, but it may be necessary sometimes, as when large numbers are grown and fattened on products in the field, to ship the animals away by rail.

Poultry on the dry farm.—Poultry should be kept on every farm where there is a family. The climatic conditions for growing it are, in nearly all localities,

very excellent, because of the dryness of the air and its temperate character. The relatively small amount of grain food called for makes the growing of fowls a safe and profitable business, where it is wisely conducted. Even where grain could only be grown once in two years on the same land, the business should be a safe and profitable one.

All the grain foods grown in dry areas may be fed with profit to poultry if suitably blended. Of these none is better or even quite so good as wheat. Hulless barley is excellent. On southern areas the seed from Milo maize and the sorghums will serve an excellent end. These are frequently fed by suspending the heads on a stretched wire and allowing the fowls to help themselves, thus furnishing them with needed exercise, especially when they have to reach high for the food. The varieties with a bent down head are most easily suspended thus. The green food may come in the form of alfalfa, rape and field roots.

The demand for these products will always continue good, as they are staples that will always be wanted, but the product can be readily transported and at moderate cost for the value. In the home the product is indispensable, and the food which it furnishes is wholesome in character. There is probably no other class of live stock that can be grown on the dry farm that will yield a larger profit on the investment or that is more easily conducted.

The size for the dry farm.—The size for the dry farm should be determined by such considerations as: (1) the amount of the precipitation; (2) the character of the soil; (3) the capacity of the individual, and (4) the style of the farming.

It is, of course, impossible to determine the relative influence which these considerations should exert, but the first consideration is certainly one of much im-

portance. It would seem safe to say that the area to be farmed should increase as the precipitation decreases; for the less the amount of precipitation, the fewer is the number of the crops that can be grown in a given term of years. It is very evident that the farmer who can grow but one crop in two years should have more land to till than the farmer who may expect to get a crop practically every year. It was this consideration that led to the granting of homesteads in certain areas of 320 acres instead of 160 acres, the usual size for such farms.

The tillage of a soil that is naturally friable and that holds moisture readily does not call for so much labor as the tillage of a heavy soil, hence the farmer whose soil is of the first class can till a much larger area than the farmer whose soil is of the second class, and with no greater expenditure of labor. When tilling the heavy soil, the compensation may come from larger yields, at least in some instances. On general principles, therefore, the lighter the soil, the larger should be the area that is capable of being farmed.

When determining the size of the farm, much depends on the capacity of the farmer. It is certainly safe to assume that the less the capacity of the farmer, the smaller should be the amount of the land which he tills. One farmer with large capacity may handle fairly well a whole section, or even more than a section, whereas another farmer may not have capacity to handle well a quarter section. Something depends on the farmer's family. A farmer whose family is sufficiently grown to enable him to do his work without hiring should succeed better on a farm large enough to utilize all the labor than on one of less size. As wages are at the present time, the dry land farmer should sedulously aim to avoid hiring to the greatest extent possible, and to accomplish this end when investing he should gauge accordingly the size of the farm that he can till.

There is another class of farmers whose work is in a sense speculative. They live in the cities. They usually own large areas and farm them in a speculative way. These men are wholly dependent on hired labor, hence in order to get a remunerative return they must of necessity farm large areas and in a wholesale way. Such farming may be successful as long as the land is new and clean, but in all states the story of such farming is the same. Within a few years the land usually becomes very foul with weeds and the crops become so unproductive that tillage operations result in loss, but substantial profits may be realized, nevertheless, from the advance in the price of the land. A locality cannot be built up by farming on those lines as it can by the effort of farmers on moderately sized farms, for reasons that will be apparent.

The nature of the farming probably more than anything else should determine the size of the farms. Where the farmer grows only grain and does the work mainly himself, 160 acres is amply large for such a farm. Where he keeps live stock and must needs confine the grazing of them within the limits of his farm, he should have not less than 320 acres of grazing land in dry areas. Land in such areas does not produce so much pasture as in areas that are moist. When the farmer can control rough range pastures contiguous to his land or that form a part of it, he may need a section or two of rough land for each quarter section of arable land in his possession. On the latter he will grow the food that he needs for winter feeding. In yet other instances the farm may be all classed as rough land, and yet within it there may be enough arable valley land to enable the farmer to grow on these the winter food needed. These farms also should not contain less probably than one or two sections. Under irrigation the small farm unit is better than the large one for the average farmer.

While 320 acres may be called for where dry land farming is to produce the best maximum results in dry land, farming 80 acres would seem ample where irrigation is practised. Where the farmer who can use irrigating waters has more than 80 acres to care for, in a majority of instances, the evidences of a neglected tillage are more or less present. This holds true of lands that are farmed more or less even on the lines of live stock production.

CHAPTER XIX

THE WATER SUPPLY IN DRY AREAS

When the home seeker is desirous of locating in the semi-arid country he should not do so until he has obtained some information with reference to the nature and extent of the possible and probable water supply for household use, and also for such live stock as it may be necessary to keep on the farm. Unless water from some source is obtained in reasonable supply, it is not possible to build a permanent home.

The scarcity of water.—The fact should be recognized that the water necessary for the various uses of life and for live stock is less plentiful than in humid areas, at least in very many instances. In the very nature of things it cannot be otherwise, because of the relatively light character of the precipitation. But the mistake should not be made that there is an exact relation between the degree of the precipitation and the degree of the water supply. Especially is this true of subterranean waters. These are found plentifully in some localities, and not far distant from the surface, even where the normal precipitation is very light.

In the search for water, as by boring or drilling, the results obtained are exceedingly variable in the same general locality. In one instance good water and in fairly liberal supply can be obtained within, say, 20 to 40 or 50 feet of the surface. In other instances water may not be obtainable in proximity to the former at a depth of 500 to 600 feet and even at a greater depth. Homesteaders, therefore, should be slow to conclude that because attempts made to obtain water have failed it cannot be obtained.

There are two principal sources of ground water. These are from precipitation which falls in the form of

rain, sleet and snow and from sheet or free water found at various depths. The natural sources of the former are springs and streams. The artificial sources are cisterns, ponds, irrigating ditches and wells. The latter is obtainable from wells of varying depth. It is believed that this free water exists everywhere beneath the earth's surface, but in some instances it is so deep that it is not practicable to reach it, for economic uses. In instances not a few, it is found at depths not far below the surface, and this is true of it in some instances in areas that are unusually dry.

Ground or free water is very abundant. It has been claimed that this free water in the earth's surface should cover it to the depth of 90 feet. If only a limited proportion of this could be obtained everywhere without too great expense, it would make possible the tillage of all the arable land in arid and semi-arid regions, providing the water was always of such a character as to properly sustain plant life.

In some instances subterranean waters are so impregnated with foreign influences, especially soda and salt, as to be unfit for use by humans, and yet they may be taken with apparent relish and without injury by live stock. In yet other instances the impregnation is so strong that it will not properly sustain animal or vegetable life. But usually such ground water is of the purest and the best. The character of the water is influenced, of course, by the substances through which and over which it passes.

The little that is known as to the whereabouts of subterranean waters, linked with the fact that they do exist not infrequently in very unlikely places, emphasizes the benefit that would accrue from determining their whereabouts. The expense that would thus be involved would be so great that it could not be borne by individuals. It is a work that may be best done by the

state or by the central government. In this way the general course of these underground basins may be so certainly traced that it would be known where water could be obtained over them.

Why water is scarce.—Water is scarce in the arid and semi-arid regions because: (1) of the low precipitation; (2) of the character of the precipitation; (3) of the hardness of the unbroken soil; (4) of the extent to which moisture from snow escapes, and (5) of the relatively rapid evaporation.

The low precipitation is one of the most potent of the reasons for the scarcity of water in dry areas. It stands to reason that where the precipitation is light the available water supply will be meagre. It is reasonable to suppose that where the rainfall is 40 inches per annum water in the soil and subsoil will be much more plentiful than where the rainfall is 20 inches, and where the rainfall is 20 inches it is much more plentiful than where it is 10 inches. Where the rainfall is 20 inches the moisture should be such as to make it easily possible to grow crops with much certainty and to establish very desirable homes. When the rainfall is 15 inches, crops may still be grown with much certainty and homes may also be built, but not so easily as under the conditions previously stated. Where the rainfall is but 10 inches, fair crops may usually be grown, but home building in the true sense of the term is difficult in the absence of irrigating waters. But the conclusion should not be reached, that the amount of the water that falls is the chief factor in determining the amount of the water present. True, it is an important factor, but it is only one of a number.

The character of the precipitation exerts a greatly important influence on the water supply. Should it come in the winter much of it may be lost to the soil because: (1) of the extent to which the soil may be

frozen; (2) of the too rapid melting of the snow, and (3) because of evaporation under some conditions. Should it come in the late spring and early summer months, the loss from evaporation under good management will be very considerable. Should it come in downpours much of it may run away over the surface and into the gullies. Should much of it come in the form of light showers, it is much liable to escape from the surface soil through evaporation. Showers long and moderate are much to be preferred.

The soil while yet unbroken is hard. For long centuries the soil has been trodden upon by the feet of animals. In many places the rains have frequently fallen upon it in dashes, which has tended to impact rather than to open up the surface. There has been an almost entire absence of the rains which sometimes fall gently for successive days in humid climates, the water entering the earth rather than running over its surface. The outcome has been that a large proportion of the precipitation that fell never entered the soil at all, and, as a rule, the amount that fell was relatively small. Of course, once in the streams it was forever lost to the soil.

In much of the semi-arid country warm winds come occasionally, even in the winter. These winds are thought to be influenced by the waters of the Pacific. They are so warm that in some instances they are capable of melting a foot of snow or more in 24 hours. When deep snow is melted thus quickly, the principal portion thereof runs away over the impacted unbroken soil, even though the soil should not be frozen. When it is frozen, the condition is still further aggravated. In this way but a fractional amount of the winter's precipitation may enter the soil.

In the semi-arid country evaporation is more rapid than it is ordinarily in humid areas. This is owing: (1)

to the less degree of the humidity in the air; (2) to the character of the winds at certain seasons of the year, and (3) to the greater tendency in many soils to form cracks than is usual in soils in humid areas. It is reasonable to suppose that dry air moving over a soil will evaporate water on the earth and for some distance beneath it more quickly than air that is already surcharged with moisture. It is also reasonable to conclude that the more rapidly the currents move along, the larger will be the amount of moisture removed. Winds are strong relatively in the spring months in the semi-arid country, the time when in many areas moisture is present in most abundance. This means that unless the escape of this moisture is prevented in some way much of it will be lost to the soil. The contraction of the soil when drying forms cracks. The more numerous and larger and deeper the cracks the greater the amount of the moisture that will be lost.

For the reasons given above, the shortage of water in dry areas is intensified. It explains why ponds or basins are so few that hold water all the year. It makes it clear why living streams are so few save in proximity to the mountains. It gives the reason also why lakes are so generally absent and why springs are so rare. Under these conditions it could not be otherwise than that water from wells would be more difficult to obtain in abundant supply than in humid areas.

The sources of water in detail.—The following are the principal channels or sources from which water is obtained in dry areas: (1) that caught from roofs and in draws; (2) that obtained from springs and streams; (3) that which comes from irrigating ditches; (4) that which is obtained from wells, and (5) that which comes from artesian sources.

The water obtained from roofs must always be limited in supply for the reason, first, that the precipita-

tion is light, and, second, that the roof surface is relatively small. A building, say, 40 by 60 feet should catch approximately 14,080 gallons of water in one year from a rainfall of 15 inches, providing none of it is allowed to waste. This may, in some instances at least, furnish water to meet the needs of the household and of a small garden as well.

The water caught in draws and ravines may be of considerable volume. Its source is water that comes from winter rains, from the melting of winter snows, and from rains in summer when the water falls so rapidly as to run away, in part at least, over the surface. To hold this water may not always be easy, because of the length and height of the dam required, and in some instances because of seepage through the soil. Water from roofs is caught and held in cement lined cisterns. Cement may also be used in arresting flood waters, but when thus used the cost entailed may be very considerable.

In all parts of the dry areas, water obtained from springs may be utilized to great advantage. The regretful fact is that springs, although so precious, are so scarce in dry areas. Notwithstanding, they may be used with much profit even though distant from the home.

Instances are on record wherein a tiny, insignificant spring has been made to supply the home, although located several miles away, the water being carried through pipes.

Water from streams is equally valuable when it is easily accessible, but in very many instances what may be termed living streams are very few and far between in dry areas. Unless sufficiently near to be fed by melting snows on the mountains, these streams are much liable to become dry and remain so soon after the season of greatest precipitation until the arrival of the season of precipitation that follows. In a few instances, the

lower depressions in the bed may carry water for stock through the year.

Irrigating ditches may be utilized in furnishing to dry land homes the necessary water when they are sufficiently near, which, however, is not the case in a great majority of instances. Dependence on such water alone is hazardous, unless the ditch is supplied with water all the year, which seldom happens. This objection may be so far met by leading a reserve of water into a reservoir, or by pumping into the same at the proper season. When water from such reservoirs can be spared to soak the land, even after the crops are reaped, it may aid the crops materially that are grown there the following year.

Water from wells comes from a very satisfactory source, providing (1) that it is sufficient in supply; (2) that it is not too costly to raise, and (3) that it has the right qualities when obtained. It is satisfactory because in the range country it is free from contamination such as may come from external sources. In some instances, however, the supply is inadequate, in others it has come from great depths, and in yet others it is so affected with undesirable substances as to be unfit for use. But in a great majority of instances subterranean waters are good.

Water from artesian sources is usually of good quality, but the first cost of obtaining it is frequently more than the farmer is able to bear. Should a flowing well be obtained on a ranch in the semi-arid country, its worth to its possessor cannot easily be overestimated. It is a continual source of blessing. Should it entail the cost of pumping it would still be a blessing. But the farmer should be slow to begin drilling for artesian water without first having a good assurance from some reliable source that his search will not be in vain.

How water that falls may be saved.—The water that falls in dry areas may be saved: (1) by constructing cement lined cisterns; (2) by erecting dams of proper construction; (3) by piping from more or less distant springs. The reference here, of course, is to the saving of water that is needed for drinking, for economic uses in the household and for live stock. The saving of the water of precipitation for the use of the crops is an entirely different proposition. To discuss that question properly is to discuss the whole question of the management of the soil when farming dry areas.

Water collected from the roofs of buildings can only be preserved in cisterns or in wells. In these the water collected cannot usually be held in the absence of a cement lining. When water may be stored thus, the loss through evaporation is almost entirely prevented. It may also be protected from contaminating influences. The cost of such storage need not be very large.

The dams that are to aid in the storage of waters will be costly in proportion to their size, to the availability of the materials for their construction and to the nature of the materials used. In size they run all the way from a few feet in height and thrown across a narrow neck of a ravine, to the dimensions of a dam that may tax the power of a large corporation to build it. It is only the small dam and the small reservoir that the average farmer should try to build. Even when this is undertaken, the plan is good which seeks advice from those skilled in such work. The materials suitable for construction may be at hand. In other instances they have to be brought some distance. Usually, however, the materials at hand will suffice, providing the aid of cement is called in when necessary. Of course, such dams will be costly of construction in proportion to the extent to which cement is called for. In some instances, however,

impervious clay furnishes a cheaper material. By a process sometimes spoken of as "puddling" it is made to prevent the seepage of water very effectively that would otherwise take place through materials such as are often used in the construction of dams.

When making such reservoirs the fact should not be lost sight of that under many conditions fully 50 per cent. will be lost by evaporation. The proportional loss from this source will not be commensurate with the capacity of the reservoir. The more shallow the reservoir in proportion to its capacity, the greater will be the loss from evaporation, because of the relatively larger amount of the water surface that is thus exposed.

Water may be conveyed from distant springs in many instances at a cost for the piping that is within the means of the farmer. But when so conveyed it ought to be gathered into a reservoir. This will prove a safeguard against any interruption in the conveyance of the same, as may temporarily occur.

How water may be raised.—In dry areas water may be raised: (1) by wind power; (2) by gasoline power; (3) by steam power, and (4) by electrical power. Which of these should be employed will depend largely on the cost entailed and on the amount of the water to be raised.

Where it is necessary to raise only small quantities of water wind power will suffice. Such power will answer as a rule to supply the needs of the household, whether the source of the supply is a well, a reservoir or an irrigating ditch. It will also suffice to raise enough water for live stock in many instances where this may be necessary. It may also be made to raise water for a few acres of garden and orchard land when this may be desired. The capacity of the mill called for will be largely dependent, first, on the amount of water to be raised, and, second, on the average velocity of air cur-

rents in the locality. The relative amount of the work done by a windmill in the plains country will be large, because of the absence of obstructions to the wind currents in their course.

That the irrigation of small areas from water pumped up by windmills is perfectly feasible has been shown in the experience of farmers in nearly all the states where semi-arid conditions prevail. The cost of the operation will vary greatly with the conditions, but for the kind of irrigation referred to, the cost should seldom exceed a few dollars per acre per year for the raising of the water. Such water must, of course, be stored in a reservoir when it is raised. In the not distant future, windmills that raise water to irrigate from a very few acres downward in proximity to the home, will be very common. It has been estimated that one good windmill with a wind velocity of, say, 10 miles an hour, will raise enough water to meet the needs of the ordinary dry farm and garden, where the water is not to be lifted many feet.

When water is to be raised from depths far down, it may be necessary to use other than wind power. For the comparatively limited uses referred to above, it will probably be found that gasoline power will raise water from considerable depths as cheaply, or even more so, than power from any other source. But it is at least questionable if it would be wise to go to the expense of raising water thus to be used on the ordinary dry land farm in the irrigation of the ordinary farm crops. It may pay well, however, to raise water thus to aid in growing fruit and truck crops where the markets for the same are good and not too distant.

Steam power is frequently used for raising water to be used in growing various kinds of farm crops, but the expense of such an operation on the dry farm would be prohibitive. Where this method of raising water is

used it is usually as a part of some irrigation project. Where the supply of subterranean water is plentiful and the lift is not too great, water may be thus raised for growing certain crops. Large areas are now being devoted to rice grown thus in Texas and Louisiana. In the United States there are not fewer than 1,000,000 acres of crops of various kinds grown from water that is pumped. In some countries, as, for instance, in India, several million acres are thus supplied with water every year. Sometime large areas of the semi-arid, and more especially the arid, country may be supplied with water thus, but, if so, that time is in the far-off future.

Electrical power will seldom be used on the dry farm for raising water, but in extensive systems of irrigation a very important place may be assigned to it. Especially will such power be used in irrigated regions and not too distant from the sources where such power may be generated. This source of power may come to be much used for lifting water from irrigating ditches to higher channels.

Reserve water and home building.—Where homes are to be built in the semi-arid regions, a supply of what may be termed reserve water is indispensable. By reserve water is meant water stored artificially or in wells where it is sufficiently accessible. In all instances such water is essential to the needs of the home itself. It is also more or less essential: (1) in the garden; (2) in the orchard; (3) in the shelter belt, and (4) in the keeping of live stock, especially such live stock as may be essential in providing for the needs of the family. When water cannot be secured for all these uses in the semi-arid region, home building is confessedly very difficult, if not impossible, howsoever feasible the cultivation of the soil and the growing of certain crops may be.

Under conditions that are very dry, it may not be possible to catch and retain enough water from roofs to supply even the needs of the household. Especially is it so in the case of the new settler, as the shack which he builds is small. In choosing the site for the same, unless the presence of ground water is assured, the possibility of collecting flood waters should be kept in mind.



DRY LAND MONTANA FARM GARDEN.

Courtesy Great Northern Railway Co.

Of course, where the presence of ground water is assured, the problem is easy.

For the needs of a garden, water must come from a tank or reservoir of considerable capacity, or from wells. The amount of the supplemental water for the garden of the farmer, when well managed, is not very large. Where the precipitation is not less than 15 inches per year, it may be dispensed with altogether. With a

less amount of precipitation some supplemental water may be necessary in order to insure growth in the late crops that it may be desirable to grow in the garden. It may also be necessary to perfect growth in small fruits in a very dry time. Where a windmill is used to raise water for house and stock uses, it may also be made to raise it for some place of storage when it would otherwise be idle. Under very dry conditions, therefore, it may be quite feasible to establish and maintain a farmer's garden.

In the semi-arid country, the farmer should not attempt to grow a large orchard, unless the conditions for the same are peculiarly favorable. Fruit for the home should in nearly all instances be the limit of his aims. A small number of thrifty trees of each species will suffice. With 15 inches of rainfall in the year, or even a little less, additional water may not be wanted for the well-managed orchard. Should it be called for, one application will usually suffice, but not under all conditions. The most economical way of supplying water, from the standpoint of the water called for, is by laying perforated pipes below the surface of the ground and not distant from the tree rows. This method of applying water is most economical and effective after the expense has been borne of supplying the pipes, an outlay that should not be heavy. But to accomplish this, a limited amount of reserve water is, of course, necessary from some source.

The home on the prairie cannot be complete without the protection of a windbreak, and, if possible, of a grove also. It is quite possible to provide such protection without using any stored or reserve water where the rainfall is 15 inches on average western soil, but to get the trees started, and even to maintain growth, where the rainfall is much less, it may be necessary to use some stored water. In any event, supplemental water

judiciously used will greatly tend to hasten growth in the shelter belt.

Some live stock, as, for instance, a cow or two, is almost as indispensable to the dry farm as horses, and water for these is, of course, as essential as for the inmates of the home. Live stock, and especially dairy cows, cannot be kept at a profit when they have to be driven long distances for water at any season of the year. A reserve supply from some source is imperative. It will be very evident from what has been said that it is absolutely indispensable that the dry land farmer shall secure a supply of reserve water for some, if not all, of the uses named. The sooner that he can accomplish this, the better will it be for the entire home and all that pertains to it. The contrast between a home thus equipped and one that is not is very great.

Applying reserve water to the soil.—Reserve water, if used on the dry farm, must, as a rule, be applied with much carefulness and judgment to the growing of any kind of crop, because of the limited supply of the same. The irrigator whose ditches carry more water than he can use can afford to be prodigal in the use of water. He may use it on all kinds of crops. It is very different with the dry land farmer. The instances are few in which he should attempt to apply such water on ordinary field crops. The application will rather be confined to the orchard and the garden, more especially if the water is raised by pumping, which is usually much more expensive than gravity water.

When reserve water is used on the dry farm, it should be so used, as a rule, to save crops, the growth of which has become well advanced toward completion, and yet without the aid of applied water the crop would not reach full fruition. It is surprising how small an application of such water may suffice to save a crop. Those who grow crops by irrigation are slow to learn

the lesson that the proportional increase in the production is by no means proportional to increase in the amount of the water applied.

Experiments conducted in Utah gave results as follows: The first 5 inches of water applied gave 40 bushels of winter wheat per acre. The application of ten times the amount increased the yield only by one-half, that is, it gave but 60 bushels per acre. The application of 50 inches would also be more or less harmful to the land, because of the excess of the application. Similar results were also obtained from the growing of other crops.

Remarkable results are frequently obtained from the use of very small quantities of water. Widtsoe cites an instance wherein a 12-foot geared windmill lifted water from a certain well in Arizona into a tank having a capacity of 5,000 gallons. The water was conveyed from this tank through iron pipes which were placed underneath the ground and within a foot or two of the trees. The pipes beneath the soil were perforated, which, of course, provided subterranean irrigation. The water sustained 87 useful trees, nearly all of them valuable fruit-bearing sorts, and 32 grape vines, with certain small bushes in addition. Many other instances may be given of remarkable results following the application of small quantities of water.

The dry land farmer should not be hasty in the conclusion that because he is a dry land farmer he does not need to seek any aid from stored water. Water is the most precious heritage of the farmer in the semi-arid country. Let him use it, therefore, to the greatest extent practicable in furnishing him with the proper surroundings of a home. To defer doing so until many years have come and gone would certainly be a mistake.

Dry farming and very light rainfall.—It is simply surprising what may be accomplished in some instances

in growing crops under a very light precipitation. Illustrations will be given from results obtained in Saskatchewan, Canada, in Utah, and in Montana.

From 1891 to 1909 the rainfall at Indian Head, Sask., Can., averaged 12.88 inches. The winter precipitation is not included, but if this were added it would bring the annual precipitation up to approximately 15 inches. The average yield of the spring wheat obtained from summer-fallowed land was 32.4 bushels. In 1904 the rainfall was 3.9 inches. The snowfall reduced to water would probably add about one inch in the precipitation. It would then be approximately 5 inches for the year. The wheat crop that year was 17 bushels from summer-fallowed land. The average given above was, of course, much higher than the average obtained by the farmers in the neighborhood. The yields cited were grown at the Government Experiment farm, which is under the management of Mr. Angus Mackay, one of the most intelligent and careful experimenters in all the west. But they show what can be done where the average rainfall is very limited.

Widtsoe states that winter wheat crops grown on summer-fallow by the Hon. J. G. M. Barnes, of Kaysville, Utah, averaged 25.5 bushels per acre. The farm, embracing 90 acres, is located 15 miles north of Salt Lake City. The period covered is 19 years and begins with 1887. The average annual precipitation was 14.82 inches, the larger portion coming in the winter and quite early spring.

The drought in Utah was most intense and prolonged in 1910. In many parts of the state, more especially to the southward, no rain fell from the close of winter until the harvest had been reaped. The harvest reports indicated that from 80 to 90 per cent. of a crop had been reaped.

Twenty-five acres of grain were grown at Chester, Mont., in the summer of 1910. The grains comprised durum wheat, speltz, oats, spring rye, white hulless and other barley and Canadian field peas.

They were grown on the Experiment farm maintained by the Great Northern railroad. The land had been summer-fallowed the previous year. The light winter snowfall at Chester was carried away in February, and much of it went into the streams. The month of March was abnormally warm and it was rainless; no rain fell in April nor until about May 10. As the land was not directly under the control of the Great Northern road earlier, no harrowing was done until about April first. By that time the moisture had so far left the soil that the grain did not germinate until rain fell in May, as stated. The total precipitation at Chester from September 1, 1909, to September 1, 1910, was less than 7 inches. The rainfall during the entire growing period was about $3\frac{1}{2}$ inches. The intensity of the drought may be understood from the statement that, save in some of the lower depressions, the grass never became green from the opening of spring until the snow fell, about the middle of the following November. The yields of the various grains ran from 10 to 18 bushels per acre. On the Great Northern demonstration farm at Cut Bank, Mont., the conditions being very similar as to weather, 20 bushels of durum wheat were reaped per acre, and 30 bushels of Swedish Select oats.

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