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WILLIAM A. TAYLOR, Chief of Bureau.



# MISCELLANEOUS PAPERS.



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## BUREAU OF PLANT INDUSTRY.

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# TESTING CULTURES OF NODULE-FORMING BACTERIA.[1]

By Karl F. Kellerman, *Physiologist in Charge of Soil-Bacteriology and Plant-Nutrition Investigations.*

## INTRODUCTION.

The importance of leguminous crops in maintaining soil fertility or in rejuvenating overcropped and worn-out fields has long been recognized by practical farmers. Critical investigations carried on both in the laboratory and in the field have shown that this method of improving soil conditions is dependent chiefly upon the simultaneous development of a leguminous crop and the variety of bacteria which can produce root nodules and fix atmospheric nitrogen in suitable form for plant food.

Although these nodule-forming bacteria are widely distributed in nature, there are regions where they are lacking, and they should be artificially introduced into the soil in these regions. This may be accomplished either by transferring from 200 to 500 pounds of soil per acre from a field where the leguminous crop shows abundant root nodules to the new field where the same legume is to be planted, or by the application of artificially prepared cultures of bacteria to the seed before planting or directly to the field itself. Though inoculation by the pure-culture method has proved less universally successful than the soil-transfer method, the artificial cultures possess certain important advantages, especially the greater ease of their transportation and application, as well as their freedom from danger of introducing weeds or plant diseases.[2]

## VARIATION IN INOCULATING POWER.

A plausible explanation for the occasional failure of cultures of *Bacillus radicicola* to properly inoculate a crop is that the bacteria, though able to grow vigorously in the culture medium, have actually deteriorated in the essential quality of being able to infect the leguminous roots and to produce nodules. Testing the cultures at frequent intervals on potted plants in greenhouses or on small plats

[1] Issued Apr. 5, 1913.

Messrs. F. L. Goll and L. T. Leonard, scientific assistants, have assisted in working out the details of construction of the testing apparatus and its utilization in the laboratory.

[2] These facts are discussed in more detail in previous publications of the Bureau of Plant Industry.

of leguminous crops in the field has been relied on to show which strains of bacteria had but a moderate or low inoculating power and which were most efficient. While these tests were useful, they were seldom entirely satisfactory, due to the frequency of chance inoculation of plants in either plats or pots by worms, insects, dust, and unsterilized water.

It is obvious that tests of cultures should be carried on under sterile conditions, which should at the same time resemble as nearly as possible the soil and climatic conditions of nature. Although nodules have been produced frequently by growing sterilized inoculated seedlings upon sterilized agar media in flasks,[1] this method of testing cultures is undesirable on account of abnormal conditions. The use of jars containing small quantities of sterilized soil has also been attempted,[2] but without success. During the last year numerous experiments have been conducted with a special type of jar supplied with a tubular neck near the bottom, and it is believed that with this simple apparatus accurate tests of the inoculating power of the bacteria may be made at frequent intervals.

## TESTING THE INOCULATING POWER.

A jar of the type shown in figure 1 is charged first with a layer of cinders or broken marble and then with coarse sand moistened with Sachs's solution lacking in nitrogen compounds; the side tubulature is plugged with cotton wool; a narrow layer of cotton wool is drawn around the jar near the top; and over this a snugly fitting beaker is carefully slipped. The jar is now sterilized in an autoclave at 20 pounds pressure for 30 minutes and is ready for use. To avoid cracking the jar the autoclave must be raised to the sterilizing temperature very gradually, and at the end of the sterilizing period the temperature must be allowed to fall very gradually. At least three hours should be consumed in this process. By using ordinary bacteriological precautions it is possible to introduce sterilized seeds through the side tubulature and later inoculate them, with practically no danger of contamination. Black paper is then wrapped around the lower part of the jar to protect the growing roots from light. A slight circulation of air results from the processes of respiration and photosynthesis within the jar, since both top and bottom offer opportunity for the passage of air through the cot-

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[1] Harrison, F. C., and Barlow, B. The nodule organism of the Leguminosæ—its isolation, cultivation, identification, and commercial application. Centralblatt für Bakteriologie [etc.], Abt. 2, Bd. 19, No. 7/9, p. 264–272, 1907.

Kellerman, Karl F. The present status of soil inoculation. Centralblatt für Bakteriologie [etc.], Abt. 2, Bd. 34, No. 1/3, p. 42–50, 1912.

[2] Wilson, J. K., and Harding, H. A. Method of keeping bacteria from growing plants. Science, n. s., v. 33, no. 849, p. 545, 1911. (Abstract.)

ton wool. The leguminous plants grow well, and if the culture used for inoculating is in proper condition normal nodules are soon formed.

By this procedure it has been possible to distinguish sharply between the inoculating power of apparently identical strains of bac-

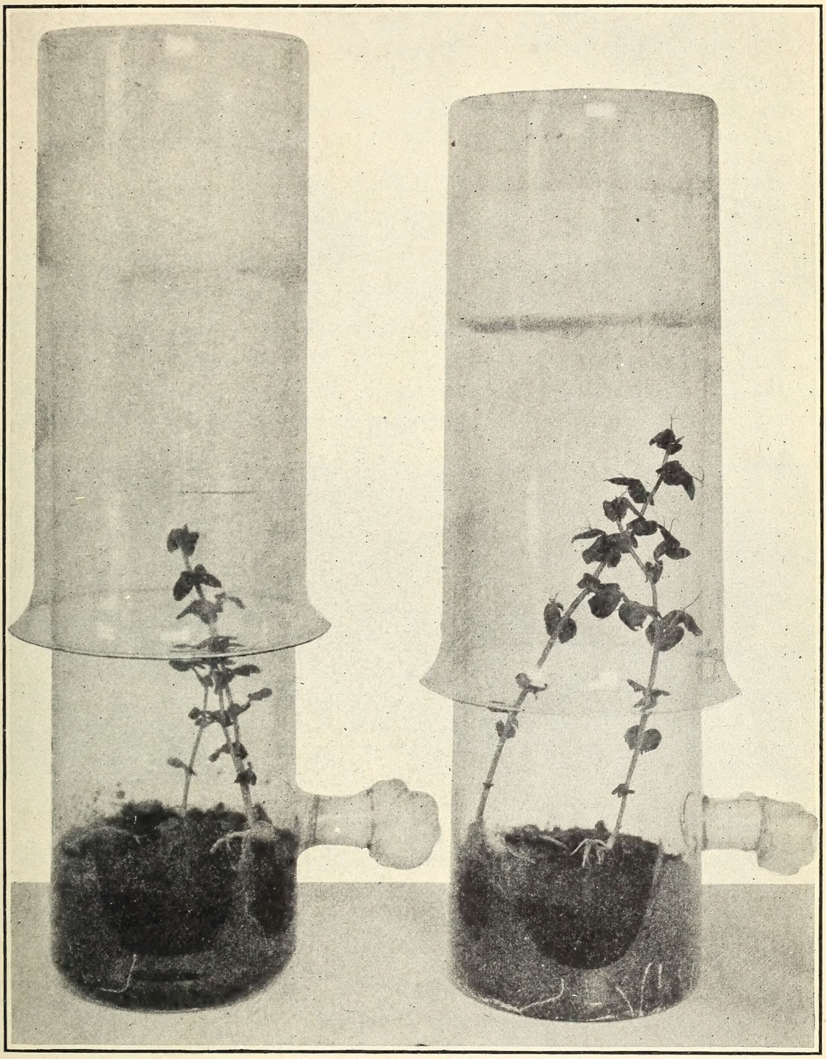

FIG. 1.—Jars for testing the inoculating power of different strains of *Bacillus radicicola*. In the jar at the right are inoculated garden-pea plants, while at the left are uninoculated ones, each 3 weeks old.

teria, and in future all stock cultures intended for distribution by the Office of Soil-Bacteriology and Plant-Nutrition Investigations to farmers and other experimenters in the United States will be tested in this manner.

# THE WORK OF THE SAN ANTONIO EXPERIMENT FARM IN 1912.[1]

By S. H. Hastings, *Farm Superintendent, Office of Western Irrigation Agriculture.*

## INTRODUCTION.

The work of the San Antonio Experiment Farm is devoted to the investigation of agricultural problems peculiar to large areas in the southwestern United States, where the conditions of soil and climate are similar to those at San Antonio. The more important lines of work carried on are tillage and rotation experiments; breeding, variety testing, and different planting methods for cotton; variety

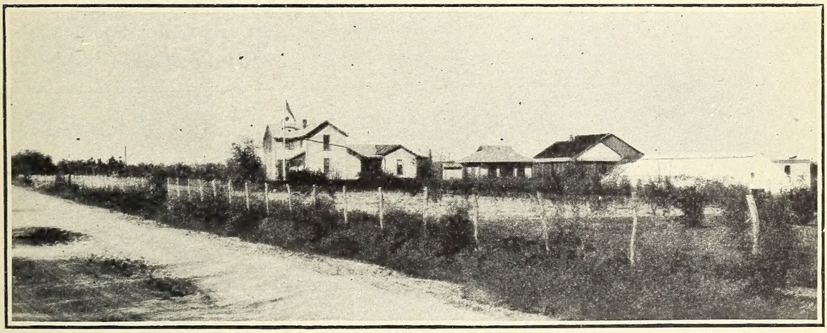

Fig. 1.—View showing the buildings on the San Antonio Experiment Farm.

testing of grain sorghum and broom corn; corn breeding and variety testing; a few forage-crop experiments; variety testing of peaches, plums, apricots, persimmons, grapes, walnuts, almonds, and other fruits, including Chinese dates. In addition to such horticultural work as is mentioned above, much attention is being given to finding stocks better adapted to the local conditions than those now used.

[1] Issued Apr. 5, 1913.

The San Antonio Experiment Farm comprises about 125 acres of land situated about 6 miles south of San Antonio, Tex. The tract belongs to the city of San Antonio and is leased to the Department of Agriculture. About 80 acres of the land are under cultivation, and 6 of these are irrigated. The farm is equipped with the buildings (fig. 1) necessary for storage, laboratory, and office purposes and for employees' quarters. The experiment farm is under the direction of the Office of Western Irrigation Agriculture of the Bureau of Plant Industry and is maintained from the funds of the Department of Agriculture. Previous general reports on the work of the farm were published in 1908 and 1909 as Bureau of Plant Industry Circulars Nos. 13 and 34.

The testing of trees and shrubs for ornamental purposes is being emphasized. The location of the experiments in 1912 is shown in figure 2.

## COOPERATIVE WORK.

The following are the offices of the Bureau of Plant Industry cooperating in the work at San Antonio, the approximate area occupied by each being noted: The Office of Acclimatization and Adaptation of Crop Plants and Cotton-Breeding Investigations has about 11 acres devoted to corn and cotton. The Office of Foreign Seed and Plant Introduction has approximately 1½ acres devoted to the testing of new plant introductions. The Office of Crop Physiology and Breeding Investigations has about 2 acres devoted to testing the Texas wild peach (*Prunus texana*) and its hybrids and to fig and pistache experiments. Approximately 3 acres are used by the Office of Corn Investigations in testing corn varieties. About 1½ acres are used by the Office of Alkali and Drought Resistant Plant Investigations in its work with pomegranates and olives. The Office of Cereal Investigations cooperates in the variety testing of grain sorghum and broom corn.

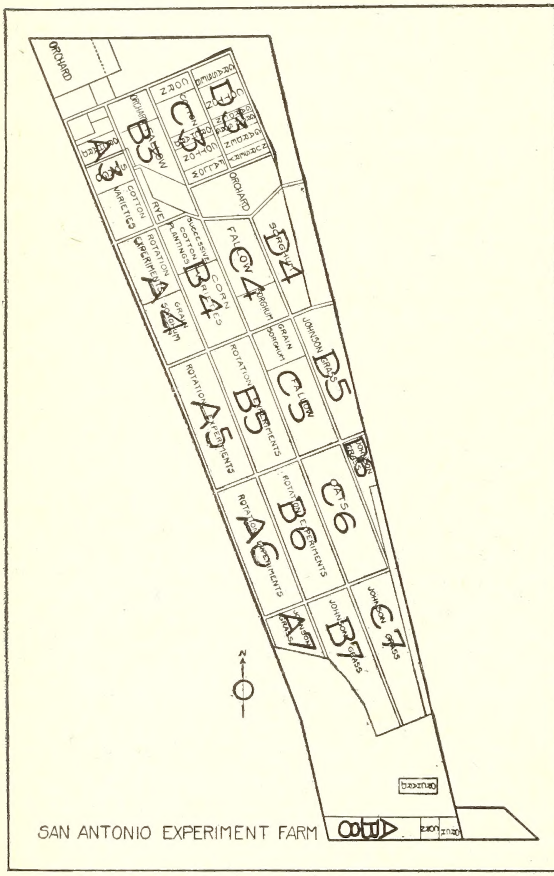


FIG. 2.—Diagram of the San Antonio Experiment Farm, showing the arrangement of the fields and the location of the experiments in 1912.

## CLIMATIC CONDITIONS.

The first part of the season of 1912 was very favorable to crop growth, and as a result the yields of early crops, such as corn, oats, and sorghum, were good. The preceding winter was one of unusual severity and the amount of winter rainfall was somewhat above the normal. From June 23 until late in September practically no rain fell, the total precipitation for the months of July and August being only 0.33 inch. This continued drought of nearly three months cut the cotton crop short. The spring was late and consequently the corn and other early-planted crops were somewhat late in maturing. The total precipitation for the year, as measured at the farm, was 26.37 inches,[1] which is practically the normal for this section, but somewhat higher than the mean annual rainfall for the period 1907 to 1912, inclusive.

The meteorological observations at the experiment farm are made in cooperation with the Biophysical Laboratory of the Bureau of Plant Industry. Table I shows the summaries for 1912 compared with the means for the six-year period 1907 to 1912, inclusive.

TABLE I.—*Summary of meteorological observations at the San Antonio Experiment Farm, 1907 to 1912, inclusive.*

PRECIPITATION (INCHES).

| Item. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. | Total. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Average, 6 years, 1907 to 1912, inclusive | 0.54 | 2.23 | 1.66 | 2.96 | 2.47 | 1.28 | 1.54 | 1.63 | 1.15 | 2.60 | 2.52 | 1.88 | 22.46 |
| For the year 1912 | .31 | 6.21 | 2.30 | 2.04 | 1.64 | 3.42 | .08 | .25 | 1.53 | 2.92 | 1.76 | 3.91 | 26.37 |

EVAPORATION (INCHES).[2]

| Item. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. | Total. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Average, 6 years, 1907 to 1912, inclusive | 2.72 | 3.12 | 4.68 | 5.32 | 6.63 | 8.40 | 8.69 | 9.39 | 7.31 | 5.23 | 3.21 | 2.38 | 67.07 |
| For the year 1912 | 2.35 | 3.35 | 3.05 | 3.88 | 7.39 | 7.02 | 10.59 | 10.65 | 8.52 | 5.41 | 3.23 | 1.83 | 67.26 |

DAILY WIND VELOCITY (MILES PER HOUR).[3]

| Item. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. | Total. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1911, highest | 10.4 | 15.9 | 9.0 | 10.6 | 9.2 | 11.9 | 12.5 | 12.1 | 6.6 | 8.5 | 9.5 | 7.2 | ....... |
| 1912, highest | 8.2 | 11.2 | 6.4 | 6.0 | 5.9 | 8.4 | 7.3 | 7.6 | 6.5 | 7.6 | 5.7 | 8.0 | ....... |
| 1911, lowest | 1.12 | 1.45 | 2.24 | 3.28 | 2.17 | 2.34 | 2.82 | 1.82 | 1.98 | .86 | 1.06 | .97 | ....... |
| 1912, lowest | .77 | .62 | .86 | .84 | 1.22 | 1.08 | 1.38 | 2.30 | 1.42 | .89 | .76 | .81 | ....... |
| 1911, average | 5.60 | 7.02 | 5.20 | 6.10 | 5.60 | 6.40 | 6.86 | 4.59 | 3.91 | 3.76 | 3.24 | 3.36 | ....... |
| 1912, average | 3.16 | 4.00 | 3.50 | 2.68 | 3.23 | 2.92 | 4.27 | 4.83 | 3.75 | 3.84 | 2.68 | 2.80 | ....... |

[1] The rainfall in the city of San Antonio in 1912, as reported by the United States Weather Bureau, was 23.7 inches, which was 3.2 inches below the normal.

[2] The evaporation measurements missing are as follows:

1909.—April, 2 days; June, 3 days; July, 6 days; August, 1 day; November, 1 day.

1910.—January, 7 days; February, 2 days; June, 3 days; July, 5 days; October, 4 days; December, 3 days.

1911.—April, 1 day; July, 2 days.

1912.—February, 2 days; April, 1 day; December, 2 days.

[3] Wind velocities are reported for the years 1911 and 1912 only.

TABLE I.—*Summary of meteorological observations at the San Antonio Experiment Farm, 1907 to 1912, inclusive*—Continued.

TEMPERATURE (°F.).

| Item. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. | Total for period. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Absolute maximum, 6 years, 1907 to 1912, inclusive | 88.5 | 87.0 | 95.0 | 102.0 | 103.0 | 108.0 | 108.0 | 105.0 | 104.0 | 98.0 | 86.5 | 82.0 | 108.0 |
| Absolute maximum, 1912 | 84.0 | 78.5 | 82.0 | 90.0 | 103.0 | 100.5 | 105.0 | 104.0 | 101.0 | 94.0 | 84.0 | 74.0 | 105.0 |
| Absolute minimum, 6 years, 1907 to 1912, inclusive | 12.0 | 13.0 | 34.0 | 38.0 | 39.0 | 56.0 | 64.0 | 64.0 | 41.0 | 32.0 | 15.0 | 17.0 | 12.0 |
| Absolute minimum, 1912 | 16.5 | 16.0 | 34.0 | 38.0 | 47.0 | 59.0 | 66.0 | 68.0 | 54.5 | 51.0 | 25.0 | 25.0 | 16.0 |
| Mean, 6 years, 1907 to 1912, inclusive | 54.1 | 54.7 | 65.0 | 68.6 | 75.2 | 82.7 | 85.2 | 85.3 | 80.3 | 69.6 | 59.6 | 50.2 | 69.2 |
| Mean, 1912 | 46.6 | 49.9 | 55.4 | 67.4 | 76.5 | 77.8 | 85.1 | 86.8 | 82.0 | 71.8 | 59.4 | 48.6 | 67.3 |

KILLING FROSTS.

| Years. | Last in spring. | | First in autumn. | | Length of frost-free period. |
|---|---|---|---|---|---|
| | Date. | Minimum temperature. | Date. | Minimum temperature. | |
| | | °*F.* | | °*F.* | *Days.* |
| 1907 | Feb. 8 | 29 | Nov. 12 | 32 | 277 |
| 1908 | Feb. 20 | 24 | Nov. 14 | 29 | 268 |
| 1909 | Feb. 25 | 30 | Dec. 6 | 31 | 284 |
| 1910 | ...do.... | 26 | Oct. 29 | 32 | 246 |
| 1911 | ...do.... | 29 | Nov. 13 | 31 | 261 |
| 1912 | Feb. 27 | 30.5 | Nov. 2 | 29.5 | 245 |

## ROTATION AND TILLAGE EXPERIMENTS.[1]

The rotation and tillage experiments, which are conducted on 82 plats of one-fourth of an acre each, were continued as previously, except that milo was substituted for corn on four plats and for oats on one plat.

The results of the rotation experiments indicate that crop rotation is an important factor in crop production in this section of Texas, the yields of crops grown in a suitable rotation being on the whole uniformly higher than when grown continuously on the same land. The average yields of all crops except cotton were the highest of any year since the work was started in 1909.

Table II gives the crops in the rotation experiments, the number of plats planted to each crop in 1912, the average yields per acre, and the highest and lowest yields per acre in 1912.

[1] These experiments are under the direct supervision of Mr. C. R. Letteer, assistant.

TABLE II.—*Average yields per acre of crops in the rotation experiments, San Antonio Experiment Farm, 1912.*

| Crop. | Average yield, 1907 to 1911, inclusive. | Yield in 1912. | | | |
|---|---|---|---|---|---|
| | | Number of plats. | Average. | Highest. | Lowest. |
| Corn.....bushels.. | 14.6 | 26 | 34.1 | 42.3 | 24.3 |
| Dwarf milo.....do.... | .......... | 5 | 40.0 | 52.0 | 32.5 |
| Oats, grain [1].....do.... | 6.5 | 10 | 26.75 | 37.0 | 19.1 |
| Cotton [2].....pounds.. | 585.3 | 25 | 621.5 | 818.0 | 448.0 |
| Sorghum: [3] | | | | | |
| 4.1 foot drills.....tons.. | 4.86 | 5 | 4.03 | 4.28 | 3.82 |
| 8-inch drills.....do.... | 2.06 | 3 | 4.68 | 5.49 | 4.16 |
| Oats, hay [1].....do.... | .83 | 4 | 2.82 | 3.09 | 2.53 |

[1] No oat yields in 1907 and 1908. [2] Seed cotton. [3] Sorghum not planted in 8-inch drills in 1908.

## MANURING.

The effect of barnyard manure on crop yields in the rotations was more noticeable this year than ever before. The average yield of corn from all plats where manure was applied at some time during the course of the rotation was slightly greater than the average of corn plats in corresponding rotations not manured. The same was true of cotton, but manuring decreased the yield of oats for grain very noticeably. The oats on plats which had been manured grew very rank and lodged much more than on plats which had not been manured. The excessive vegetative growth and consequent lodging probably account largely for the decreased yield of grain.

While the results indicate the value of barnyard manure, the difference in favor of manure is much less on crops grown in a rotation than where grown continuously on the same land and manured each year. (See figs. 3 and 4.)

Table III gives the yields for 1912 and the average yields for 1910, 1911, and 1912 of crops grown continuously on the same land manured [1] each year compared with plats not manured.

TABLE III.—*Yield [2] for 1912 and average yields for 1910, 1911, and 1912 of crops on manured and unmanured plats planted continuously to the same crops at the San Antonio Experiment Farm.*

| Crop. | Manured. | | Not manured. | | Difference in favor of manuring. | |
|---|---|---|---|---|---|---|
| | Average, 1910 to 1912. | 1912. | Average, 1910 to 1912. | 1912. | 1910 to 1912. | 1912. |
| Corn..... | 15.9 | 30.5 | 11.6 | 26.6 | 4.3 | 3.9 |
| Dwarf milo [3]..... | .......... | 52.0 | .......... | 32.5 | .......... | 19.5 |
| Cotton..... | 455.3 | 572.0 | 397.3 | 474.0 | 58.0 | 98.0 |

[1] The manure is applied at the rate of about 15 tons per acre.
[2] Corn and milo in bushels per acre; cotton in pounds of seed cotton per acre.
[3] The plats from which dwarf milo yields are given had previously been planted to corn for three years.

## SUMMER FALLOWING.

Three years' results have now been obtained from the tests in summer fallowing land for corn, oats, and cotton. As in 1911, the yields of crops on land summer-fallowed the previous season were generally low, corn yielding at the rate of 24.7 bushels per acre, as compared with the average of 34.1 bushels per acre on the 26 plats in the rotation experiments. The corn on the summer-fallowed plat yielded the lowest, save one, of any of the 26 plats.

Cotton on summer-fallowed land yielded at the rate of 448 pounds of seed cotton per acre, as compared with an average of 621.5 pounds per acre on the 25 plats of cotton, giving the lowest yield of the 25 plats.

FIG. 3.—Cotton on plat B 5–3, land continuously cropped and not manured. This plat has yielded an average of 397 pounds of seed cotton per acre during the past three years. Compare with figure 4. (Photographed June 26, 1912.)

Oats for grain on a fallowed plat yielded at the rate of 37 bushels per acre, the highest yield obtained from the 10 plats of oats. The average yield from 10 plats was 26.75 bushels per acre. While the oats on summer-fallowed land yielded somewhat higher than the others, the increase was not sufficient to indicate that summer fallowing is a desirable practice under the conditions at San Antonio, even for oats.

## SUBSOILING.

Subsoiling tests have been a rather important part of the rotation and tillage experiments. The results have been summarized and published in Circular No. 114 of the Bureau of Plant Industry.

The results from subsoiling in 1912 were corroborative of those of previous years, namely, that subsoiling does not materially increase the yields of crops, and in many instances decreases the yields, and that, owing to its being an expensive operation, it can not be recommended as a regular farm practice in connection with corn, oats, and cotton in the San Antonio region of Texas.

## ROOT-ROT.

Root-rot, a fungous disease of plants,[1] is doubtless one of the most serious diseases with which farmers have to contend in the Black Lands of Texas. It affects such crops as cotton, cowpeas, and alfalfa,

FIG. 4.—Cotton on plat B 5–4, land continuously cropped and fertilized each year with barnyard manure. This plat has yielded an average of 455 pounds of seed cotton per acre during the past three years. Compare with figure 3. (Photographed June 26, 1912.)

but does no perceptible damage to plants belonging to the grass family, such as corn, oats, wheat, etc. In many cotton fields it causes the premature death of a large proportion of the plants. It was observed in 1912 that in a number of the rotations with cotton and corn the root-rot was much more widespread and did more damage to the cotton on plats which were spring-plowed than on plats which were summer or fall plowed. The same condition was apparent in 1911. It was also observed in 1912 that where cotton was grown in rotation with corn or oats the damage due to root-rot was much less noticeable than on plats continuously planted to cotton.

[1] This disease is caused by *Ozonium omnivorum*. For an account of the disease and methods of lessening its damage, see the paper entitled "The control of Texas root-rot of cotton," in Bureau of Plant Industry Bulletin 102.

## HORTICULTURAL WORK.[1]

### THE MEXICAN SEEDLING PEACH.

The Mexican seedling peach trees[2] bore a heavy crop of fruit, and the early prospects were good that more data on the comparative merits of different trees might be secured. The earlier ripening trees gave a heavy yield of good fruit, but the continued drought of midsummer damaged all the peaches from the later maturing trees, making the tests with these trees nearly worthless. Nearly all the trees bore an exceptionally heavy crop, but they were not able to hold the fruit through such a long period of drought.

Fig. 5.—English walnut grafted on native Texas black walnut in February, 1912. (Photographed August 28, 1912.)

The trees are becoming overcrowded, owing to their size and close planting, bringing out the point that to obtain the best results the distance between the trees will have to be greater than is ordinarily adopted in more humid sections. The trees were planted 16 feet apart, but it is now apparent that better results would be secured if they were 22 feet apart.

The Office of Foreign Seed and Plant Introduction put in 324 buds from what were considered the best 9 trees of the Mexican seedling orchard. These budded trees are to be distributed to cooperators in southwest Texas to test their value under varying conditions.

[1] The horticultural experiments were under the direct charge of Mr. R. E. Blair, scientific assistant.

[2] The seed from which these trees were produced was collected in Mexico by Mr. Gilbert Onderdonk, under the direction of the Office of Foreign Seed and Plant Introduction. They are listed under S. P. I. Nos. 9320 and 9321.

OTHER PEACH VARIETIES.

In the variety peach orchard on Field A1, where there are 35 varieties of peaches, set out in 1906, an unusually heavy crop of fruit set. Even the northern peaches in most instances were heavily loaded for the first time in the history of the orchard. This should not be taken as an indication that this class of peaches is adapted to these conditions. Those belonging to the South Chinese type are the most reliable bearers. Of the varieties on trial the following have proved to be the best: Pallas, Honey, Imperial, and Triana. The wild peach from China (*Amygdalus davidiana*) is proving to be exceptionally good for peach stock, but there is difficulty in securing seed, as thus far it has not fruited here, with the exception of two fruits which ripened in 1912.

PLUMS.

The tests of plums include 16 varieties that have been under trial since 1906. The tests so far conducted indicate that the plum is probably the most reliable fruit for the San Antonio section. The American-Japanese hybrids bear somewhat more heavily than the pure Japanese sorts. The plums that have proved the best adapted to the conditions at San Antonio are the Gonzales, Burbank, Wickson, Terrel, El Paso, and Transparent.

FIG. 6.—Xenia grape grafted on native mustang grape in February, 1912. (Photographed June 28, 1912.)

NATIVE TREES AND SHRUBS.

Much work has been done on the domestication of native trees and shrubs suitable for use as grafting stock (fig. 5) or for crossbreeding.

Hybridization and grafting work has been done on the peach, plum, persimmon, and grape. Successful crosses between the native *Prunus texana* and the peach and plum have been made. The grafting of the better types of grapes on the native mustang grape has been done successfully (fig. 6). Some attention is also being given to grafting the English walnut on the native black walnut.

### PERSIMMONS.

The propagation of persimmons has been tried, a special effort being made to utilize as a stock the native Texas persimmon (*Diospyros texana*), which grows so abundantly and persistently on the semiarid lands of western Texas and in the limestone canyons. This tree has long been regarded as a probable stock for the Japanese persimmon, but until recently it was impossible to produce a union. Successful results have lately been accomplished by inarching with *Diospyros texana* seedlings small enough to be handled in pots. In this method of inarching, the small native seedling is transferred to a paper pot after most of the soil has been removed from the roots, and the pot is filled with sphagnum. It is necessary that the pots be small and light, for under normal summer conditions the wind would prevent securely fastening a heavy pot in position long enough to permit the formation of a union. The stock and scion will commonly unite in about 30 days, but as the persimmon grows rather slowly even more time is desirable. Until this method was devised, no successful *Diospyros kaki* plants had been produced on *D. texana* stock. A few crown grafts were made to start, but no others. Budding has been attempted repeatedly by shield, patch, flute, and ring methods, with no success whatever. The following combinations have been successfully accomplished here by the inarch method described:

*D. kaki* on *D. texana* stock.
*D. virginiana* on *D. texana* stock.
*D. texana* on *D. kaki* stock.
*D. texana* on *D. virginiana* stock.

A small planting of varieties of Japanese persimmons worked on the native stock is to be made under dry-land conditions as soon as the trees can be propagated. Several have already been set to orchard positions. As most species of the Japanese persimmon suffer from chlorosis on the soils of the San Antonio region, it is believed that the use of this resistant stock may be a remedy for this trouble unless the scion proves to rapidly outgrow the stock.

## ORNAMENTAL PLANTS.

Ornamental trees and shrubs suitable for the San Antonio section have been tried in large numbers. Particular attention is also being given to native trees and shrubs not already known or whose desirable qualities are not fully appreciated. In addition to the native trees and shrubs, about 100 varieties of roses and a collection of bamboos, palms, yuccas, agaves, and many others have been assembled.

## FORAGE CROPS.

The results of all the forage-crop experiments conducted at the farm from 1908 to 1912, inclusive, have been assembled and published as Circular No. 106 of the Bureau of Plant Industry. This circular contains an extensive discussion of the results with the forage crops tested during the past five years. For this reason, only brief mention will be made here of the main features of the work in 1912.

Among the more conspicuous new forage crops that are particularly well adapted to the section may be mentioned Canada field peas and Sudan grass. So far Canada field peas have given a higher hay yield than oats, and apparently there is at least one variety that will stand nearly, if not quite, as much cold. Last winter there were on trial three lots, known as S. P. I. Nos. 30307, 18806, and 30134. During the winter there was a minimum temperature of 15° F. Nos. 30307 and 18806 were almost completely killed out, but, while the plants on the other planting (No. 30134) were killed nearly to the ground, new growth was put out and a grain yield of 14 bushels per acre was obtained. As a winter cover crop this is the most promising that has been tested.

Excellent results were obtained with Sudan grass in both 1911 and 1912. The yield of Sudan grass in 1912 was 5.66 tons per acre, based on the weights from a one-tenth-acre plat. Sorghum planted in the same way on the rotation fields gave a yield of 4.68 tons per acre.

A rate-of-seeding test consisting of seven one-tenth-acre plats of Sumac sorghum in 8-inch drills was conducted, as there is a variance of opinion among farmers as to the best rate, quality of forage and yield considered. The rates varied from 26 to 174 pounds per acre. The highest yield was obtained from the plat seeded at the rate of 88 pounds per acre, or slightly more than 1½ bushels. The quality of the forage was apparently equal to that produced by the heavier seedings and better than that in the thinner seedings.

Japanese sugar cane, which has been grown here for the past three seasons, gave a yield in 1912 of 13.08 tons per acre, the average yield for the past three years being 12.84 tons per acre. This crop is grown under irrigation.

## VARIETY TEST OF COTTON.[1]

A variety test of cotton was conducted with seven varieties and five selections of Triumph. Sixteen-rod rows of each variety were planted in triplicate. Table IV gives the results of the test.

TABLE IV.—*Yields obtained in a variety test of cotton at the San Antonio Experiment Farm, 1912.*

| Variety. | Seed cotton per acre. | Percentage. | |
|---|---|---|---|
| | | Lint. | Stand.[1] |
| | *Pounds.* | | |
| Vergatus [2] | 735 | 32.4 | 100 |
| S. A. 1,000 (Triumph) | 635 | 35.5 | 90 |
| Roundnose | 580 | 37.6 | 97 |
| S. A. 920 (Triumph) | 580 | 37.8 | 89 |
| Lone Star | 525 | 34.2 | 78 |
| Rowden | 525 | 32.8 | 89 |
| Triumph, general seed | 520 | 37.2 | 93 |
| Durango | 496 | 27.8 | 87 |
| Triumph, 152 | 480 | 37.9 | 87 |
| Triumph, Mebane | 480 | 38.2 | 94 |
| Acala [3] | 410 | 35.7 | 80 |
| Saunders No. 2 | 335 | 34.0 | 69 |

[1] Percentage of stand determined from an actual count of the plants in each row.
[2] Lint very short.
[3] Lint but little better than Triumph.

As is shown, the Vergatus gave the highest yield, but the lint was very short, making it an undesirable variety.

## GRAIN SORGHUMS.

The experiments in grain sorghums reported on last year [2] were continued. Both variety and time-of-planting tests were made. Table V gives the average yields of the varieties for three plantings.

TABLE V.—*Yields obtained in a variety test of grain sorghum at the San Antonio Experiment Farm in 1912.*

| Variety. | Bushels per acre. | Variety. | Bushels per acre. |
|---|---|---|---|
| Dwarf milo | 50.5 | White sorghum | 25.4 |
| Standard milo | 46.8 | White durra | 22.6 |
| Blackhull kaoliang | 36.5 | Standard Blackhull kafir | 19.9 |
| Sudan durra | 33.1 | Red kafir | 19.9 |
| Dwarf Blackhull kaoliang | 29.7 | Shallu | 11.7 |
| Brown kaoliang | 27.9 | | |

The sorghum midge did not appear this season until somewhat later than in previous years, so with the earlier maturing varieties,

[1] The variety test here reported is additional to an extensive series of experiments with cotton conducted by the Office of Acclimatization and Adaptation of Crop Plants and Cotton-Breeding Investigations, the results of which will be reported elsewhere.

[2] U. S. Department of Agriculture, Bureau of Plant Industry, Bulletin 237, entitled "Grain-sorghum production in the San Antonio region of Texas."

such as milo, plantings made as late as April 1 gave heavier yields than earlier plantings. This was due largely to the fact that there was a poor stand in the earlier plantings.

### GRAIN-SORGHUM YIELDS COMPARED WITH CORN.

Two varieties of grain sorghum, Dwarf milo and Sudan durra, were grown in comparison with 42 of the most common types of Texas corn. Sudan durra gave a yield of 57 bushels per acre and Dwarf milo 63 bushels per acre, while the best strain of corn gave a yield of 40 bushels per acre, with an average of about 30 bushels for the field.

FIG. 7.—Dwarf broom corn on the San Antonio Experiment Farm. An average yield of 657 pounds of brush per acre was obtained from plantings made on three different dates in 1912. (Photographed June 15, 1912.)

### DISTRIBUTION OF SORGHUM SEED.

More than 150 requests for grain-sorghum seed were received from near-by farmers, and 209 packages were sent out to 103 of these. The varieties distributed were Dwarf milo, Sudan durra, and Dwarf Blackhull kafir. Much interest is being shown by the farmers in western Texas in the production of this grain crop, since the corn yields have been low during the past four years.

### BROOM CORN.

In connection with grain-sorghum tests, three varieties of broom corn were planted, Dwarf broom corn (fig. 7) being planted on three different dates and the others on two. The average yields from these plantings were as follows:

| | |
|---|---|
| Dwarf broom corn, G. I. No. 442 | 657 pounds per acre. |
| Broom corn, G. I. No. 243-5-4 | 640 pounds per acre. |
| Standard broom corn, G. I. No. 446 | 730 pounds per acre. |

The brush was of fair quality.

## PUBLICATIONS.

As rapidly as results of a conclusive nature are secured from the experiments at the farm they are prepared for publication. In this way the facts brought out in the experimental work are promptly made available to the farmers of the region. During the year 1912 three publications dealing in detail with some of the problems under investigation were prepared. The first of these[1] treats of the production of grain sorghum, the most important grain crop of the region; the second[2] reports the results of five years' experimentation with forage crops, and the third[3] deals with the effects produced on crop yields and soil moisture by the practice of subsoiling. Similar papers dealing with other problems will be issued from time to time as the experimental results warrant publication.

[1] U. S. Department of Agriculture, Bureau of Plant Industry, Bulletin 237, "Grain-sorghum production in the San Antonio region of Texas," by Carleton R. Ball and Stephen H. Hastings.

[2] U. S. Department of Agriculture, Bureau of Plant Industry, Circular 106, "Report of the forage-crop work at the San Antonio Experiment Farm," by S. H. Hastings.

[3] U. S. Department of Agriculture, Bureau of Plant Industry, Circular 114, article entitled "Experiments in subsoiling at San Antonio," by S. H. Hastings and C. R. Letteer.

# INHERITANCE OF WAXY ENDOSPERM IN HYBRIDS WITH SWEET CORN.[1]

By G. N. Collins, *Botanist*, and J. H. Kempton, *Assistant, Office of Acclimatization and Adaptation of Crop Plants and Cotton-Breeding Investigations.*

## INTRODUCTION.

As soon as European settlers in America became familiar with the different varieties of maize, the obvious classification of varieties based on the character of the seeds came into use. In very early literature we find such terms as flint, dent, and sweet referred to as representing classes already well known. The popular classification was crystallized into formal descriptions by Salisbury in 1849, but it was not until 1884, when Sturtevant extended the classification and applied as technical names Latin equivalents of the popular names, that the classification was generally recognized by scientific writers.

With the exception of pod corn, which is known only as a curiosity, these groups are all distinguished by the texture or composition of the endosperm. The discovery in China of a type of maize with a new form of endosperm added another member to this long-established series.[2]

## BEHAVIOR OF THE HYBRIDS.

The waxy endosperm, characteristic of this Chinese variety, has never been observed in any American variety, while in all of the importations of this Chinese variety nothing but waxy seeds have been observed. When crossed with varieties that have a horny endosperm the waxy endosperm is completely recessive, the immediate result of the cross being seeds that are indistinguishable from those of horny varieties. In the second generation of crosses segregation appears to be complete, and the proportion of waxy to horny seed approximates the Mendelian monohybrid ratio, 1:3, with small, though significant, deviations. Detailed results of a series of crosses between waxy and horny are given in another place.[3]

In a general way waxy endosperm may be said to behave like sweet endosperm, which has also been found to be recessive to horny

[1] Issued Apr. 5, 1913.

[2] Collins, G. N. A new type of Indian corn from China. U. S. Department of Agriculture, Bureau of Plant Industry, Bulletin 161, 1909.

[3] Collins, G. N., and Kempton, J. H. Inheritance of waxy endosperm in hybrids of Chinese maize. IVe Conférence Internationale de Génétique, Paris, 1911, p. 347–357, 1913.

in the first or xenia generation and to segregate as a monohybrid in the following generation. Since both sweet and waxy endosperms are recessive to horny, it became of interest to know what a hybrid between sweet and waxy would produce. Six such crosses were made in the season of 1911. In every instance the resulting ears were all horny, the endosperm in every way resembling the horny endosperm of ordinary varieties.

This synthetic production of horny endosperm from nonhorny varieties at once suggests the idea that both sweet and waxy endo-

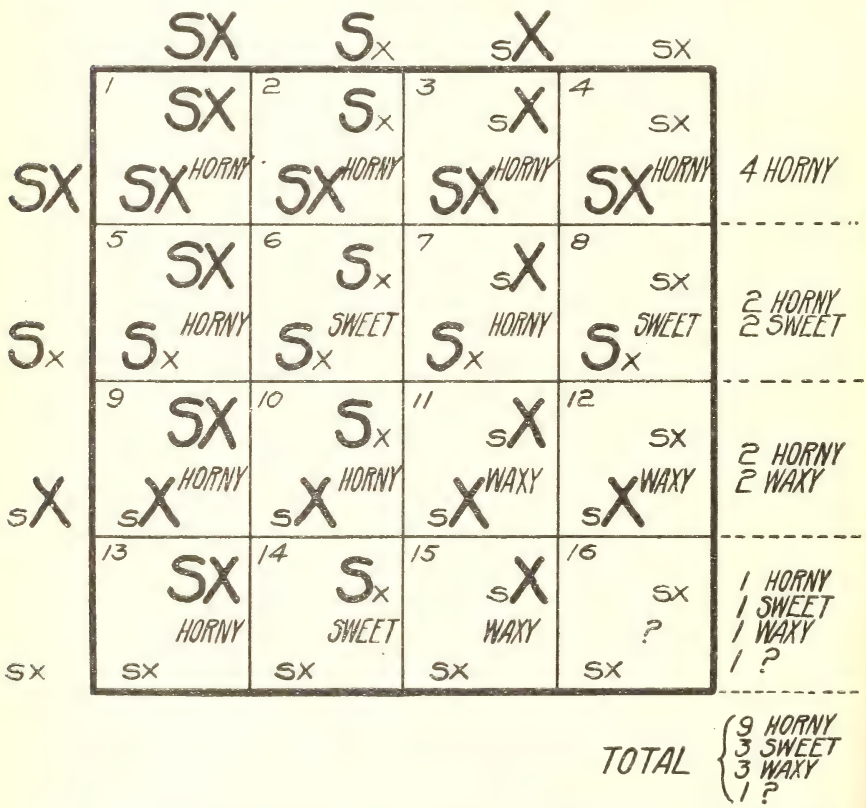


FIG. 1.—Diagram showing the gametic composition of second-generation hybrids between waxy and sweet varieties of maize.

sperms represent an imperfect development through the loss or failure of some element or hereditary factor and that what is lacking in the sweet is supplied by the waxy, and vice versa. It has often been suggested that sweet endosperm resulted from a failure of complete development of horny endosperm, but no suggestion has been made regarding the nature of the deficiency. It now appears that what is lacking in a sweet variety is supplied by the waxy, and, conversely, that what is lacking in the waxy is supplied by a sweet variety. While the horny seeds resulting from the cross between sweet and waxy were indistinguishable from ordinary horny seeds, it was, of course, to be expected that differences would appear in the progeny.

Four of the six ears obtained as a result of the crosses made in 1911 were selected for planting in 1912. The ancestry of these ears is as follows:

Dh221. White Chinese (waxy) × Voorhees Red (sweet).
Dh209. White Chinese (waxy) × Black Mexican (sweet).
Dh216. White Chinese (waxy) × Black Mexican (sweet).
Dh207. White Chinese (waxy) × Black Mexican (sweet).

The same individual plant was not used as the parent of more than one cross.

From these 4 ears 55 ears were produced in 1912. Every ear bore seeds of all three classes—horny, sweet, and waxy. The entire 55 ears had 22,132 seeds, of which 57.4 per cent were horny, 24.8 per cent sweet, and 17.8 per cent waxy. These proportions approximate the 9:4:3 Mendelian ratio involving two factors.

Since in the first generation sweet combined with waxy produced horny, it has been assumed that something necessary to produce horny is lacking in both the sweet and the waxy, and an attempt has been made to analyze the behavior of these hybrids with this idea in view. The residual factor which when it occurs alone is assumed to cause the sweet character will be called $S$, while $X$ will be used to indicate the factor of the waxy character. Small letters, $s$ and $x$, are used to denote the absence of these factors. Since in both sweet and waxy the alternative factor necessary to produce horny is assumed to be lacking, the gametes produced by sweet varieties will be represented by $Sx$ and the gametes produced by varieties with waxy endosperm by $sX$. The synthetic horny will then be represented by a combination of these, or $SxsX$. Assuming a chance recombination of these factors in the gametes derived from these synthetic horny seeds, the gametes will be of four kinds. Both the sweet and the waxy may be present ($SX$), or the sweet may be present without the waxy ($Sx$), or the waxy without the sweet ($sX$), or both may be absent ($sx$). At fertilization each of these kinds of gametes may unite with any one of the four corresponding kinds derived from the other parent, producing 16 zygotic combinations. The formation of these combinations is represented in the conventional diagram, figure 1. The four classes of gametes from one parent are given in the horizontal row at the top, and the same four classes from the other parent in the vertical row at the left. Each gametic combination from the top is repeated four times in the squares below, while each combination at the side occurs four times in the corresponding horizontal row of squares. Thus each of the squares represents the result obtained by combining the gametes representing the horizontal and vertical rows that intersect at that point. In all cases where both $S$ and $X$ occur together the seed should be horny, where only $S$ occurs the seed should be sweet, when only $X$ occurs it should be waxy, and in one square (No. 16), where neither $S$ nor $X$ occurs, no prediction can be made, since this is presumably a new condition.

Leaving the nature of the seed from square 16 out of consideration for the present, it can be seen that there are 9 squares in which both $S$ and $X$ occur (horny), 3 in which $X$ alone occurs (waxy), and 3 in which $S$ alone occurs (sweet). With respect to the horny and waxy seeds, these numbers approximate the ratios that were actually obtained, there being roughly 9 horny seeds to 3 waxy, but the sweet seeds occur as 4 instead of 3 out of every 16. We must therefore assume that the new type, $sxxx$, represented in square 16 and containing neither the sweet nor the waxy factor is or resembles sweet. Careful scrutiny of the sweet seeds failed to show any consistent differences that would allow another class to be separated, but if the present method of looking at the cross is to be of use it should be possible to detect the differences between the ordinary sweet seeds and this new class by analytical breeding.

One way to test the theory that this new class of apparently sweet seeds really lacks the element ordinarily concerned in the production of the sweet character is to cross it with pure waxy. The cross of sweet and waxy has heretofore always produced horny, but if this new class lacks the factor for sweet, the cross should have the gametic composition represented by squares 12 and 15 and should result in waxy instead of horny seeds. Another test could be applied by crossing the new class with ordinary horny varieties. The first generation of this cross should be horny, but the formula of gametic composition, $SXsx$, would be the same as for the synthetic horny, and in the second generation 3 out of every 16 seeds should be waxy.

Thus, if the present assumption regarding the nature of this class is correct we may expect two apparent anomalies, not observed hitherto, viz, waxy seeds as the immediate result of crossing sweet and waxy, and waxy seeds in the second generation of a cross between sweet and horny.

## COMPARATIVE WEIGHT OF HORNY, SWEET, AND WAXY SEEDS.

The view that waxy as well as sweet endosperm may be compared to incomplete stages in the production of the horny endosperm is strengthened by the relative weights of the sweet, waxy, and horny seeds where all three classes occur on the same ear. The horny seeds are the heaviest, followed by the waxy and sweet. A total of 3,161 horny seeds weighed 790.3 grams, 2,387 waxy seeds weighed 565 grams, and 5,247 sweet seeds weighed 1,028.3 grams. Reduced to weight per seed, these results give 0.253 gram for the horny, 0.237 gram for the waxy, and 0.196 gram for the sweet. The average weight of the four classes, white horny, white waxy, white sweet, and colored sweet, was determined on 49 ears belonging to four families.[1] The results are shown in Table I. Since the average weight of seed differs on different ears, the comparative weights of the different classes are expressed in terms of the weight of the horny seeds.

TABLE I.—*Weight of white waxy, colored sweet, and white sweet seeds of maize.*

| Family. | Number of ears. | White horny. | White waxy. | Colored sweet. | White sweet. |
|---|---|---|---|---|---|
| Dh221 | 12 | 100 | 93.8±1.02 | 77.7±1.52 | 77.4±1.40 |
| Dh209 | 13 | 100 | 95.6± .77 | 76.2±1.71 | 76.4±1.45 |
| Dh216 | 15 | 100 | 96.5± .95 | 79.3± .94 | 77.8±1.28 |
| Dh207 | 9 | 100 | 94.2± .93 | 76.8±1.20 | 72.4±1.90 |
| Total | 49 | 100 | 95.2± .45 | 77.6± .65 | 76.4± .71 |

There appears to be no real difference in weight between the white and colored sweet seeds. The sweet seeds are, however, consistently lighter than the waxy, which in turn are lighter than the horny. The average difference between the sweet and waxy seeds is 22.5 per cent of the weight of the sweet; that between the waxy and horny is 5 per cent of the waxy. The volume and specific gravity of the classes of seeds were also determined in eight of the ears. The results showed that the differences in weight were associated with corresponding differences in volume, the specific gravity being the same for all classes.

## COMPARISON OF RESULTS WITH MENDELIAN EXPECTATION.

In the previous pages the classes occurring in the second generation of the sweet × waxy cross have been referred to as approximating a 9:4:3 ratio. While this approximation is so close as to exclude the possibility of finding any other ratio that will more closely fit the observed number, the deviations are too large to be ascribed to chance.

Table II gives the number of horny, sweet, and waxy seeds compared with the number expected in accordance with the above ratio. For both the horny and waxy it will be seen that the deviation for the entire series is more than five times the probable error. In the case of the sweet seeds the total deviation is no greater than should

[1] The two classes, colored horny and colored waxy, could not be weighed accurately, since these seeds had been clipped in order to determine whether they were horny or waxy.

be expected, but an examination of the separate families indicates that this agreement is accidental, for of the four families one is above the expected number by nearly five times the probable error and two are below by more than three times the probable error.

TABLE II.—*Proportion of sweet, waxy, and horny seeds of maize compared with the expected ratios.*

| Descriptive data. | Family. | | | | Total. |
|---|---|---|---|---|---|
| | Dh221. | Dh209. | Dh216. | Dh207. | |
| Number of ears | 12 | 14 | 17 | 12 | 55 |
| Number of seeds | 6,033 | 5,769 | 6,413 | 3,917 | 22,132 |
| Sweet seeds: | | | | | |
| Number | 1,399 | 1,358 | 1,720 | 986 | 5,463 |
| Expected number | 1,508±22.7 | 1,442±22.2 | 1,603±25.4 | 979±18.3 | 5,533±43.4 |
| Deviation | −109 | −84 | +117 | +7 | −70 |
| Deviation divided by probable error | 4.8 | 3.8 | 4.6 | .04 | 1.6 |
| Per cent | 23.2 | 23.5 | 26.8 | 25.1 | 24.7 |
| Waxy seeds: | | | | | |
| Number | 1,085 | 1,059 | 1,132 | 665 | 3,941 |
| Expected number | 1,131±20.4 | 1,082±20.0 | 1,202±21.1 | 734±11.5 | 4,149±39.1 |
| Deviation | −46 | −23 | −70 | −69 | −208 |
| Deviation divided by probable error | 2.3 | 1.1 | 3.3 | 6.0 | 5.3 |
| Per cent | 18.0 | 18.4 | 17.7 | 17.0 | 17.8 |
| Horny seeds: | | | | | |
| Number | 3,549 | 3,352 | 3,561 | 2,266 | 12,728 |
| Expected number | 3,394±25.9 | 3,245±25.3 | 3,608±26.8 | 2,204±20.9 | 12,450±49.6 |
| Deviation | +155 | +107 | −47 | +62 | +278 |
| Deviation divided by probable error | 6.0 | 4.2 | 1.8 | 3.0 | 5.6 |
| Per cent | 58.8 | 58.1 | 55.6 | 57.8 | 57.5 |

## CONCLUSIONS.

The general classification of maize varieties is based on the characters of the seed. Varieties with horny, soft, and sweet endosperm have been recognized since early colonial times, and these three types represent the only forms in which the endosperm of maize was known to exist until the discovery of waxy endosperm in a variety of maize introduced from China in 1908. Investigations of the heredity of this new type of endosperm show that when the Chinese variety is crossed with sweet varieties seeds are produced which, unlike either parent, have a horny endosperm. Although this synthetic horny endosperm is indistinguishable from that of ordinary field varieties, it behaves in an entirely different manner in the following generation.

All of the plants grown from these hybrid seeds produced ears with horny, sweet, and waxy seeds. The proportion in which the three classes occurred approximated nine horny, four sweet, and three waxy, a ratio indicating that the sweet and waxy characters are the result of independent factors and that one out of every four sweet seeds, though indistinguishable from ordinary sweet seeds in the first generation, represents a new type of sweet corn. Experiments have been outlined for isolating and determining the nature of this new type.

Since all three classes of seeds occurred on the same self-pollinated ear, it was possible to compare the weights of the three classes where the parentage of all was identical. The horny, waxy, and sweet seeds from each of 49 ears were separately weighed. The result showed that in nearly every ear the horny seeds were heavier than the waxy, which were in turn heavier than the sweet. Specific-gravity determinations of the different classes showed no significant differences. The differences in weight must therefore be due to differences in size.

[Cir. 120—D.]

# LEAF-CUT, OR TOMOSIS, A DISORDER OF COTTON SEEDLINGS.[1]

By O. F. Cook, *Bionomist in Charge of Crop Acclimatization and Adaptation Investigations.*

## INTRODUCTION.

Seedlings and young cotton plants are subject to a peculiar disorder that results in extensive injury to the leaves and frequent abortion of the terminal bud. While these injuries are seldom fatal, they undoubtedly impede the growth of the plants, delay the period of production, and reduce the crop. Though not taken into account hitherto, the losses occasioned by the leaf-cut disorder, though most severe in the Southwestern States, seem to be very general and must amount to millions of dollars every year. With the advance of the boll weevil this form of injury to the young plants acquires a more serious aspect, because it is of the utmost importance to shorten the period of production in order to avoid damage by the weevil. The leaf-cut handicap can be reduced by improved cultural methods, as stated in previous publications of the Bureau of Plant Industry.[2]

## LEAF-CUT DISTINGUISHED FROM LEAF-CURL.

Leaf-cut is suggested as a popular name because mutilations of the leaves are the most characteristic symptom of the disorder. The name "juvenile leaf-curl" has been applied in previous publications, but is inconveniently long and not sufficiently distinctive. Moreover, the leaves of cotton seedlings are subject to another malformation, induced by plant lice, for which the name "leaf-curl" is more appropriate.

Leaf-cut is very widely distributed and familiar to planters, though generally confused with the leaf-curl caused by plant lice. Though both forms of injury are likely to be found in the same field, or even on the same individual plant, they are easily distinguished. (Fig. 1.) The leaf-curl is a crumpling or arching up of the leaf between the veins, but without perforations or rents. Even in cases of great distortion by leaf-curl the tissues of the leaf are left entire, without

[1] Issued Apr. 5, 1913.

[2] See Report of the Chief of the Bureau of Plant Industry, U. S. Department of Agriculture, for 1911, p. 24; for 1912, p. 27; and U. S. Department of Agriculture, Bureau of Plant Industry, Circular 96, p. 13.

being punctured or torn. Leaf-cut injuries, on the other hand, represent an actual destruction of some of the tissues of the leaf, leaving irregular holes or marginal incisions. In single words, leaf-curl may be described as distortion of the leaves, leaf-cut as mutilation. In allusion to this distinction the word "tomosis" is proposed as a technical name for the leaf-cut disorder, while the distortion caused

FIG. 1.—Young plant of Egyptian cotton grown at Lanham, Md. The lower leaves are affected by leaf-cut and upper leaves by leaf-curl. (Natural size.)

by the plant lice may be called "hybosis." The insects inhabiting the badly distorted upper leaves of figure 1 were identified by Mr. Th. Pergande, of the Bureau of Entomology, as *Aphis gossypii* Glover.

And in addition to the open wounds that result from leaf-cut there are usually some that have healed, giving a characteristic torn-and-mended appearance. Such scars, like other leaf-cut wounds, often lie in a somewhat radiating position between the principal veins. Healing of wounds and regeneration of lost parts show that the injuries are liable to occur at a very early stage in the development of the leaf. Sometimes an extensive new growth or regeneration takes place, resulting in a curious doubling or overlapping of lobes of injured leaves. The power of the injured tissues to heal is also responsible for adhesions between parts that lie folded together in the bud. These adhesions are usually responsible for failure of normal expansion of the blade. None of these secondary symptoms occur with the leaf-curl induced by plant lice.

## CAUSES OF LEAF-CUT INJURIES.

Leaf-cut is hardly to be reckoned as a disease unless the word is used in its most general application that includes any departure from normal structure or function. Neither of the two general classes into which diseases are usually divided, constitutional and parasitic, would include the leaf-cut. Though some of the cells are destroyed, the remaining tissues of the plant do not become abnormal in any way, and there is no indication that parasitic organisms of any kind—bacteria, fungi, insects, mites, or worms—are involved. Another class of ecological disorders may need to be recognized, intermediate between physiological diseases and mechanical injuries or traumatisms. Leaf-cut is a disease only in the sense that frostbite, snow blindness, and other environmental injuries are to be considered as diseases.

Young cotton plants are often subjected to extreme conditions during the early stages of growth, when the leaf-cut injuries occur. The leaves and roots are still close to the surface soil, where they can be chilled at night and scorched in the daytime. Cold nights are sometimes looked upon as the cause of the injury, and may be an intensifying factor, but the sudden heat of a bright morning sun seems more likely to kill the cells of the young leaves than low temperatures during the night. Leaf-cut often affects late plantings long after the night temperatures have ceased to approach the freezing point. It has been noticed that exposure to a bright morning sun after a cold night will throw cotton seedlings temporarily into a wilted state, doubtless because the leaves lose water by transpiration faster than it can be absorbed by the chilled roots. Leaf-cut seems to be especially prevalent under such conditions.

That leaf-cut is in some way connected with exposure or wilting of the delicate tissues is also shown by the fact that the injuries are most severe and occur most frequently along radiating lines midway between the principal veins. These lines of greater susceptibility represent the most exposed parts of the upper surface of the young leaf as it lies folded in the bud. The only suggestion for explaining the very irregular manner in which the cells are killed is that some of them may be unable to complete their divisions and nuclear readjustments during the night and may thus be left in an unusually susceptible condition. Sections of injured leaves prepared by Dr. Albert Mann, of the Bureau of Plant Industry, show that nuclear and protoplasmic disintegration are the earliest symptoms. The damage often begins with the death of a single cell, which results, of course, in increased exposure for the neighboring cells.

Plants protected by partial shade suffer less than those that are fully exposed, but, on the other hand, full exposure does not induce leaf-cut when the plants are growing on wet land, where the surface remains moist and is kept cool by evaporation. The moist atmosphere and partial shade afforded by ordinary greenhouse conditions also afford complete protection from leaf-cut.

Even in parts of the same field there may be obvious differences in the extent of leaf-cut injury. Plants that stand close together often show much less injury than more scattering plants in the same rows. Where the soil is too dry to germinate all the seed the leaf-cut injuries are more extensive. Such differences indicate the possibility of avoiding or reducing the damage from leaf-cut by giving better attention to the seed bed and to methods and times of planting and thinning.

## ABORTION OF TERMINAL AND AXILLARY BUDS.

Though mutilation of the leaves is the most frequent and familiar symptom of the leaf-cut disorder, abortion of terminal buds is a more serious injury. In severe cases of leaf-cut, from 30 to 60 per cent of the plants have been found with their terminal buds aborted. When the leaf-cut injuries are confined to the individual leaves the effect is merely to retard the growth of the plant, but when the terminal bud is lost the plants are permanently deformed and usually produce a much smaller and later crop than normal individuals in the same field.

In the most severe form of the disorder the young seedlings lose the buds in the axils of the cotyledons as well as the terminal bud. Such plants are unable to form any true leaves, but the cotyledons increase in size and the hypocotyl becomes much thickened. In some cases the root begins to form a subterranean shoot, like those that develop vegetative buds when plants have been killed to the ground in the winter. When abortion of the bud takes place higher up, so that the plants have one or two true leaves, the blades grow much larger than usual and the petioles become greatly elongated. If thinning be deferred until the normal plants are 10 inches or a foot high it is easy to distinguish and remove the deformed individuals and leave only the healthy and vigorous ones. Under the usual plan of thinning the cotton early it is much more difficult to recognize and remove the injured plants.

## SUSCEPTIBILITY AND IMMUNITY.

Susceptibility to leaf-cut is usually limited to the seedlings and young plants less than 10 inches high. Sometimes the change from susceptibility to immunity is very abrupt. Plants that have had every leaf injured up to the sixth or eighth may then begin to put out entirely uninjured leaves. These abrupt changes may affect whole rows or fields of cotton, as if the later uninjured vegetation had grown out after a hailstorm. Whether the plants become immune to leaf-cut simply because larger stature carries the new growth farther away from the overheated soil, or because a deeper root system affords a more regular supply of moisture, or because the weather conditions become more uniform as the season advances has not been determined. All these factors may cooperate, or there may be others as yet unsuspected.

A few cases of abnormal individuals have been observed where injuries very similar to leaf-cut continued during the whole life of the plant. Some of these plants were hybrids and others were mutations, but all of them were abnormal in other ways, as well as in the irregular texture of the foliage. It seems not unreasonable to suppose that abnormal plants should remain more susceptible to any external conditions that have adverse effects upon the activities of the cells.

Though all the different types and varieties of cotton seem to be susceptible to leaf-cut injuries, certain differences have been noticed. The leaves of the Durango cotton and other Upland varieties are often injured much more seriously than those of Egyptian cotton in adjacent rows, but at the same time the Egyptian cotton may show a larger percentage of abortion of terminal and axillary buds. The immunity may lie in the improvement of conditions rather than in an increased resistance on the part of the plant. With the plant-lice injuries there is a gradual reduction of the amount of distortion that the insects are able to produce, which may indicate the development of a different kind of immunity in this disorder. It is true that the plant lice usually disappear as the season advances, but even when the insects remain abundant the distortion becomes less as the plants grow larger.

## CONCLUSIONS.

Leaf-cut is a disorder of cotton seedlings characterized by mutilation of the leaves and abortion of the terminal buds. Leaf-cut has been confused with the distortion of the leaves by plant lice, but the two malformations are readily distinguished.

Leaf-cut is in the nature of an environmental injury, not due to parasitic organisms or to constitutional weakness, but apparently connected with exposure to heat and dryness. All varieties of cotton are susceptible during the early stages of growth.

Though leaf-cut is not fatal, it is responsible for much damage by retarding the growth of the young plants. The loss of the terminal buds interferes with normal habits of branching, and the plants are permanently deformed. Damage from leaf-cut can be avoided or reduced by improved cultural methods, and the deformed plants can be removed by later thinning.



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