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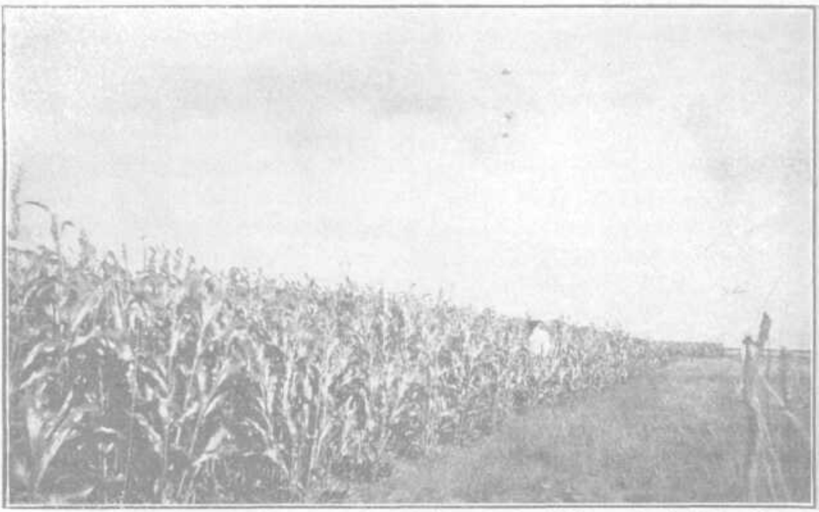

A field of Early Amber sorghum grown by a Sulphur Spring Valley settler in 1908 without irrigation.

Dry-Farming in the Arid Southwest

By R. W. Clothier

Tucson, Arizona, February 1, 1913

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Visitors are cordially invited, and correspondence receives careful attention.

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PREFACE

The statement has often been made that remunerative crops can be grown in southern Arizona by irrigation only; and it has been customary to measure the possibilities of agriculture in the region by the irrigating water supply to be derived from stream-flow, by storage, and from wells.

It is usual, however, in the investigation of a new subject, or of an old subject under new conditions, to proceed from self-evident facts to those refinements of natural truth, less easily perceived, that are often of greatest significance and value to humankind. In the study of arid-region agriculture we have thus been led from the gross application of acre-*feet* of irrigating water in a semi-arid region to an effective use of *inches*.

Dry-farming practice, as applied in regions further to the north and east, has been found of uncertain value in Arizona, due to the severer climatic conditions. Because of smaller rainfall and greater evaporation, soil mulches do not conserve moisture as they do in Colorado, Utah or Montana; but their maintenance leads to the formation of subsurface crusts, with consequent water loss and adverse soil conditions. Consequent upon these differences in climate, we find it necessary to revise dry-farming practice and adapt it to the requirements of a semi-arid and subtropical country. Methods of culture must be modified; crop plants must be chosen with more than ordinary care; results must be insured by means of supplemental irrigating water applied at critical times to start or save a crop; and plans of farm management must be devised for the most advantageous use of resulting produce.

The studies recorded in this publication have outlined for us a likely plan of agriculture for the great valleys of southern Arizona, with elevations of 3,000 to 5,000 feet. The main features of this plan are: (1) conservation, for the earliest possible use by crops, of rainfall by dry-farming methods of culture; (2) the use of supplemental, stored or pumped irrigating water; (3) the hardiest and most drouth-resistant crop plants; (4) silos to conserve forage supplies; and (5) livestock to convert crops grown, into marketable produce.

Of these several features the most distinctive is the use of supplemental irrigating water. This is applied in small amounts to start certain crops, such as corn, during the dry fore-summer in time to mature before frost; to develop the root systems of plants in time to make maximum use of summer rainfall, and to tide crops through periods of drouth. Two acres of milo maize, thus irrigated with four inches of supplemental water pumped from a depth of 180 feet, is stated to produce a crop, at no greater cost and equal in value, to six tons of alfalfa grown on one acre with four acre-feet of water pumped from a depth of 30 feet. This statement, if true, prophesies the development of great areas of new country hitherto considered fit only for grazing purposes.

The farmer himself, however, is by far the most important factor in Southwestern dry-farming practice, for the system is complex, requiring good knowledge of the properties of soils, intelligent choice and use of tools, knowledge of methods of planting, skill with machinery, and expertness in the management of animals. The successful farmer, therefore, must develop along several technical lines before he is ready to unlock the bounties of his desert acres. Nowhere is it more true that

"Strength of heart and might of limb,
But, mainly, *use and skill* are winners
In this pastime of our King."

Primarily, then, the problem is educational, and calls for the use of every feasible means to instruct and inform the men who are entering upon the exacting work of reclamation. It is upon this understanding that we now propose to demonstrate dry-farming methods upon a well equipped farm in Sulphur Spring Valley, and spread better knowledge of correct agricultural practice among the people of the region by means of farmers' institutes and short courses of instruction.

R. H. FORBES.

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DRY-FARMING IN THE ARID SOUTHWEST

By R W Clothier

INTRODUCTION

Dry-farming is not a new system of farming. Rather, it is a new name for practices which, probably since ancient times, have been employed by certain of the Old World peoples in the cultivation of their semi-desert empires. In the United States, however, it is of comparatively recent development. It was employed as early as 1865 by the farmers of Bear River Valley, Utah,* in growing wheat on higher lands after their fields had been ruined by over-irrigation. Later, H W. Campbell, a farmer of North Dakota, began experiments in accumulating and conserving moisture by methods of tillage; and he invented an implement called a subsurface packer This work brought him before the public, and the Santa Fe Railroad made arrangements with him for investigations on a much larger scale in western Kansas and western Nebraska. The results of these investigations, together with his invention, have now identified his name with dry-farming wherever it is practiced Since the beginning of Campbell's work, investigations have been made and publications on various phases of the subject have been issued by the Experiment Stations of many western states and by the United States Department of Agriculture.

Dry-farming is not farming without water, as has been supposed by many persons not conversant with the system, but who have heard of the results obtained by it. Briefly defined, dry-farming consists in accumulating and retaining in the soil as much as possible of a limited rainfall, until sufficient water is stored to mature a crop. The most economical use possible is then made of the stored water by growing early, quickly maturing, and drouth resistant crops, and by giving such crops thorough intertillage while growing, provided their habits of growth allow such intertillage

TECHNIQUE OF DRY-FARMING

Water is accumulated in the soil by means of deep plowing, or subsoiling, thus providing a large amount of loose soil into which the

*Utah Sta. Bull 112, p 95

rainfall percolates quickly and is absorbed, instead of running off into drainage streams, as is the case where it falls upon hard ground. Extended experiments by the Utah Experiment Station have shown that, in Utah, the proper depth of plowing is eight to ten inches. While occasional increased yields are obtained by deeper plowing, up to fifteen inches, the increase has not been sufficient to pay for the added labor. Experiments in subsoiling have shown that the practice is of doubtful value compared with plowing eight to ten inches deep.*

Moisture, which has been accumulated, is conserved in the soil by summer fallowing and intertillage. Summer fallowing consists in allowing the plowed land to lie uncropped through one season's rainfall, and planting it the succeeding season. By this system a crop is grown each alternate year, or two successive crops may be grown and the land fallowed one year; or, when conditions are extremely unfavorable, the land may be fallowed two years and cropped one year. During the time of fallowing no weeds are allowed to grow, and, when possible, the land is harrowed or cultivated after every rain to form a loose, dry blanket through which moisture from below finds difficulty in passing. This is called the "dust mulch." Its effectiveness consists: *First*, in breaking the capillary passages between the soil below and the surface by creating pores so large that capillary water will not rise through them; for, as shown by experiment, capillary water rises only .545 inches in a tube one-tenth of an inch in diameter,† and this rise increases directly as the diameter diminishes. *Second*, the dust mulch prevents the circulating air above from coming in contact with the moist soil beneath. While crops are growing, the dust mulch is maintained by intertillage. Various kinds of cultivators are used for this purpose with crops that can be grown in rows, while grain crops are harrowed until too large for such treatment.

Summer fallowing has been successful nearly everywhere it has been tried in the United States and Canada. A typical result obtained by the Utah Experiment Station shows a total yield of 83.4 bushels of wheat per acre produced in three crops and two fallows against 73.7 bushels per acre in five successive crops. While the labor required to keep the fallowed land harrowed was no doubt greater than similar labor performed on the continuously cropped land, the fallowed land was plowed only three times against five times for the continuously cropped land, and the labor of seeding and harvesting in the two systems was also in the same ratio.

*Utah Sta Bull 112 p 134
†F H King, The Soil, p 138

The crops best adapted to dry-farming are the Turkish varieties of hard winter wheat, the Durum wheats, and various varieties of hard spring wheat for certain of the more northern regions, and the common Californian barley and Kherson oats for the inter-mountain states and Canada; while the Durum and hard winter wheats, Spanish peanuts, Early Amber sorghum, and the grain-bearing sorghums have been found best for the middle and southern parts of the Great Plains region.

The soils upon which the Utah Experiment Station* has conducted its investigations would all be classed as light to heavy sandy loams, according to their physical analysis, though one of them is reported as the "heaviest clay thus far encountered in Utah."

At Indian Head, Canada, 95 to 132 bushels of oats per acre have been produced on extremely heavy lacustrine clay. The general opinion expressed among investigators is, that if the soil is not too coarse the type is not so important as the depth. All agree that dry-farming soils must be six feet or more in depth to afford a reservoir large enough to store sufficient moisture for successful crops.

The chief tillage implements used in dry-farming are the plow, the disk harrow, the Acme harrow, the common peg-tooth harrow, the "sweep," which may be used as a separate implement or attached to the common cultivator instead of ordinary shovels, the Planet Junior 14-tooth harrow and other similar implements, common cultivators with narrow shovels, the disc press drill, the common lister, and the subsurface packer. This implement, invented by Mr. Campbell, is designed to pack the soil beneath the surface, and is stated by him to be effective in assisting the rise of capillary water from the deeper subsoil into the zone occupied by plant roots, while at the same time it provides a loose and somewhat cloddy dry mulch at the surface which prevents evaporation and holds the soil in place against heavy winds. The Langly loose ground lister, of comparatively recent invention, also gives promise of being a valuable implement. In extensive operations gang plows with from two or three to a dozen or more plows are used. These are drawn by several teams of heavy horses or by traction engines. The nature of dry-farming operations makes it desirable that large implements with adequate power be used in order to do the work as quickly as possible. Thus, the cost of the labor is greatly reduced, making it possible to farm lands at a profit with less yields than when labor is not so economically administered.

*Utah Sta Bull 112, p 142

RAINFALL IN DRY-FARMING REGIONS

The annual rainfall in the dry-farming regions of the United States varies from comparatively high in some years to very low in others. In Utah, during seven years of experimentation, the average has been 13.15 inches in a six years' record at the farm having the least precipitation, and 19.09 in a four years' record at the farm having the greatest precipitation; while other records show 14.62 inches as an average of fourteen years in one locality, and 11.88 inches as an average of thirteen years in another locality. In Montana the average precipitation is from 12 to 15 inches. In Wyoming it runs from 13 to 20 inches in the regions believed to possess dry-farming possibilities. In eastern Colorado the annual rainfall is from 13 to 19 inches. In the dry-farming regions of western Kansas, Nebraska, Oklahoma and Texas, it is from 16 to 20 inches. In the Columbia Basin it runs from 10 to 25 inches. In Saskatchewan it runs from 14 to 23 inches, the average at Indian Head being 16.55 inches for a period of sixteen years. Of course, the rainfall is more effective for crop production in the cooler regions. The season of the year in which it falls is also of importance in determining what crops will be successful. For example, nearly all the rain in Utah falls during the winter and spring months, making ideal conditions for the production of wheat. Sixteen inches of rain distributed at this season of the year should be as effective in the production of wheat as double that amount in eastern Kansas, where the greatest precipitation occurs during the summer months. The annual rainfall in the proven dry-farming regions of North America will average very close to sixteen inches, while very few successes are reported with rainfall of less than twelve inches.

DEVELOPMENT OF DRY-FARMING IN ARIZONA

The well known rapid rise during recent years in the price of good farm lands in the more humid regions, as well as in the irrigated sections of the United States, has forced prospective farmers with limited capital to seek homes in the more arid parts of the country. By the use of dry-farming methods these men have shown that successful farming is possible in regions hitherto believed to be unreclaimable. The publication of their results and those of other investigators, and the bringing of these more prominently before the public by the International Dry-Farming Congress, have stimulated an interest in dry-farming throughout the world. The people of Arizona have shared in this general interest; but it is only quite recently that they have awakened to the possibility of applying this method to their own lands.

Some of the earliest settlements in Arizona were in isolated mountain valleys where farming without irrigation was carried on to a limited extent by stockmen, and with considerable success, but no general attempts were made elsewhere. Previous to 1905, a long series of years in which the annual rainfall was much below the normal average discouraged all attempts at dry-farming. In 1905, however, the annual rainfall was much above the normal and moisture conditions were such that a crop of barley could have been grown successfully on almost any mesa in the State, as was done in several instances. In the two years following 1905, the rainfall was also again above normal, and further attempts at dry-farming were made in various places. Then a general interest was awakened and requests began coming to the Experiment Station for advice and assistance, chiefly from St. Johns and Snowflake in the northeast and from Sulphur Spring Valley in the southeast.

THE DRY-FARMING DISTRICTS IN ARIZONA

As a result of these inquiries reconnaissance trips were made into these two sections of the State, and into several others, to determine the probable area of dry-farming lands, and to gain some idea of the possibility of reclaiming them. The information obtained on these trips may be summarized briefly as follows:

There are two climatic zones in Arizona, defined by altitude rather than by latitude, in which attempts at dry-farming have been made with more or less success. One of these consists of the narrow valleys, open parks, and table-lands lying at an altitude of from 5,000 to 8,000 feet in the various mountain chains of the State. The other consists of broad mesas and wide valleys lying between mountain ranges at elevations from 3,500 to 5,000 feet or more.

In the first zone are found the open parks in the San Francisco Mountains near Flagstaff, estimated to contain 35,000 acres; those near Williams, estimated at 10,000 to 20,000 acres; similar parks and valleys in the White Mountains, and a rolling table-land covered with cedar and pine trees lying in the Mogollon range, between the districts covered by the old lava flows from the San Francisco peaks and those from the extinct volcanoes of the White Mountains, estimated to contain at least 500,000 acres; and several small valleys lying south of Prescott, together with several similar valleys in the Huachuca Mountains, containing in all probably 15,000 acres. These are the most important districts in this zone.

In these places farming without irrigation has been carried on for many years with considerable success. Grain hay has been reported to yield from one to three tons per acre; potatoes, one to twelve tons; and corn, ten to forty bushels. All kinds of vegetables do well, and fruit trees, especially apples, thrive and bear abundantly when the blossoms are protected from frost. These districts are surrounded by fine grazing country, and the opportunities to combine dry-farming with stock raising are good. The rainfall varies, but some indication of its amount is found in Table I.

TABLE I.—AVERAGE RAINFALL IN THE MOUNTAIN VALLEYS AND TABLE-LAND DISTRICTS OF ARIZONA

Locality	Date of record	Number of years averaged	Average annual rainfall in inches
Prescott	1870-1911	42	15.66
Congress	1897-1910	14	13.54
Natural Bridge	1890-1911	22	21.94
Jerome	1897-1911	14	18.67
Tonto	1893-1910	15	16.53
Fort Apache	1876-1911	34	18.75
Flagstaff	1898-1911	14	23.41
Fort Huachuca	1886-1911	26	16.75

Several large districts are found in the second and lower dry-farming zone. Of these, Sulphur Spring Valley, lying between the Chiricahua and Pinaleno ranges on the east, and the Galiuro, Dragoon and Mule Mountains on the west, is the largest. It contains about 1,000,000 acres. Its elevation averages a little more than 4,000 feet, and it slopes gently to the south. Its soil is varied in nature, ranging from a quite porous sand to a heavy black silt. The heavy soil is covered with a luxuriant growth of grasses, while the sandy soil supports a more or less dense covering of low-growing mesquite.

Many claims have been filed on in this valley, the centers of settlement being Douglas, McNeal, Whitewater, Light, Cochise and Willcox. The rainfall of the district is indicated by the records found in Table II.

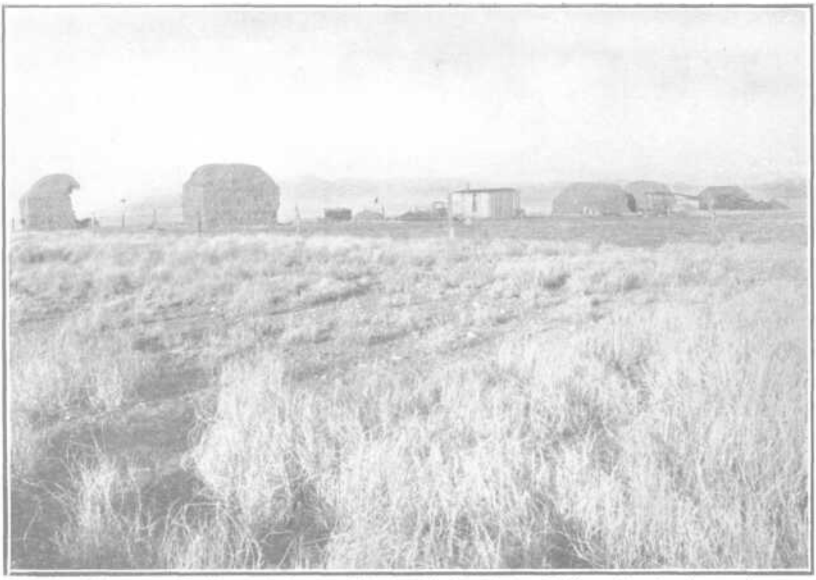

Fig. 1.—View on a dry-farmer's desert claim in Sulphur Spring Valley, showing house, horse-power pumping device for well and stacks of native hay. Elevation 4,100 feet.

Fig. 2.—An open park in the San Francisco Mountains. Elevation 7,000 feet.

PLATE II.—TWO TYPES OF DRY-FARMING COUNTRY IN ARIZONA DEFINED BY ALTITUDE RATHER THAN BY LATITUDE.

TABLE II.—AVERAGE ANNUAL RAINFALL IN SULPHUR SPRING VALLEY, ARIZONA

Locality	Date of record	Number of years averaged	Average annual rainfall in inches
Cochise	1890-1910	19	11 51
Willcox	1881-1910	30	10 50
Douglas	1890-1896, 1904-1911	15	14 24
Allaire's Ranch	1895-1910	16	11 53

The average rainfall given for Douglas is perhaps a little higher than would be typical of this part of the valley, as the records from 1890 to 1896, inclusive, were taken at Walnut Ranch, a point about fifteen miles northeast of the present town of Douglas in the Swisshelm Mountains at an elevation of 5,600 feet.

An area somewhat similar to Sulphur Spring Valley begins at Naco and extends in a broken belt, four to twelve miles wide, around the east and north slopes of the Huachuca Mountains, the north slope of the Canille Hills, the west slope of the Whetstone Mountains, and the east slope of the Santa Rita Mountains. A fair estimate of dry-farming lands in this district would be 500,000 acres. A considerable number of settlers have filed claims, the centers of settlement being Canille, Elgin, and Greaterville. The records given in Table III, taken either in or near the district, indicate the rainfall.

TABLE III.—AVERAGE ANNUAL RAINFALL IN UPPER SAN PEDRO VALLEY AND EMPIRE RANCH DISTRICTS, ARIZONA

Locality	Date of record	Number of years averaged	Average annual rainfall in inches
Pantano.......... ...	1881-1894	14	12.40
Calabasas.....	1890-1894	5	12.34
Camp Crittenden	1869-1873	5	16.51
Fairbank...	1890-1892	3	10,83
Empire Ranch...	1895-1908	14	15.62
Fort Huachuca	1886-1911	26	16.75

A large district with good soil and medium rainfall surrounds the town of Bowie. Many settlers are filing claims there. East of Bowie, at San Simon, an artesian water belt is being opened up, and it is probable that this district will be favorable to a combination of dry-farming methods with pumping. The annual rainfall at Bowie is 14.10 inches, this being the average of records for twenty-three years, taken between 1868 and 1907.

The northeastern part of the State contains quite a large area believed to possess dry-farming possibilities. It consists of broad mesas and narrow valleys extending away from the mountains on the north and south of the Little Colorado River. Its elevation averages about 5,000 feet. The southern portion of this area supports a few farmers who are trying to grow crops without irrigation; while in the stream courses of the north the Navajo and Moqui Indians have grown "squaw" corn for many generations. Very little reliable information about the rainfall of this region has been obtained, but the records given in Table IV probably represent the extremes of the district.

TABLE IV.—AVERAGE ANNUAL RAINFALL IN ST JOHNS AND SNOWFLAKE DISTRICTS, ARIZONA

Locality	Date of record	Number of years averaged	Average annual rainfall in inches
Showlow	1890-91, 1894-96, 1902-3	7	19.75
Winslow	1899-1900, 1909-10	4	7.08
Holbrook	1887-1910	20	9.00
St Michaels	1852-1860	21	13.77
Fort Defiance	1897-1911		

Between Prescott and Flagstaff is another large district estimated at 500,000 acres which has dry-farming possibilities. Lonesome Valley, Big Chino Valley, and Little Chino Valley, are the largest areas in this district. The soil is deep, free from alkali, and varies from a heavy silt to a sandy silt loam. We have almost no rainfall records taken within the district itself, but those given in Table V, were taken at contiguous points and indicate its possibilities.

TABLE V.—AVERAGE ANNUAL RAINFALL IN THE LONESOME VALLEY DISTRICT, ARIZONA

Locality	Date of record	Number of years averaged	Average annual rainfall in inches
Walnut Grove	1898-1908	11	12.64
Columbia	1907-1911	5	16.28
Congress	1897-1910	14	13.54
Yarnell	1899-1909	11	19.00
Prescott	1870-1911	42	15.66
Jerome	1897-1911	14	18.67

Settlements have been made in the upper San Simon Valley near Rodeo, New Mexico, and have met with limited success. The soil and general lay of the land is somewhat similar to that of Sulphur Spring Valley. The rainfall is also probably similar, although we have no records for this district.

PLANS FOR EXPERIMENTAL WORK IN DRY-FARMING

In the fall of 1908 the El Paso and Southwestern Railroad gave to the Experiment Station the sum of $2,000 to be used for dry-farming investigations in the southern end of Sulphur Spring Valley. In the spring of 1909, the Twenty-fifth Territorial Legislature appropriated $3,000 to be used for dry-farming investigations in the northeastern and southeastern parts of the State. A dry-farm for investigations in the northeast was obtained at Snowflake, and another for investigations in the southeast was obtained near McNeal, a station on the Courtland branch of the El Paso and Southwestern Railroad, situated about eighteen miles northeast of Douglas, Arizona.

THE SNOWFLAKE DRY-FARM

For administrative reasons the dry-farm at Snowflake, in the northeastern district was not plowed until the winter of 1909-1910. Consequently, the first plantings were made in May 1910, and these proved failures due to adverse climatic conditions. Therefore, the major part of this bulletin is devoted to work in Sulphur Spring Valley, but many of the observations made there are applicable to other districts in Arizona.

The rainfall at Snowflake during the first crop season was but 3.72 inches and the crops were all failures. Plantings were again made in the spring of 1911, beginning April 20 and ending April 29. Heavy winds, occurring May 13 to 19, blew out all plants on land that was summer fallowed the year before, and frost on May 16 damaged all beans considerably. Winds again, May 29 to June 2, blew off all the dust mulch from the summer fallowed land that had been disced after the preceding wind, and also blew out all plants on the continuously cropped land. Several plots that were close to a bluff, out of the way of the blowing sand, and brought up by supplemental irrigation, escaped damage from the wind. The plots that were destroyed by the wind were replanted June 13 to 17, but there was insufficient moisture in the ground to bring them up until after the rain on July 1. The total rain from October 1910 to October

1911 was 14.10 inches, of which 9.87 inches fell during the growing season of 1911, most of which was probably available to plants. The crops were cultivated after rains, and weeds were kept hoed out. Frost, sufficient to kill all plants, occurred October 19, but most of the crops were harvested before this frost. The grain of milo, sorghum and Kafir did not mature. Also, the grain of Red Dent corn did not mature. Some of the more promising yields are shown in Table VI.

TABLE VI.—YIELDS OF VARIOUS DRY-FARM CROPS AT SNOWFLAKE, 1911

Crop	Pounds per acre	
	Forage	Grain
	Irrigated once before planting	
Milo maize	3240	Immature
Sorghum	3240	Immature
Kafir corn	4960	Immature
Red Dent corn	4840	Immature but heavily eared
White Flint corn	1680	252
Pink beans	...	128
Yellow tepary beans	....	220
Cream Dent corn	3636	1120 Partly immature
	Summer fallowed the previous year	
White Flint corn	2540	440
Broom corn	4108	Straw immature
Sorghum	4000	Immature
Pink beans	....	204
Milo maize	2460	Immature
Kafir corn	2400	Immature

The greatest difficulty encountered at Snowflake was the heavy winds that occurred after the plants were up in the spring. The plants were not only blown out of the ground by the winds in May, but the soil was removed to a depth of five inches. However, it was believed that the soil of this farm was damaged more by winds than average soils in the locality, and that results obtained here, though suggestive of success in the region, were not representative. The farm was abandoned in 1911, and a new one selected four miles farther south, in a location believed to be more typical of the district. The rainfall during the time the farm was operated is recorded in Table VII.

TABLE VII.—RAINFALL AT DRY-FARM, SNOWFLAKE, ARIZONA

Date	Rain-fall in inches	Total for month	Date	Rain-fall in inches	Total for month	Date	Rain-fall in inches	Total for month
1910			1911					
May........	.00	.00	Jan. 12....	.10	...	July 28.....	.10	5.89
June 26.....	.25	...	Jan. 13.....	.17	...	Aug. 8	.34	..
June 27.....	.35	.60	Jan. 23.....	.03	...	Aug. 9. ..	.23	...
July 14......	.10	...	Jan. 26.....	.08	.38	Aug. 11. .	.06	...
July 17......	.20	...	Feb. 4	.35	..	Aug. 15 ..	.20	..
July 22......	.32	...	Feb. 12....	.08	..	Aug. 19 .	.18	..
July 23......	.25	...	Feb. 16.....	.41	...	Aug. 20 ..	.24	..
July 24......	.16	...	Feb. 20.....	.05	...	Aug. 21 ..	.21	.
July 25......	.14	...	Feb. 28....	.03	.92	Aug. 22 .	.09	..
July 26......	.50	1.67	March 4...	.03	...	Aug. 24 ..	.06	...
Aug. 4.	.10	...	March 6...	.25	...	Aug. 25.....	.13	...
Aug. 10.....	.12	..	March 11...	.25	...	Aug. 27 . .	.06	1.80
Aug. 18.....	.21	...	March 19..	.02	...	Sept. 2. . .	.02	..
Aug. 19.....	.51	...	March 21..	.08	...	Sept. 11. .	.02	..
Aug. 25.....	.18	...	March 22 ..	.15	...	Sept. 12. ..	.12	..
Aug. 26.....	.23	...	March 24...	.15	.93	Sept. 15....	.21	..
Aug. 31.....	.10	1.45	April 2.....	.28	...	Sept. 16...	.24	..
Sept. 21.....	.06	.06	April 7.....	.13	.41	Sept. 18....	.03	...
Oct. 18......	.41	...	May........	.00	.00	Sept. 28...	.20	...
Oct. 19......	.23	.64	June 11.....	.08	.08	Sept. 29...	.50	...
Nov. 4......	.27	...	July 1......	.87	...	Sept. 30...	.05	1.39
Nov. 5......	.03	...	July 2......	.73	..	Oct. 5......	.10	...
Nov. 13.....	.06	...	July 3......	.35	...	Oct. 6......	.70	...
Nov. 14.....	.30	...	July 6......	.76	...	Oct. 26.. ..	.35	...
Nov. 26.....	.20	.86	July 11.....	.03	...	Oct. 27.....	.60	...
Dec.	.00	.00	July 12.....	1.50	...	Oct. 28	.22	1.97
			July 17.....	.34	...	Nov.	.00	.00
Total	.....	5.28	July 18	.03	...	Dec. 18.....	.60	...
			July 19.....	1.04	...	Dec. 24.....	.40	...
			July 25.....	.03	...	Dec. 29.....	.10	1.10
			July 26.....	.02	...			
			July 27.....	.09	...	Total...	.....	14.87

INVESTIGATIONS ON MOISTURE AND SOIL TYPES IN SULPHUR SPRING VALLEY

The precipitation in Sulphur Spring Valley during the three years, 1905 to 1907, was considerably above the normal. At Allaire's ranch, the station nearest the place where our work was done, the precipitation was 22.04 inches, 13 96 inches, and 17.34 inches, respectively. When compared with the average of 11.53 inches for this locality, it will be seen that these years were extremely favorable ones. A few miners from the neighboring mining towns, and a few families from Oklahoma and Texas moved into the Valley and filed upon claims; and, as the ground had become pretty well soaked with moisture from the recent excessive rainfall, the results obtained by them were favorable enough to attract the attention of real estate agents and promoters, who began to advertise the Valley as affording wonderful opportunities for new settlers. In the fall of 1908, when we began our investigations, it was estimated that at least one thousand claims had been filed upon. Occasional reports of large yields, such as thirty bushels of corn, three and a half tons of sorghum, and five hundred to one thousand pounds of beans to the acre added to the allurements of the Valley.

Very few of the settlers, however, put into practice the scientific principles that govern successful dry-farming, and they made slow progress. By means of windmill irrigation many of them engaged in gardening on small patches of ground, hauling their produce, in some cases, twenty-five miles to market; and in this manner managed to live. Meanwhile a few hundred acres were broken and experimented upon with corn, sorghum, and beans, growing the crops without irrigation. Only a small acreage on the various claims had been put under cultivation when the investigations to be described herein were begun. Such crops as were grown, were planted after the summer rainy season began, and given little cultivation. After the harvest the ground was allowed to lie unplowed until the next summer's rainy season. Information as to the best varieties of crops to grow was meager. No attempt had been made to store moisture or to conserve it. It was not known which of the various types of soil in the Valley would prove best adapted to dry-farming. Many settlers chose the sandy soil, even though this necessitated grubbing out the mesquite before it could be farmed, while others were just as eager to select the heavy black silt found in the prairie region of the Valley.

Three problems seemed to require investigation: *First*, to what extent may we store water, and conserve it through long periods of hot dry weather, by methods of tillage. *Second*, which of the various types of soil found in the Valley will prove best adapted to dry-farming under southern Arizona conditions. *Third*, what varieties of crops are likely to prove best adapted to the conditions prevailing in the Valley. Later, a fourth problem, that of supplemental irrigation, was added.

For these investigations a farm belonging to Mr. Ed. Bower, who acted as foreman, was secured. The land was situated one mile east of Whitewater Wash and contained three distinct types of soil: a heavy black silt, a lighter and more sandy silt, and a medium light sandy loam. The depth to underground water was thirty-five feet. Eleven acres had been under cultivation two years and had grown crops of corn in 1907 and 1908. Fifteen acres more were broken in January and February, 1909, for experimental purposes.

EXPERIMENTS IN MOISTURE CONSERVATION

Attempts to conserve the moisture were made both by intertillage and by summer fallowing, with more or less success modified by adverse conditions other than drouth. The following discussion of rainfall conditions will assist in interpreting the results of this work. Records at Willcox extending over a period of thirty years, and at Allaire's ranch extending over a period of sixteen years, both stations being near the center of the Valley, show that a little less than two-thirds of the annual rainfall occurs during July, August, September, and October, and a little more than one-third during November, December, January, February, and March. The former months constitute the growing season for summer crops. The rainfall during April, May, June and often half of July is so small as to be useless and may be disregarded.

At the dry-farm only one-fourth of the annual rainfall occurred during the winter months in 1909, less than one-eighth in 1910, and about one-fifth in 1911. During the three years covered by our experiments the winter rainfall has been very much below normal. In 1909 the summer rainfall was normal, and in 1910 and 1911 it was above normal, as is shown in Table VIII.

TABLE VIII.—SUMMER RAINFALL AT THE DRY-FARM NEAR MCNEAL, ARIZONA, 1909 TO 1911

Year	June	July	August	September	October	Total
1909	0.00	2.79	3.92	0.41	0.12	7.24
1910	0.46	1.92	8.33	0.00	0.00	10.71
1911	0.94	3 13	1.73	3.25	2.04	11.09

The winter rainfall has occurred for the most part in light showers which have not penetrated the soil deeply enough to be retained. In no case has the winter penetration been more than nine inches. Five inches of this is necessarily lost in creating the dust mulch, and the balance soon dries out during the windy and sometimes very hot weather of April. Winter rainfall, therefore, has been of no value and may be disregarded in considering moisture conditions, although it necessarily figures in the total annual precipitation.

The summer rainfall is always local in character, sometimes falling in torrential storms and at other times in frequent light showers which do not penetrate the soil, and, therefore, are lost in the same manner as the winter rainfall. As an example of the local and torrential character of the rainfall the following incidents may be related. In August, 1911, at a point three and one-half miles north of the dry-farm, a rainfall of two inches occurred in twenty-five minutes, while beyond a radius of three miles in all directions from the storm center there was no precipitation whatever. In like manner, during August, 1910, the dry-farm was favored with several torrential rains which were not general in the Valley, and which brought the total rainfall for that month up to the very abnormal amount of 8.33 inches. Much of this precipitation was lost by running off as floodwater. It seems impossible to place the soil in condition to conserve moisture and at the same time to allow the penetration of two inches of water in twenty-five minutes. This was especially true of the heavier types of soil. On the other hand, a few plots received floodwater from other plots and from the surrounding prairie sod in such a manner as to allow penetration, and to raise their moisture content above normal. Evidence of this is presented in the moisture tables.

If rains are isolated, at least one-half inch must fall to penetrate the soil deeply enough to be of value, and even such rains must be followed by others within ten days or the moisture accumulated from them will be lost. Observations lead the writer to believe that no rain less than one-quarter inch is retained by the soil, except possibly by the most sandy soils; but that small showers of one-quarter inch or more are effective if they fall at intervals of not more than two days. Tables IX, X, and XI show the complete precipitation during the three years of our work, also the frequent light showers, the occasional torrential storms, and the amount of water believed to have penetrated the soil sufficiently to have been of some value.

The total amount of rain possible to have entered the soil during the three years was 29.97 inches, of which 1.43 inches came after operations had practically ceased, late in the fall of 1911. We attempted to conserve this by the usual three methods practiced in dry-farming; viz., by deep plowing to assist penetration and storage; by intertillage of crops to conserve as much water as possible for their use; and by fallowing the land, and harrowing or discing it after

TABLE IX.—RAINFALL RECORDS AT THE DRY-FARM NEAR MCNEAL, ARIZONA, 1909

Date	Rainfall inches	Pene-trating	Not pene-trating	Total by months	Date	Rainfall inches	Pene-trating	Not pene-trating	Total by months
Jan. 27...	.03	....	.03	.03	July 24..	.18	....	.18	....
Feb. 7...	.03	....	.03	....	July 31..	.33	.33	....	2.79
Feb. 11..	.11	....	.11	....	Aug. 2...	.22	.22	....	....
Feb. 21..	.18	....	.18	....	Aug. 4...	.04	....	.04	....
Feb. 22..	.04	....	.04	.36	Aug. 7...	.74	.74	....	....
Mar. 10..	.37	.37	....	....	Aug. 9...	.22	.22	....	....
Mar. 12..	.52	.52	....	....	Aug. 11..	.32	.32	....	....
Mar. 26..	.32	....	.32	1.21	Aug. 12..	1.11	1.11	....	....
April....	.00	....	....	.00	Aug. 14..	.02	....	.02	....
May.....	.00	....	....	.00	Aug. 15..	.02	....	.02	....
June.....	.00	....	....	.00	Aug. 16..	.06	....	.06	....
July 5...	.40	.40	....	....	Aug. 17..	.59	.59	....	....
July 6...	.33	.33	....	....	Aug. 22 .	.12	....	.12	....
July 15..	.07	....	.07	....	Aug. 30..	.04	....	.04	....
July 16..	.02	....	.02	....	Aug. 31..	.42	.42	....	3.92
July 17..	.03	....	.03	....	Sept. 2..	.05	....	.05	....
July 18..	.17	....	.17	....	Sept. 3..	.16	....	.16	....
July 20..	.05	....	.05	....	Sept. 5..	.20	....	.20	.41
July 21..	.30	.30	....	....	Oct. 2...	.12	....	.12	.12
July 22..	.83	.83	....	....	Nov. ...	.00	....	....	.00
July 23..	.08	....	.08	....	Dec. 18..	.65	.65	....	....
					Dec. 23..	.27	.27	....	.92
					Totals..	9.76	7.62	2.14	9.76

TABLE X.—RAINFALL RECORDS AT THE DRY-FARM NEAR MCNEAL, ARIZONA, 1910

Date	Rainfall inches	Penetrating	Not penetrating	Total by months	Date	Rainfall inches	Penetrating	Not penetrating	Total by months
Jan. 11...	.09	....	.09	.09	Aug. 2...	04	...	04	....
Feb. 5...	.20	....	.20	.20	Aug. 8...	.60	.60	..	....
Mar. 18..	.09	....	.09	.09	Aug. 9...	.94	94	....	....
April 8...	.07	....	.07	.07	Aug. 12..	.14	....	.14	....
May.....	.00	....	...	.00	Aug. 17..	.14	....	.14	...
June 2...	.16	....	.16	....	Aug. 21..	2.65	2.65	....	....
June 3...	.07	....	.07	....	Aug. 23.	.79	79	....	...
June 27..	.20	....	.20	....	Aug. 28..	.67	.67	....	....
June 28..	.03	....	.03	.46	Aug 29..	.32	.32	....	8.33
July 13..	.13	....	.13	...	Sept.....	.00	....	....	.00
July 14..	.24	....	.24	....	Oct. 1 ..	.17	....	17	.17
July 17..	.14	....	.14	....	Nov. 3...	.10	....	10	....
July 22..	1 11	1 11	....	....	Nov. 13 .	73	.73	....	.83
July 24..	.22	.22	....	....	Dec.	.00	....	....	.00
July 27..	.08	....	08	1.92					
Aug. 1...	2 04	2.04	....	...	Totals..	12.16	10 07	2.09	12.16

every rain for the purpose of conserving the water of one season for use in growing crops the following season.

PLOWING

At the beginning of operations on the farm in January, 1909, part of it had been under cultivation two years and had grown two crops of corn. It had not been plowed after the second crop, but had been well disced, though the discing was shallow. Half of this land was cropped during the summer of 1909 and plowed eight inches deep after the crops were removed. The other half was fallowed and plowed eight inches deep as soon as possible after the summer rains had penetrated nine inches. The entire field was plowed eight inches deep after the removal of the crops grown in 1910. This field was designated "North Field."

The remainder of the land used in the experiments was broken six inches deep during the months of January and February, 1909. The sod, which was disced until fine, soon rotted. It was not plowed again until after half of it had grown crops in 1910, when it was all plowed eight inches deep. This land was designated "South Field."

TABLE XI.—RAINFALL RECORDS AT THE DRY-FARM NEAR MCNEAL, ARIZONA, 1911

Date	Rainfall inches	Penetrating	Not penetrating	Total by months	Date	Rainfall inches	Penetrating	Not penetrating	Total by months
Jan. 11...	.23	....	.23	....	Aug 10..	.19	....	.19	....
Jan. 12...	.08	....	.08	....	Aug. 13..	.05	....	.05	....
Jan. 17...	.06	....	.06	....	Aug. 16..	.15	....	.15	....
Jan. 23...	.49	.49	....	.86	Aug. 19..	.12	....	.12	....
Feb. 15..	.06	....	.06	....	Aug. 20..	.14	....	.14	....
Feb. 17..	92	.92	....	. . ..	Aug. 21..	.02	....	.02	....
Feb. 18..	.04	....	.04	....	Aug 22 .	.07	....	.07	....
Feb. 28..	.63	.63	....	1.65	Aug. 25..	.33	.33	....	....
Mar. 1...	.02	....	.02	....	Aug. 26..	.03	....	.03	....
Mar. 5...	.04	....	.04	....	Aug. 27..	.52	52	....	1.73
Mar 21..	.02	....	.02	....	Sept. 9..	.22	....	.22	....
Mar. 25..	.07	....	.07	15	Sept. 12.	90	90	....	....
April 2...	50	.50	....	50	Sept. 13.	20	20	....	....
May.....	.00	....	....	00	Sept. 14.	06	...	.06	....
June 11..	.78	.78	....	....	Sept. 16.	11	11	....	....
June 19..	.10	....	.10	....	Sept 17.	20	.20	....	....
June 28..	.02	....	.02	....	Sept. 18.	.33	33	....	....
June 29..	.04	....	.04	.94	Sept 25.	05	....	.05	....
July 2...	.18	....	.18	....	Sept. 26.	19	....	.19	....
July 8...	.05	. ..	.05	....	Sept 28.	98	98	....	3.[illegible]
July 9...	.63	.63	....	....	Oct. 5 ..	1 40	1.40	....	....
July 10..	.02	....	02	...	Oct. 26..	47	47	....	....
July 11..	.56	.56	...	....	Oct 28..	14	....	14	2.01
July 14..	.38	.38	....	..	Nov. 4. .	.09	...	.09	.09
July 16..	.40	.40	....	...	Dec. 8...	.64	.64	....	....
July 19..	.11	....	.11	....	Dec. 18 .	.09	....	09	....
July 20..	.59	.59	....	....	Dec. 21..	.32	.32	....	....
July 24..	.24	....	.24	3 16	Dec. 25.	.12	....	.12	1.17
Aug. 2...	08	....	.08	....					
Aug. 8...	.03	....	.03	....	Totals..	15 50	12.28	3.22	15.50

INTERTILLAGE

Summer plots were all cultivated in 1909 and 1910 with a fourteen-tooth Planet Junior harrow. In 1911, a two-horse John Deere cultivator with three narrow shovels on a side was used at least once on all plots, and other tillage was given with the Planet Junior fourteen-tooth harrow. In 1909 all crops were cultivated six times, and the work was done very effectively. In 1910 the cultivation was unsatisfactory for administrative reasons. The plots in the north field were cultivated three times. In the south field half of them were cultivated only twice and the remainder but once. Cultivation was not begun until after the rain of August 1, which so packed the ground that the crust formed in the rows was neither covered nor broken by the Planet Junior harrow. A luxuriant crop of weeds sprang up in the rows and grew rapidly. These, together with the capillary action of the crust, without doubt robbed all crops of much moisture that otherwise they might have used. In 1911 all crops were cultivated thoroughly at least three times. Weeds gave no trouble and it is doubtful whether any more moisture could have been conserved by more frequent cultivation.

It was intended at the beginning of the experiments to cultivate all crops after every rain, but, at times the rainy periods came so close together that sufficient labor could not be obtained to carry out the plan. With the exception of the season of 1910, it is probable that as much tillage was given as would be found profitable or practicable by the average farmer.

SUMMER FALLOWING

The soil in the north field was lighter colored and sandier than that in the south field, which was a heavy black silt. The two fields were selected to be handled separately as a test of two types of soil. Neither was uniform, however, each containing small areas of other types of soil which are noted in reporting the yields of crops. Only three types of soil are distinguished, and for convenience and simplicity these are referred to as "heavy," "medium," and "light." Moisture conditions will be best understood by discussing each field separately, then comparing results.

FALLOWING IN THE NORTH FIELD

The crop of corn grown in the north field in 1907, was estimated by Mr. Bower at twenty bushels to the acre. A second crop of corn in 1908 measured about ten bushels to the acre. Both years were favorable, as shown by the following data: The rainfall in 1905 had been about twenty-two inches, and in 1906 about fourteen inches (13.96 at Allaire's ranch, 13.12 at Douglas, and 17.95 at Willcox). The first rain in 1907, which was stated to have been a heavy one, came in May, and was sufficient to bring corn up and keep it growing until the later summer rains came. The soil, therefore, must have been fairly well filled with water when Mr. Bower began operations.

In 1907 the rains continued late in the fall, and there was a good early winter rainfall. The total precipitation at the farm for the year 1907 must have been fifteen or sixteen inches. (17.34 at Allaire's ranch, 14.74 at Douglas, and 17.83 at Willcox.) The summer rain of 1908, however, as reported by Mr. Bower, was deficient and the high yield of the previous year was cut from twenty bushels to ten bushels to the acre. The moisture in the soil was also considerably depleted as shown by determinations made later. Mr. Bower did not plow this land after removing the crop, but tried, instead, the experiment of discing to conserve the moisture, which it seemed best to continue when we began work on the farm in January. The experiment was not successful, probably because the discing was not deep enough. The dust mulch was not over two and a half inches deep, and the soil crusted very badly beneath it. At the time of planting in July, this crust ranged from four inches thick in the light type of soil to nine or ten inches in the medium soil.

Moisture was determined at four points in the field on December 30, 1908, on April 17, 1909, and on July 4, at planting time, just before the first rain of the summer season. Several samples were taken in July in addition to those from the original four places in the field. The field was then divided into two parts, the north half, which was to be cropped continuously, being planted at once; while the south half was fallowed in 1909 and cropped in 1910. Since there was no assurance that the work would be continued more than two years, no provision was made for fallowing the land in 1910 to be cropped in 1911. Fortunately, however, one plot in the light type of soil was so fallowed and the results will be discussed further on. In all types of soil, and in continuously cropped as well as fallowed land, the moisture was determined three times a year; viz., at the close of the winter rainy season, just before the summer rains began, and immediately after the summer rainy season closed. A few samples were taken at other times. The samples were taken with a 1½-inch soil auger; and, after the first few samples, all holes were bored eight feet deep, and each foot of soil saved separately for moisture determination. The general field samples were taken in the same region of the field each time, so that the results might be comparable, the places of boring being located by taking the northeast corner of the field as a datum point and pacing the distances west and south from this point.

TREATMENT OF FALLOWED LAND

The field was harrowed with a spike-tooth harrow after each rain. When the rainy seasons closed in the fall and in the spring, it was double disced five inches deep. If this did not dry out the dust mulch completely, the discing was repeated until a layer of dry soil five inches deep was formed, after which the land was not worked until the next rain. This treatment made a finer dust mulch than is desirable, and caused floodwater losses during the heaviest summer rains; but it is doubtful whether any treatment that would have conserved the moisture already in the ground would have prevented this loss because of the torrential nature of such rains. The following field notes show the amount of tillage necessary to keep the dust mulch loose and dry.

Single disced after harvest of 1908 Single disced December 19, after a light rain Single disced January 9, 1909 Double disced heavier soil and single disced lighter soil March 13 Harrowed with spike-tooth March 23. Single disced March 29 Harrowed with spike-tooth April 6 Double disced heavier soil May 5 Harrowed with spike-tooth July 7, July 23, and July 27. Began plowing July 29 and harrowed each day's plowing at the close of the day with the spike-tooth; about half the field plowed by August 7. Harrowed August 3, August 19, and September 6 Double disced September 21. Began plowing remainder of fallow land September 22, and finished September 25, harrowing the day's plowing each evening Harrowed with spike-tooth December 22. Harrowed with weighted spike-tooth January 24 Double disced April 5. Planted to crops, using lister, June 9 to 15, 1910 Crops cultivated three times during the summer, the last cultivation being on September 5, after the last rain of the season Double disced November 21, after a rain of .73 inches November 13 Plowed eight inches deep January 30 to February 6. Single disced February 6. Harrowed with spike-tooth February 22, March 4, and March 30 Double disced March 29 Harrowed with spike-tooth April 6. Double disced April 11. Harrowed with spike-tooth May 9 Weedy patches disced May 31. Harrowed with spike-tooth June 14, July 17, and July 26. Cultivated with two-horse cultivator August 7 Harrowed with spike-tooth September 2. Cultivated with two-horse cultivator October 18.

The land that was to be cropped continuously received the same tillage as the fallowed land, except that it was planted to crops with a lister July 4, 1909, and the crops were cultivated six times, the last cultivation being given September 1, after the last penetrating rain of the season. The crops were removed the first week in October and the land double disced October 21. It was plowed at odd times between December 14, 1909, and January 15, 1910. In 1910 crops were planted with a lister and cultivated three times during the season, the last cultivation being given after the last rain of the summer.

After harvesting the 1910 crops the land was disced November 23 and plowed January 4 to 16. The next crop was planted June 12, 1911, with a Hoosier double-disc press drill, harrowed after planting and cultivated four times during the summer.

Tables XII, XIII, XIV, and XV show the moisture conditions produced by this treatment in both the continuously cropped and the fallowed land. The number of inches of water was calculated from the volume weight of the soil, which was determined with the laboratory samples by an empirical method that, in the hands of the writer, gave results fairly identical with those obtained for the soil in its natural position.

The distribution of medium and light soils in the north field, and the treatment received by the various parts of the field during the period of and immediately before the experiments are shown in the following diagram. The numbers give the location of the borings from which the moisture samples with corresponding numbers were taken.

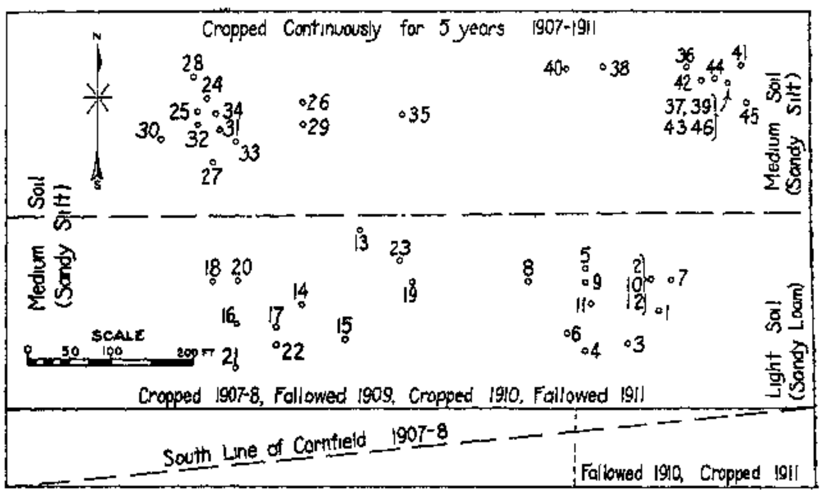

Fig 1.—Diagram of the north field showing location of borings from which soil samples for moisture were taken.

TABLE XII.—MOISTURE DETERMINATIONS IN LIGHT SOIL, NORTH FIELD, FALLOWED 1909, CROPPED 1910, FALLOWED 1911

No.	1		2		3		4	
Date	December 30, 1908		April 17, 1909		July 5, 1909		September 17, 1909	
Depth in ft.	Percent moisture	Inches water	Percent moisture	Inches water	Percent moisture	Inches water	Percent moisture	Inches water
1	6.88	1.21	8.08	1.35	7.46	1.26	12.77	2.09
2	7.26	1.23	6.70	1.14	7.93	1.37	12.20	2.04
3	5.31	1.02	6.55	1.13	7.57	1.35	5.67	1.02
4	3.34	0.59	6.87	1.19	10.70	1.77	6.70	1.18
5	8.64	1.14	6.68	1.39	10.43	1.73	7.93	1.32
6	8.72	1.37	11.90	1.90	15.65	2.48	8.50	1.38
7	.....	....	.....	....	17.67	2.75	13.75	2.10
8	.....	....	.....	....	13.03	2.11	14.95	2.35
Totals		.....		....		**14.82**		**13.48**

No.	5		6		7		8	
Date	September 17, 1909		April 3, 1910		June 11, 1910		June 11, 1910	
Depth in ft.	Percent moisture	Inches water	Percent moisture	Inches water	Percent moisture	Inches water	Percent moisture	Inches water
1	12.56	2.04	9.59	1.61	3.41	0.57	4.13	0.68
2	9.57	1.60	7.27	1.23	9.12	1.54	12.31	2.05
3	5.33	0.99	6.34	1.16	11.55	2.09	14.50	2.40
4	5.85	1.09	6.82	1.18	8.37	1.45	9.56	1.63
5	7.05	1.19	7.58	1.26	7.20	1.19	10.27	1.60
6	7.02	1.29	11.55	1.83	9.47	1.51	14.35	2.20
7	6.09	1.11	14.86	2.28	14.65	2.25	10.84	1.63
8	7.42	1.26	10.79	1.72	10.56	1.69	9.67	1.58
Totals		**10.57**		**12.27**		**12.29**		**13.77**

No.	9		10		11		12	
Date	September 17, 1910		June 10, 1911		September 15, 1911		November 1, 1911	
Depth in ft.	Percent moisture	Inches water	Percent moisture	Inches water	Percent moisture	Inches water	Percent moisture	Inches water
1	10.55	1.77	6.99	1.17	14.92	2.51	11.61	1.95
2	12.77	2.16	7.46	1.26	13.99	2.37	10.54	1.78
3	11.83	2.14	7.21	1.31	11.39	2.06	15.19	2.75
4	11.68	2.02	6.43	1.11	11.18	1.93	15.69	2.71
5	7.11	1.18	7.50	1.24	7.92	1.31	11.27	1.87
6	13.28	2.12	8.08	1.29	11.11	1.77	10.92	1.74
7	13.26	2.04	5.89	0.90	15.52	2.39	14.42	2.21
8	10.63	1.70	8.30	1.32	14.48	2.30	8.08	1.27
Totals		**15.13**		**9.60**		**16.64**		**16.28**

TABLE XIII.—MOISTURE DETERMINATIONS IN MEDIUM SOIL, NORTH FIELD, FALLOWED 1909, CROPPED 1910, FALLOWED 1911

No.	13		14		15		16	
Date	December 30, 1908		April 17, 1909		July 5, 1909		September 17, 1909	
Depth in ft.	Percent moisture	Inches water	Percent moisture	Inches water	Percent moisture	Inches water	Percent moisture	Inches water
1	9.52	1.61	9.90	1.57	7.02	1.16	16.51	2.58
2	7.50	1.39	9.05	1.41	8.05	1.30	12.58	1.99
3	11.63	1.93	8.46	1.37	8.27	1.39	11.40	1.75
4	15.45	2.43	6.77	1.19	6.29	1.15	9.55	1.55
5	19.23	2.96	10.47	1.61	10.47	1.64	12.21	1.77
6	18.78	2.89	13.56	2.05	14.37	2.19	14.70	2.15
7	.....	....	14.90	2.23	12.33	1.93	14.04	2.07
8	.....	....	10.71	1.71	7.69	1.37	10.67	1.64
Totals		....		13.14		12.13		15.50

No.	17		18		19		20	
Date	April 3, 1910		June 11, 1910		June 11, 1910		September 17, 1910	
Depth in ft.	Percent moisture	Inches water	Percent moisture	Inches water	Percent moisture	Inches water	Percent moisture	Inches water
1	9.04	1.50	6.04	1.00	5.62	0.93	12.23	2.03
2	8.86	1.48	9.37	1.56	7.61	1.27	14.50	2.42
3	10.31	1.71	10.23	1.69	9.72	1.61	19.76	3.27
4	5.91	1.01	11.90	2.03	7.79	1.33	22.82	3.89
5	10.15	1.58	10.88	1.70	9.57	1.49	17.88	2.79
6	15.05	2.31	9.07	1.39	13.56	2.08	16.50	2.53
7	13.29	2.01	7.31	1.12	10.97	1.66	10.74	1.62
8	9.24	1.51	6.03	0.98	10.67	1.74	7.99	1.30
Totals		13.11		11.47		12.11		19.85

No.	21		22		23	
Date	September 17, 1910		June 10, 1911		September 15, 1911	
Depth in ft.	Percent moisture	Inches water	Percent moisture	Inches water	Percent moisture	Inches water
1	15.40	2.55	9.74	1.61	21.19	3.51
2	16.43	2.74	11.41	1.90	19.06	3.18
3	10.86	1.80	9.74	1.61	11.99	1.99
4	8.50	1.45	8.46	1.44	9.32	1.59
5	7.45	1.16	12.72	1.98	9.78	1.53
6	11.59	1.78	18.07	2.78	13.36	2.05
7	14.22	2.63	13.16	1.99	11.58	1.75
8	8.47	1.08	8.46	1.08	10.50	1.71
Totals		15.19		14.39		17.31

TABLE XIV.—MOISTURE DETERMINATIONS IN MEDIUM SOIL, NORTH FIELD, CONTINUOUSLY CROPPED

No.	24		25		26		27	
Date	April 17, 1909		July 5, 1909		July 5, 1909		September 17, 1909	
Depth in ft.	Percent moisture	Inches water	Percent moisture	Inches water	Percent moisture	Inches water	Percent moisture	Inches water
1	9 23	1.55	7.91	1 32	4 85	0.90	8.11	1 36
2	10.93	1.68	11.90	1.79	10.35	1 85	10.77	1.63
3	12.07	1.81	13.27	1.99	12.74	1.90	11.85	1.77
4	7.96	1 34	10.07	1.57	12.63	1.94	12.63	1.93
5	9.58	1.48	11.14	1.71	8 37	1.40	12 46	1.94
6	6.71	1.13	9.00	1 41	8.53	1.43	7.90	1.30
7	7.65	1 24	8.53	1.37	4.87	0.89	7.42	1.19
8	9.31	1.45	8 90	1.40	4.78	0.89	6.77	1.06
Totals		11.68		12 56		11.29		12.18

No.	28		29		30		31	
Date	October 12, 1909		September 17, 1909		October 7, 1909		June 13, 1910	
Depth in ft.	Percent moisture	Inches water	Percent moisture	Inches water	Percent moisture	Inches water	Percent moisture	Inches water
1	12.23	1.94	5.30	1.11	8.77	1.45	4.81	0.80
2	17.01	2.51	6.36	1.09	9.70	1.46	7.63	1.14
3	15.46	2.41	9.25	1.49	14.52	2.20	10.45	1.58
4	8.15	1.40	12.29	1.90	16.48	2.67	10.41	1.69
5	5.21	0.96	10.65	1.69	16.28	2.56	9.81	1.52
6	7.81	1.35	6.40	1.06	11.38	1.88	8.48	1.40
7	10.28	1.52	6.35	1.11	7.97	1.28	7.42	1.19
8	11.34	1.77	5.35	0.96	8.17	1.27	6.77	1.06
Totals		13.86		10.41		14.77		10.38

No.	32		33		34		35	
Date	September 17, 1910		June 15, 1911		September 15, 1911		November 1, 1911	
Depth in ft.	Percent moisture	Inches water	Percent moisture	Inches water	Percent moisture	Inches water	Percent moisture	Inches water
1	9.93	1.64	6.32	1.05	10.80	1.79	10.63	1.66
2	10.82	1.62	9.80	1.49	10.94	1.64	10.99	1.65
3	13.35	2.02	12.36	1.87	12.67	1.91	8.02	1.21
4	13.91	2.25	13.54	2.19	13.76	2.23	5.49	0.89
5	12.23	1.89	10.30	1.59	10.76	1.66	5.61	0.87
6	10.34	1.71	6.98	1.16	8.21	1.40	8.93	1.48
7	8.59	1.38	11.07	1.78	8.42	1.35	13 03	2.10
8	8.48	1.36	17.39	2.71	8.82	1.38	11.62	1.81
Totals		13.87		13.84		13.36		11.67

TABLE XV.—MOISTURE DETERMINATIONS IN MEDIUM SOIL IN NORTH FIELD, CONTINUOUSLY CROPPED, LOCATION NO. 2

No.	36		37		38		39	
Date	April 17, 1909		July 5, 1909		July 5, 1909		October 12, 1909	
Depth in ft.	Percent moisture	Inches water	Percent moisture	Inches water	Percent moisture	Inches water	Percent moisture	Inches water
1	8.83	1.44	7.07	1.23	7.45	1.31	8.21	2.68
2	8.71	1.37	10.15	1.60	12.08	1.94		
3	7.96	1.30	8.74	1.42	11.45	1.83	8.63	2.88
4	6.06	1.04	10.12	1.63	14.44	2.31		
5	4.95	0.88	6.25	1.13	7.65	1.39	7.82	2.58
6	4.98	0.88	9.28	1.54	7.42	1.32		
7	.....	....	6.88	1.17	6.58	1.19	10.39	3.34
8	.....	....	11.98	1.94	5.27	0.95		
Totals				11.66		12.24		11.48

No.	40		41		42		43	
Date	October 12, 1909		April 4, 1910		June 13, 1910		September 17, 1910	
Depth in ft.	Percent moisture	Inches water	Percent moisture	Inches water	Percent moisture	Inches water	Percent moisture	Inches water
1	7.53	2.62	7.46	1.24	7.42	1.24	8.94	1.49
2			9.60	1.53	7.61	1.21	11.31	1.81
3	10.59	3.43	9.70	1.59	6.38	1.05	13.25	2.18
4			7.48	1.25	5.76	0.96	12.29	2.05
5	6.80	2.51	6.75	1.17	5.41	0.94	8.44	1.47
6			7.68	1.30	6.70	1.13	9.40	1.56
7	4.67	1.89	11.26	1.86	7.12	1.18	10.08	1.67
8			10.55	1.70	5.42	0.97	10.93	1.76
Totals		10.45		11.64		8.68		13.99

No.	44		45		46	
Date	June 10, 1911		September 15, 1911		November 1, 1911	
Depth in ft.	Percent moisture	Inches water	Percent moisture	Inches water	Percent moisture	Inches water
1	6.95	1.16	11.54	1.92	10.55	1.96
2	10.72	1.71	9.28	1.48	10.92	1.74
3	9.06	1.49	9.66	1.59	11.21	1.84
4	8.28	1.38	13.00	2.17	13.34	2.22
5	6.25	0.97	11.39	1.98	8.83	1.48
6	6.20	1.03	8.92	1.51	8.00	1.35
7	8.54	1.37	8.92	1.51	9.41	1.56
8	11.59	1.81	8.54	1.37	12.82	2.06
Totals		10.92		13.53		14.21

TABLE XVI.—COMPARATIVE YIELDS OBTAINED IN 1910 ON LAND FALLOWED IN 1909, AND ON LAND CONTINUOUSLY CROPPED SINCE 1907

Crop	Land fallowed in 1909				Land continuously cropped			
	Stand	Pounds per acre		Soil type	Stand	Pounds per acre		Soil type
		Total	Grain			Total	Grain	
Pink beans	None	None	None	Medium	Very poor		52	Medium
White Flint corn	Half	600	120	Medium	Half	1200	321	Medium
Dwarf milo maize	Very poor	1780	None	Medium	Very poor	1880	None	Medium
Etter's Red Dent corn	Good	2800	124	Medium	Half	1120	12	Medium
Early Amber sorghum	Good	5120	None	Medium	Medium	2520	None	Medium
Laguna Mex June corn	Good	2800	50	Medium	Very poor	800	None	Medium
Yellow tepary beans	Very poor	..	232	Medium	None	None	None	Medium
Minnesota No 13 corn	Good	1252	148	Medium	Very poor	280	None	Medium
Dwarf milo maize	Very poor	320	None	Medium	Very poor	100	None	Light
Mex. White Dent corn	Good	2900	200	Light	Good	1492	58	Light
White tepary beans	Very poor	...	296	Medium	None	...	None	Light
Australian Flint corn	Poor	600	122	Light	Poor	300	None	Light
Red Indian beans	Very poor	...	88	Light	None	...	None	Medium
Blue Aztec corn	Fair	1560	588	Light	Medium	1280	330	Medium
Hansen beans	Very poor	...	64	Light	None	...	None	Medium
Yellow Aztec corn	Good	1472	510	Light	Fair	880	421	Medium
Broom corn	Medium	1280	...	Light	Medium	2300	...	Medium
White Aztec corn	Medium	980	403	Light	Poor	768	214	Medium

The attempt to accumulate moisture in this field and store it for use the following year has not been successful. While considerable amounts of moisture have been accumulated during the rainy season, especially in the upper four feet, it has all been lost before the beginning of the next rainy season, despite the careful tillage given. The crust, which invariably begins to form under the dust mulch during the latter part of March and the first of April, constantly thickens until the beginning of the next rainy season. It has been suggested that spring plowing would prevent this crust from forming; but while late plowing in January and February, 1911, was fairly effective in this respect, it did not conserve the moisture. At the same time, it must be conceded that, although the fallowed land did not accumulate any moisture, it entered the season of 1910 with as much water as it contained in 1909, while the continuously cropped land had been considerably depleted in stored moisture by the crops of 1909, and, consequently, put at a disadvantage for yields in 1910.

The yields on the fallowed land slightly exceeded those on the continuously cropped land in 1910, but not much weight can be attached to these comparisons because the stands were poorer on the continuously cropped land. These poorer stands were due to the large clods, which were left by the winter plowing, falling into the lister furrows, where they were broken down by the torrential rain, thus adding to the already deep covering of the seeds, and preventing the plants from coming up. The stand on the fallowed land, also, was greatly damaged in the same manner.

The three plots of Aztec corn, and the broom corn on the fallowed land came up in June. None of the other plots came up until after the rain of July 22, and in them many plants did not come through the ground till after the rain of August 1. Table XVI presents the yields obtained on the two parts of the north field in 1910.

FALLOWING IN THE SOUTH FIELD

The south field was divided into two parts to be treated in the same manner as the north field—half to be cropped continuously and half to be fallowed and cropped alternately. On account of the failure of the crops planted in 1909 to come up, the plan was changed and half the field was fallowed in 1909, cropped in 1910, and fallowed in 1911. The other half was fallowed in 1909 and 1910, and cropped in 1911. This change in plan added materially to the value of the moisture experiments considered as a whole. The history of the field and tillage given is as follows:

In prairie sod up to September 8, 1908, when two acres on the northwest corner of the field were plowed about six inches deep. Remainder plowed to the same depth in January and February, 1909. Disced after plowing to cut up sod, but too dry for work to be very effective. Redisced March 15 to 18, and again March 24 to 30 Harrowed with spike-tooth April 6, and reported in good condition One-fourth of the field furrowed for crops July 3, balance harrowed with spike-tooth July 7. Crops failed to come and whole field harrowed with spike-tooth July 23 to 27 Harrowed with spike-tooth August 5, 16, and 26, and September 3. Double disced September 13. Harrowing with spike-tooth December 27, and again January 18 to 28, 1910. Double disced March 31.

The field was divided, and the east half planted with a lister June 15 to 18. The crops came up after the rain July 22, part receiving two cultivations and the remainder only one. Many plants, however, did not get through the ground till after the rain August 1. The yields obtained are shown in Table XVII. The sorghum plot and the plot of Red Kafir corn both received some floodwater in addition to the rainfall of the season.

TABLE XVII.—YIELDS OBTAINED IN 1910 ON THE SOUTH FIELD AFTER FALLOWING IN 1909

Crop	Stand	Pounds per acre		Soil type
		Total	Grain	
Pink beans	Half	.....	64	Heavy
White Flint corn	Good	948	80	Heavy
Dwarf milo maize	Medium	1312	None	Heavy
Etter's Red Dent corn	Good	2764	None	Heavy
Early Amber sorghum	Good	6556	None	Heavy
Laguna Mexican June corn	Good	2268	None	Heavy
Yellow tepary beans	Medium	.....	160	Heavy
Minnesota No 13 corn	Medium	1540	100	Heavy
Dwarf milo maize	Very poor	400	None	Heavy
Mexican White Dent corn	Medium	1440	None	Heavy
White tepary beans	Medium	.....	248	Heavy
White Australian Flint corn	Poor	764	160	Heavy
Red Indian beans	Medium	.....	175	Heavy
Yellow tepary beans	Medium	.....	370	Heavy
Blue Aztec corn	Medium	1572	220	Heavy
Pink beans	Two-thirds	.....	84	Heavy
Yellow Aztec corn	Medium	880	176	Heavy
Dwarf broom corn	Medium	1520	.....	Medium
White Flint corn	Medium	1300	180	Medium
Red Kafir corn	Poor	4116	None	Medium
North Dakota Special corn	Very poor	480	None	Medium
Black-eyed peas	Very poor	.....	112	Medium
Cream Dent corn	Half	800	None	Medium
Leopard Wax beans	Half	.....	104	Medium
Montezuma corn	Half	600	None	Medium

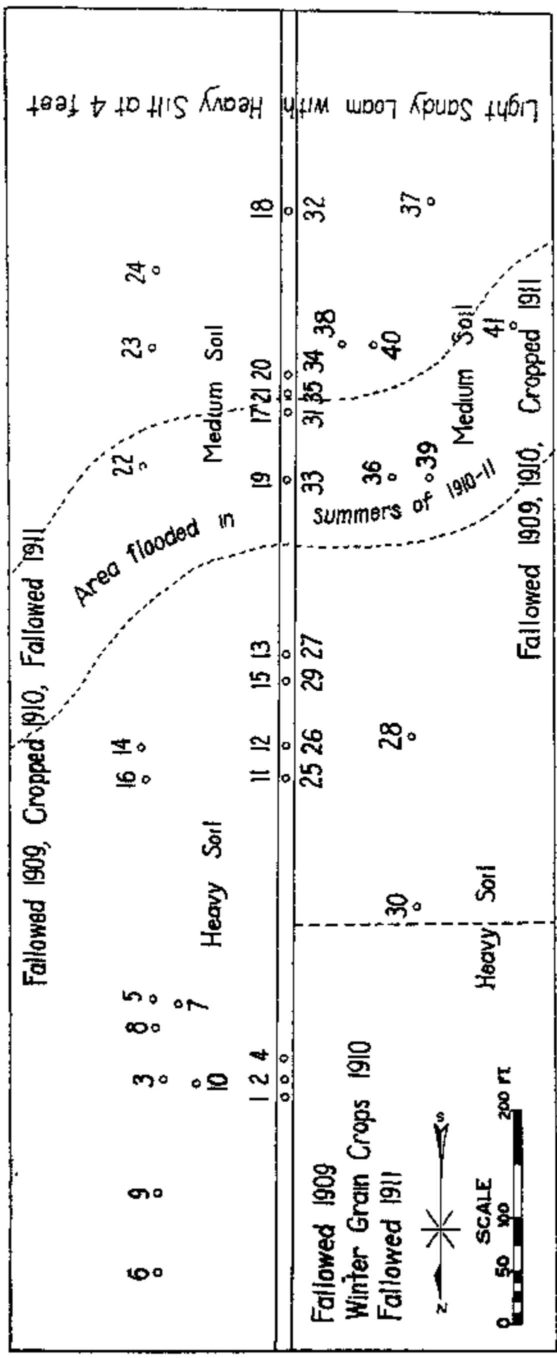

Fig. 2.—Diagram of the south field showing location of borings from which soil samples were taken.

TABLE XVIII.—MOISTURE DETERMINATIONS IN HEAVY SOIL, SOUTH FIELD, FALLOWED 1909, CROPPED 1910, FALLOWED 1911; LOCATION NO. 1

No.	1		2		3		4	
Date	July 5, 1909		September 17, 1909		September 17, 1909		April 6, 1910	
Depth in ft	Percent moisture	Inches water	Percent moisture	Inches water	Percent moisture	Inches water	Percent moisture	Inches water
1	11.29	1.83	22.47	3.56	15.65	2.48	15.37	2.43
2	13.74	2.15	17.83	2.82	13.83	2.19	15.17	2.40
3	12.71	2.06	16.06	2.50	13.93	2.17	13.84	2.16
4	7.28	1.25	12.09	1.92	13.04	2.07	11.80	1.87
5	8.28	1.33	11.21	1.76	8.51	1.31	9.00	1.41
6	10.23	1.64	9.11	1.37	9.60	1.47	8.84	1.33
7	12.65	1.96	8.34	1.28	10.78	1.66	8.94	1.37
8	17.32	2.79	17.32	2.79	16.57	2.66	16.24	2.61
Totals		15.01		18.00		16.01		15.58
No.	5		6		7		8	
Date	June 13, 1910		September 17, 1910		September 17, 1910		June 10, 1911	
Depth in ft	Percent moisture	Inches water	Percent moisture	Inches water	Percent moisture	Inches water	Percent moisture	Inches water
1	13.36	2.12	14.62	2.32	13.74	2.18	15.60	2.47
2	14.30	2.27	13.62	2.16	13.75	2.18	15.35	2.43
3	13.68	2.14	14.40	2.25	12.61	1.97	14.98	2.34
4	11.46	1.82	10.37	1.64	9.91	1.60	12.72	2.01
5	8.39	1.32	9.06	1.42	9.33	1.47	10.57	1.56
6	11.11	1.67	11.61	1.74	11.27	1.69	10.16	1.52
7	11.22	1.72	14.92	2.29	12.12	1.96	10.94	1.68
8	15.86	2.55	12.61	2.03	18.74	3.01	9.41	1.51
Totals		15.61		15.85		16.06		15.52
No.	9		10					
Date	September 15, 1911		November 2, 1911					
Depth in ft.	Percent moisture	Inches water	Percent moisture	Inches water				
1	21.30	3.37	23.61	3.94				
2	17.61	2.69	19.98	3.16				
3	16.93	2.64	16.73	2.61				
4	10.05	1.59	12.26	1.94				
5	7.05	1.01	8.20	1.29				
6	9.30	1.40	8.21	1.23				
7	7.87	1.22	9.32	1.43				
8	13.97	2.25	10.76	1.73				
Totals		16.17		17.33				

TABLE XIX.—MOISTURE DETERMINATIONS IN HEAVY SOIL, SOUTH FIELD, FALLOWED 1909, CROPPED 1910, FALLOWED 1911; LOCATION NO. 2

No.	11		12		13		14		15		16	
Date	September 16, 1909		April 6, 1910		June 13, 1910		September 17, 1910		June 14, 1911		November 2, 1911	
Depth in ft.	Percent moisture	Inches water	Percent moisture	Inches water	Percent moisture	Inches water	Percent moisture	Inches water	Percent moisture	Inches water	Percent moisture	Inches water
1	14.04	2.22	19.25	3 05	11 02	1 75	17.17	2.72	14.11	2.24	21.83	3.46
2	12.06	1.91	13 61	2 16	8.84	1.40	13.76	2.18	11.66	1 85	13.98	2.21
3	9 22	1.44	9.86	1.54	6.14	0.96	17.01	2.65	10.47	1 63	11 09	1.76
4	9.22	1.46	9.03	1.43	9.46	1.50	10.75	1.70	10.85	1.72	8 80	1.39
5	10.19	1.60	9.68	1.52	10.28	1.62	6.31	0.99	8.00	1.26	9 29	1.46
6	8 94	1.34	9.17	1.38	12 05	1.81	12.14	1.82	9.16	1.37	10.72	1.61
7	11 68	1.79	10.57	1.62	13.59	2.09	14 11	2.17	11.92	1.83	13 01	2.00
8	12.01	1.93	13 29	2.14	10.07	1.62	14.10	2.27	14 77	2.38	13 65	2.19
Totals		13.69		14.84		12.75		16.50		14.28		16.08

After the crops were removed, the ground was left in bad condition; and, owing to uncertainty as to whether the experiments would be continued another year, it received no tillage until January 13, when plowing was begun and finished January 30. The plowed land received the following treatment:

Harrowed with spike-tooth February 23 and again March 6. Double disced March 28. Harrowed with spike-tooth April 6. Double disced April 12. Harrowed with spike-tooth June 17, and July 18 and 27. Cultivated with two-horse cultivator July 29, and again August 12. Harrowed with spike-tooth September 4 and 23, and October 14. Cultivated with a two-horse cultivator October 26.

The moisture conditions in the heavy and medium types of soil in the south field under this treatment during the three years are shown in Tables XVIII, XIX, and XX.

TABLE XX.—MOISTURE DETERMINATIONS IN MEDIUM SOIL, SOUTH FIELD, FALLOWED 1909, CROPPED 1910, FALLOWED 1911

No.	17		18		19		20	
Date	April 17, 1909		September 16, 1909		September 16, 1909		April 6, 1910	
Depth in ft.	Percent moisture	Inches water	Percent moisture	Inches water	Percent moisture	Inches water	Percent moisture	Inches water
1	13 55	1.98	16 13	2 55	20.47	3.24	16 89	2 68
2	12 82	1.92	8 57	1 36	19 57	3 10	17 23	2 73
3	12 35	1.78	4.97	0.78	19.39	3 02	18 50	2.89
4	12.48	1.90	9 28	1 47	13 13	2 08	15 17	2 40
5	11.43	1.83	11 11	1 75	16.05	2 52	10 64	1 67
6	17.49	2.52	16.51	2 48	13 38	2 01	12 77	1 92
7	18.66	2.62	16 14	2 48	12 24	1 88	16 00	2.46
8	13 74	2.14	11.40	1 83	11 21	1 88	16 10	2 59
Totals		16.69		14.70		19 73		19 34

No.	21		22		23		24	
Date	June 13, 1910		September 17, 1910		June 10, 1911		November 2, 1911	
Depth in ft.	Percent moisture	Inches water	Percent moisture	Inches water	Percent moisture	Inches water	Percent moisture	Inches water
1	8 92	1 31	16 60	2 63	3 90	0 62	20 06	3.18
2	12 56	1 88	16 77	2 66	11 16	1 77	19.88	2.15
3	13 40	1 93	19 92	3 11	12 35	1 93	15 13	2 36
4	12 12	1 85	19 70	3 12	10 32	1 63	..	..
5	8 70	1 39	18 73	2 97	13 21	2 08	10 44	1 64
6	13 59	1 96	29 36	4 40	14 74	2 21	11 76	1.76
7	15 42	2 16	19 44	2 99	16 33	2 51	. ..	....
8	13 94	2 17	14 38	2 31	15 70	2 52	. ...	....
Totals		14 65		24 19		15 27		

The other half of the south field received the following treatment after June 18, 1910:

Double disced July 27. Harrowed with spike-tooth July 29, and August 4, and 15. Single disced September 3. Double disced November 10. Harrowed with spike-tooth November 22. Plowed eight inches deep December 28 to January 2, 1911. Double disced January 13. Harrowed with spike-tooth February 23 and March 6. Double disced March 27. Harrowed with spike-tooth April 7. Double disced April 12. Planted to crops June 14 to 17, using the lister. Crops cultivated four times. Floodwaters crossed the field in its southern part in 1910 and 1911.

From the above history it is seen that at no time since this field was first plowed in January, 1909, was it for any length of time without an effective dust mulch, and, although it went for two years without plowing, it was double disced frequently to a depth of at least six inches. It has been in good tilth all the time, and should show beneficial effects of summer fallowing if there were any such effects. The increased moisture in the plot which received floodwater in both 1910 and 1911 is shown in the moisture tables. Tables XXI and XXII show the moisture conditions in heavy and medium soil in south field under this treatment during three years.

TABLE XXI.—MOISTURE DETERMINATIONS IN HEAVY SOIL, SOUTH FIELD, FALLOWED 1909, 1910, CROPPED 1911

No	25		26		27		28	
Date	September 16, 1909		April 6, 1910		June 13, 1910		September 17, 1910	
Depth in ft	Percent moisture	Inches water	Percent moisture	Inches water	Percent moisture	Inches water	Percent moisture	Inches water
1	14 04	2 22	19 25	3 05	11 02	1 75	18 36	2 91
2	12 06	1 91	13 61	2 16	8 84	1 40	14 05	2 22
3	9 22	1 44	9.86	1 54	6 14	0 96	11 33	1 77
4	9 22	1 46	9 03	1 43	9 46	1 50	11 83	1 87
5	10 19	1 60	9 68	1 52	10 28	1 62	8 10	1 27
6	8 94	1 34	9.17	1 38	12 05	1 81	6 64	1 00
7	11 68	1 79	10 57	1 62	13 59	2 09	9 11	1 40
8	12 01	1 93	13 29	2 14	10 07	1 62	12 14	1 95
Totals		13 69		14 84		12 75		14 39

No	29		30	
Date	June 14, 1911		September 15, 1911	
Depth in ft	Percent moisture	Inches water	Percent moisture	Inches water
1	14 11	2 24	21 36	3 38
2	11 66	1 85	21 40	3 39
3	10 47	1 63	15 30	2 39
4	10 85	1 72	11 09	1 76
5	8 00	1 26	10 57	1 66
6	9 16	1 37	9 41	1 41
7	11 92	1 83	11 20	1 72
8	14 77	2 35	19 61	3 15
Totals		14 28		18 86

The results in the south field are similar to those obtained in the north field. It has been impossible to save any considerable amount of water from one summer's rainy season to the next. At the close of each season the moisture determinations have shown an accumulation of several inches of water in the upper four feet of

TABLE XXII.—MOISTURE DETERMINATIONS IN MEDIUM SOIL, SOUTH FIELD, FALLOWED 1909, 1910, CROPPED 1911

No.	31		32		33		34	
Date	April 17, 1909		September 16, 1909		September 16, 1909		April 6, 1910	
Depth in ft.	Percent moisture	Inches water	Percent moisture	Inches water	Percent moisture	Inches water	Percent moisture	Inches water
1	13.55	1.98	16.13	2.55	20.47	3.24	16.89	2.68
2	12.82	1.92	8.57	1.36	19.57	3.10	17.23	2.73
3	12.35	1.78	4.97	0.78	19.39	3.02	18.50	2.89
4	12.48	1.90	9.28	1.47	13.13	2.08	15.17	2.60
5	11.43	1.83	11.11	1.75	16.05	2.52	10.64	1.67
6	17.49	2.52	16.51	2.48	13.38	2.01	12.77	1.92
7	18.66	2.62	16.14	2.48	12.24	1.88	16.00	2.46
8	13.74	2.14	11.40	1.82	11.21	1.88	16.10	2.59
Totals		16.69		14.69		19.73		19.54

No.	35		36		37		38	
Date	June 13, 1910		Spetember 17, 1910		September 17, 1910		June 10, 1911	
Depth in ft.	Percent moisture	Inches water	Percent moisture	Inches water	Percent moisture	Inches water	Percent moisture	Inches water
1	8.92	1.31	25.76	4.08	8.33	1.32	3.90	0.62
2	12.56	1.88	24.50	3.98	9.95	1.58	11.16	1.77
3	13.40	1.93	28.36	4.42	10.51	1.64	12.35	1.93
4	12.12	1.85	26.03	4.12	14.01	2.22	10.32	1.63
5	8.70	1.39	24.32	3.82	21.19	3.33	13.21	2.08
6	13.59	1.96	19.96	2.99	27.58	4.14	14.74	2.21
7	15.42	2.16	21.42	3.29	24.87	3.82	16.33	2.51
8	13.94	2.17	19.31	3.11	15.90	2.56	15.70	2.52
Totals		14.65		29.81		20.61		15.27

No.	39		40		41	
Date	September 15, 1911		September 15, 1911		September 15, 1911	
Depth in ft	Percent moisture	Inches water	Percent moisture	Inches water	Percent moisture	Inches water
1	18.49	3.13	12.90	2.04	17.79	2.82
2	15.57	2.47	10.88	1.72	15.26	2.42
3	17.56	2.74	10.63	1.66	15.19	2.37
4	17.32	2.64	10.64	1.69	17.13	2.61
5	12.46	1.96	11.81	1.86	13.89	2.18
6	19.96	2.99	13.44	2.02	21.78	3.27
7	24.63	3.78	16.03	2.46	28.72	4.41
8	23.77	3.82	13.94	2.22	26.30	4.23
Totals		23.53		15.67		24.31

soil, but this has all been lost in most cases before the beginning of the next rainy season. Where water has been applied in larger amounts than afforded by the natural rainfall, as in the plots in the south field that were flooded by runoff, there has been some water saved in the subsoil until the next year (See borings 22, 36, 39, and 41). In the lighter soil, where the rainfall penetrates deeply and quickly, and especially where such soil is underlaid with heavier soil at a depth of four feet or more, there seems to have been some saving of water in the heavy subsoil (See boring 37). Also, where water has been applied during the winter, as in the plots given supplemental irrigation, a considerable amount has been saved until crops were planted to use it. But, in general, the natural rainfall has not been conserved from one year until the next by the methods of tillage we have used. Whether other methods might be devised which would be successful is a question for further experimentation.

DAILY RANGE OF TEMPERATURE AND LOSS OF MOISTURE

The writer suggests as one of the reasons for this failure to conserve moisture, the great daily range of temperature which prevails throughout the year in southern Arizona. There is often a difference of sixty degrees between the day and night temperatures during our warmest weather, and, except during rainy seasons, the difference rarely falls below forty degrees. Table XXIII shows the mean daily range for each month during the three years of our experiments.

TABLE XXIII.—SHOWING AVERAGE DAILY RANGE IN TEMPERATURE AT MCNEAL, IN SULPHUR SPRING VALLEY, DURING 1909, 1910, AND 1911

	Degrees daily range in temperature		
	1909	1910	1911
January	35.0	36.1	34.5
February	34 8	40.7	29.0
March	34.8	43.1	36.2
April	42.1	46.2	42.4
May	44.0	47.6	47.9
June	47.0	43.7	44.4
July	32.0	37.0	31.0
August	29.1	31.9	36.8
September	33.3	37.0	30.0
October	46.9	39.9	34.2
November	41.7	39.1	36.0
December	33.7	39.6	29.1
Average	37.9	40.2	36.0

Under daily variations in temperature of such magnitude as has been shown, the air within the dust mulch, as well as that above it, would expand and contract nearly one-tenth its volume. Expansion being necessarily upward would produce a constant interchange between the air in the dust mulch and the surrounding atmosphere. Since the air in the mulch has been in contact with and has probably partly penetrated the moist soil below the mulch, it would be saturated with water when leaving the soil. The drying effect of this interchange of air would be especially strong in our climate, since, during the greater part of the year, the air that enters the soil is extremely dry and in condition to absorb a maximum amount of water. Convection currents no doubt greatly assist expansion and contraction in causing circulation of air within the dust mulch, since during the day, in spring and early summer, the temperature of the mulch becomes twenty-five to thirty degrees higher than the air above it. Such high temperatures, taken June 9 and 10, 1910, at the McNeal dry-farm are recorded in Table XXIV.

TABLE XXIV.—SOIL TEMPERATURES JUNE 9 AND 10, 1910

Time	Temperature in degrees Fahrenheit			
	Dust mulch			Air
	Depth 5 inches	Depth 2½ inches	Depth 1 inch	4 feet above soil
1:30 P. M.	95	104	Not taken	103
5:30 P. M.	99	108	Not taken	98
7:25 P. M.	95	99	Not taken	89
7:00 A. M.	77	72	Not taken	80
11:30 A. M.	90	104	125	97
5:30 P. M.	100	113	120	102

The minimum night temperature of the air was 60 degrees and the maximum day temperature during the two days covered by the table was 107 degrees, giving a daily range of 47 degrees.

It can be seen readily that temperatures as high as those that have been shown to exist in the dust mulch tend to drive out the moisture in the layer of soil immediately beneath it, causing a crust to form; and that this crust would increase capillary attraction, causing water from still deeper layers of soil to rise to take the place of that driven out by the heat or carried way by the circulating air. It has been stated that the effectiveness of a dust mulch consists: *first,* in breaking the capillary connection between the moist soil and the mulch itself; and, *second,* in preventing air circulating over the dust mulch from reaching the layer of moist soil beneath it. Under our conditions, however, the mulch becomes hot enough to drive moisture out of the soil beneath it, while convection currents caused by this heat, and air expansion and contraction due to the great daily range in temperature, produce a constant circulation of air within the mulch itself, thus practically nullifying its effect during much of September and October, and during the spring and summer months of March, April, May, June, and part of July.

YIELDS OBTAINED BY FALLOWING

The yields obtained by fallowing have corroborated the results obtained by moisture determinations. They have in general been little in excess of those obtained by continuous cropping for the year that both fields were cropped, while the total yields obtained by continuous cropping during the three years are much in excess of those obtained by fallowing. There is, however, one exception to this general conclusion. One plot of light soil fallowed in 1910 yielded 29.9 bushels of milo maize per acre in 1911; but, as stated under the discussion of soil types, the writer believes this due wholly to the fact that the light type of soil, together with a timely rain which gave the plants an early start, made it possible for them to use all the water from the summer rains of 1911, and that the crop was made entirely on these rains.

Fallowing did not pay for the labor expended. At the same time, however, it is seen that continuous cropping has resulted in steadily diminishing yields, especially with corn, sorghum and milo maize, and cannot be recommended without the use of supplemental water. The yields obtained in the south field by fallowing in 1909 and 1910, and cropping in 1911 are presented in Table XXV.

With the exception of the first two plots in the table, the crops were not up until after the rain, July 9. These two plots came up after the rain, June 11, but died in the August drouth. Also, nearly all the plants in the next three plots died in the same drouth—a fact explained in the discussion of soil types.

Yields obtained on the continuously cropped part of the north field in 1911 are presented in Table XXVI. The crops were planted with a press drill immediately after a rain which occurred on June 11, and all came up at once. The stand of yellow tepary beans and of milo maize was considered too thin and the plots were replanted, the second planting not coming up till after the rain, July 9. The milo did not mature before frost and, therefore, yielded no grain.

TABLE XXV.—YIELDS OBTAINED IN THE SOUTH FIELD BY FALLOWING IN 1909 AND 1910, AND CROPPING IN 1911

Crop	Stand	Pounds per acre		Soil type
		Total	Grain	
White Flint corn	Good	None	None	Heavy
Blue Aztec corn	Good	None	None	Heavy
Pink beans	Good	.....	48	Heavy
Early Amber sorghum	Good	1048	None	Heavy
Laguna Mexican June corn	Good	1024	192	Heavy
Pink beans	Good	.....	128	Heavy
Early Amber sorghum	Good	1416	None	Heavy
Laguna Mexican June corn	Good	2480	332	Heavy
Pink beans	Good	.....	144	Heavy
Early Amber sorghum	Good	4904	None	Medium
Laguna Mexican June corn	Good	1600	168	Medium
Dwarf milo maize	Good	2192	460	Medium
Yellow Aztec corn	Good	1184	340	Medium
White tepary beans	Good	.....	480	Medium
White Flint corn	Good	1508	736	Light
Mexican Flint corn	Good	3840	528	Light

TABLE XXVI.—YIELDS OBTAINED IN THE NORTH FIELD, 1911, ON LAND CROPPED CONTINUOUSLY FOR FIVE YEARS

Crop	Stand	Pounds per acre		Soil type
		Total	Grain	
Yellow tepary beans	Good	....	730	Medium
White Flint corn	Good	680	140	Medium
Dwarf milo maize	Good	1844	None	Medium
Red Dent corn	Good	1838	354	Medium
Pink beans	Good	....	66	Light
Australian White Flint corn	Good	None	None	Light
White tepary beans	Good	....	392	Light
Laguna Mexican June corn	Good	1870	338	Medium
Early Amber sorghum	Good	2730	None	Medium
Blue Aztec corn	Good	None	None	Medium

The plot of yellow tepary beans received some floodwater. In 1909 the same plot yielded 496 pounds of Pink beans per acre, and very probably received floodwater that year, though no record was made of it. In 1910 it received floodwater, but the stand was so poor that only 52 pounds of Pink beans per acre were produced. No other plots in this field received floodwater. The yields on the continuously cropped land in 1909, when there were no crops grown on fallowed land with which to compare, may be found in the tables stating yields of the various varieties of crops tested.

The general results in yields, stated in pounds per acre, obtained by the three systems of farming are shown in Table XXVII.

TABLE XXVII.—TOTAL YIELDS OBTAINED IN THREE YEARS BY CONTINUOUS CROPPING; BY ALTERNATE FALLOWING AND CROPPING; AND BY FALLOWING TWO YEARS AND CROPPING ONE YEAR

	Continuous cropping				Alternate fallowing and cropping		Fallowing two years, cropping one year	
	Total yield grown three years Pounds per acre		Total yield grown two years Pounds per acre		Total yield in two years Pounds per acre		Total yield in three years Pounds per acre	
	Total	Grain	Total	Grain	Total	Grain	Total	Grain
White and Yellow Aztec corn.......	....	....	2348	783	1025	324	1184	340
Mexican White Dent corn.......	....	....	4156	178	2170	100	....	...
Laguna Mexican June corn........	4604	404	2736	66	2534	25	1368	231
Early Amber sorghum........	8542	100	5812	100	5842	None	2684	None
Milo maize........	6604	260	4760	260	2619	838	2192	460
Tepary beans......	....	1018*	....	457*	....	261	....	480
Pink beans........	....	614	....	548	....	74	....	107

*The yield of 1018 lb. was from two crops, 1909, 1911; that of 457 lb. was from a single crop in 1909.

FURROW FALLOWING

The furrowing of plots in the heavy soil in 1909, and the subsequent failure of the crops to come up, gave an opportunity to test the efficiency of this method of fallowing against level culture. The frequent harrowing after rains to conserve moisture filled the furrows, and at the end of the season it could not be said that there was more moisture on the furrowed land, or that it penetrated deeper, than on the unfurrowed land. The method was tested again in 1911; but, again, the harrowing filled the furrows, and nothing was gained. It is possible that by furrowing deeply at the beginning of the season at right angles to the slope of the land, and that by keeping the furrows open, flooding from violent storms might be prevented, and more complete penetration secured; but whether the loss of water by evaporation in the absence of the dust mulch would equal the gain by furrowing remains to be determined. After the rainy season the ground should be treated as any other fallow.

EXPERIMENTS WITH SUPPLEMENTAL IRRIGATION

Having observed the short growing season in Sulphur Spring Valley, due to the late date at which the rains begin, it occurred to the writer that, if crops could be brought up in June by the addition of small quantities of water, they would develop root systems sufficient to utilize practically all the rainfall as fast as it fell, and, at the same time, gain sufficient headway to mature grain before being struck by frost. A single plot was planted in 1909 to test this idea. The crop selected was Laguna Mexican June corn, because ordinarily the season is too short for this variety. Its tight shuck, moreover, giving resistance to smut and worms, makes it a desirable variety for the Valley, if other conditions can be made favorable. The corn was planted in lister furrows June 16, and water was run down the furrows until it reached the ends, a distance of 250 feet. No attempt was made to determine how far this water was distributed laterally, but it reached a depth of two feet in the bottoms of the furrows, and moisture determinations made July 5 showed a moisture content of 12.05 percent and 11.54 percent, respectively, in the first two feet of soil. The corn came up quickly and grew rapidly. When the rainy season opened, July 22, it was three feet high; while corn planted July 1, and brought up by light rains, July 5 and 6, was only four inches high on the same date. As the season drew to a close, it was noticed that part of the plot was more thrifty and remained green longer than the remainder of it. In determining yields, a division of the plot was made, and the best part of it (the end farthest from the source of irrigation-water supply) yielded at the rate of 3746 pounds of air dry matter per acre, of which 15.4 bushels was shelled corn. The remainder of the plot yielded at the rate of 2784 pounds of air dry matter per acre, of which 4.1 bushels was shelled corn. In searching for the reason for this difference in yield between the two parts of the plot, it was discovered that irrigation water had been allowed to escape upon the best part of the plot at least twice during the preceding summer; and, evidently, in this case a part of it was conserved until the following season. This was upon a light type of soil with a heavy subsoil at a depth of four feet.

These results were so promising that more extensive experiments were planned for succeeding years. In 1910 two and one-half acres of light soil were selected, and water added during the winter. The water was pumped into an adobe tank by a windmill, and, from there, run onto the land in furrows. The furrows were 568 feet long, and, when the water reached the lower ends, it was shut off at the tank. All the land was watered once in this manner, and two-thirds of it received a second application of water. As soon after irrigating as the land was dry enough to work, the furrows were closed and then harrowed. At the second application of water the ridges between the preceding furrows were opened for new furrows, and water applied as before. Only a few furrows could be irrigated at one time. At intervals during the winter the land already irrigated was disced and harrowed to keep the dust mulch loose and effective. It required from December 1 to May 17 to irrigate the two and one-half acres the first time in this manner, but after May 17 there was more wind, and it was possible to irrigate two-thirds of the land a second time before planting was begun, June 8. That part of the land that was irrigated twice was quite moist at planting time, but that irrigated only once was somewhat crusted beneath the dust mulch and contained much less water. In fact, the water content had become so low that crops failed to come up until after the July rains on that half of the land farthest away from the source of water supply. The amount of water applied at each irrigation was equivalent to about two acre-inches. A moisture determination made June 8 in the land receiving two irrigations gave the results presented in Table XXVIII.

TABLE XXVIII.—MOISTURE JUNE 8, 1910, IN LIGHT SOIL RECEIVING TWO ACRE-INCHES OF WATER ABOUT MARCH 1, AND TWO ACRE-INCHES ABOUT JUNE 1

Depth, in feet	Percent moisture	Inches of water
1	14.45	2.43
2	13.52	2.29
3	8.20	1.49
4	4.96	0.86
5	12.41	2.06
6	10.76	1.72
7	15.90	2.44
8	15.75	2.51

By this method of applying water it is seen that the penetration was not deeper and the amount stored was no more than in the preceding season when only one application was made. The plots were laid off at right angles to the direction of the irrigation furrows; and this gave plots having no uniform moisture content, since the land nearest to the source of supply undoubtedly absorbed more water during irrigation than that farthest away, as shown by observation at planting time and by the subsequent failure of the crops to come up on the land farthest away, which had been irrigated but once. Planting was done June 8 and 9, and the plants were soon out of the ground. They grew rapidly, and the corn was at least four feet high by the time the summer rains began, July 22. The August rains were unusually heavy, the total precipitation being 8.33 inches, and on this light type of soil there was no evidence of loss by runoff. The crops were intertilled four times, thus forming a dust mulch after most of the rains. They were large enough to shade the ground and prevent the enormous growth of weeds that occurred on other plots. The large root systems, developed before the rains set in, also enabled the plants to make use of practically all the rain that fell, as may be seen by Table XXIX which records the moisture in samples taken September 17, at a point near those taken June 8 and shown in Table XXVIII.

TABLE XXIX.—MOISTURE IN PLOT GIVEN SUPPLEMENTAL IRRIGATION, AT CLOSE OF RAINY SEASON, SEPTEMBER 17, 1910, AFTER CROPS WERE MATURED

Depth, in feet	Percent moisture	Inches of water
1	7.48	1.32
2	8.64	1.46
3	7.63	1.38
4	6.27	1.08
5	8.69	1.44
6	9.72	1.58
7	11.02	1.69
8	18.12	2.89

There was no hot, dry weather, sufficient to check growth, at any time after the plants started, and the result was the largest yields obtained during the three years covered by the experiments. The best plot of dent corn was cut before it matured, thus reducing its yield somewhat, but, otherwise, all plots had as good a chance as could have been given by the season. The yields per acre are shown in Table XXX. The plots were 192 feet long and 56¾ feet wide, and contained one-fourth acre each. The distances are given from the irrigation-water supply to the center of the plots.

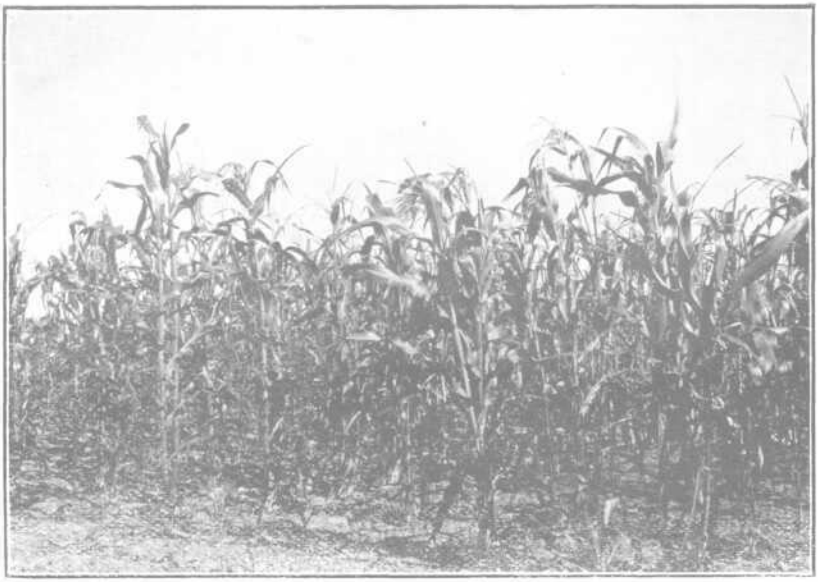

Fig. 1.—A plot of Etter's Red Dent corn brought up by 4 inches of pumped water applied before seeding.

Fig. 2.—A plot of Etter's Red Dent corn on land fallowed the previous year but receiving no supplemental irrigation. The denser stand at the further end of the rows is due to slightly more moisture, which started the plants before the summer rains.

PLATE III.—TWO PLOTS OF THE SAME CORN AT THE McNEAL DRY-FARM, AUGUST 20, 1910. BOTH PLANTED JUNE 9, ONE WITH, THE OTHER WITHOUT SUPPLEMENTAL IRRIGATION.

TABLE XXX.—YIELDS OF PLOTS GIVEN SUPPLEMENTAL IRRIGATION, 1910

Crop	Distance from water supply, in feet	Stand	Pounds per acre	
			Total	Grain
Pink beans	540	Medium; half not up till after rains July 22	....	132
White Flint corn	484	Good; one-third not up till after rains July 22	1611	927
Dwarf milo maize	428	Good; one-third not up till after rains July 22	3382	1160
Etter's Red Dent corn	372	Good; one-third not up till after rains July 22	2228	320
Early Amber sorghum	316	Poor; two-thirds not up till after rains July 22	4272	400
Laguna Mexican June corn	260	Good; all up in June soon after planting	2976	488
Yellow tepary beans	204	Good; all up in June soon after planting	...	732
Etter's Red Dent corn	148	Good; all up in June soon after planting; harvested immature	3232	616
Dwarf milo maize	92	Good; all up in June soon after planting	3916	2808
Pink beans	36	Good; all up in June soon after planting	.	232

The experiments were repeated in 1911 on the same ground, but with a change in the method of applying the water. This year the irrigation furrows were made to run parallel with the plots. While this did not insure a uniform moisture content in all the plots, it did insure practically uniform moisture conditions within any given plot, which was not the case in 1910. The plots nearest the source of supply received water earliest in the season, and, therefore, having a longer time for evaporation, contained less water at planting time than those plots farthest away.

The water was applied in furrows as in the preceding season, but the second application was made as soon as possible after the first, and in the same furrows. At the first application the furrows were half-filled with water which was allowed to soak into the ground. As soon as dry enough to cultivate, the bottoms of the furrows were harrowed. When sufficient water had accumulated in the tank to half-fill the furrows, it was applied the second time, the furrows closed and the land harrowed. The second application of water was usually made within ten days after the first. No more water was applied before the summer rains, but the land was disced and harrowed often enough to prevent bad crusting, and to keep the dust mulch dry and loose. Irrigation was begun December 16, and by June 8 two and one-fourth acres had been irrigated with three and one-half acre-inches of water. That the method of applying the water this year produced deeper penetration and resulted in better conservation than in 1910, is shown by a moisture determination made June 14, at a point about one-third of the distance across the field and, therefore, probably irrigated during the latter part of February. The results of these determinations are presented in Table XXXI. For comparison the moisture at planting time in 1910 is also shown.

TABLE XXXI.—MOISTURE AT PLANTING TIME IN PLOTS GIVEN A SMALL AMOUNT OF WINTER AND SPRING IRRIGATION

Depth, in feet	1910. Four acre-inches applied in two irrigations, March 1 and June 1, in different furrows		1911. Three and one-half acre-inches applied in February in two irrigations at intervals of ten days, in same furrows	
	Percent moisture	Inches of water	Percent moisture	Inches of water
1	14.54	2.43	13.33	2.24
2	13.52	2.29	15.52	2.63
3	8.20	1.49	16.64	3.02
4	4.96	0.86	12.40	2.14
5	12.41	2.06	5.62	0.93
6	10.76	1.72	8.71	1.39

The plots were planted June 10 to 14 and all came up immediately. They grew as rapidly as in 1910, until checked by a long, hot, dry spell lasting from July 20 to August 25. This drouth and hot weather greatly damaged all corn plots, prevented the setting of any Pink beans, and completely ripened all teparies that had already set. The milo maize and sorghum suffered greatly but were resuscitated by additional irrigation water applied during the latter part of August, one plot of milo receiving 3.14 acre-inches, another 1.32 acre-inches, and the sorghum 1.32 acre-inches. The remainder of the plots received no irrigation water except that applied before planting. When the rains began again in September, the Pink beans blossomed and set a small crop of seed. The teparies from which 318 pounds of beans to the acre had been harvested during the first seventy-five days of their growth, in spite of the extremely unfavorable conditions that prevailed, took a second growth and produced an additional 457 pounds of beans to the acre. The corn plants were so badly damaged, the tassels and silks being dessicated, that they were benefited very little by the rains of September. All plots were cultivated four times. The yields obtained are presented in Table XXXII.

TABLE XXXII.—YIELDS IN POUNDS PER ACRE ON PLOTS GIVEN SUPPLEMENTAL IRRIGATION IN 1911

Crop	Water applied	Pounds per acre	
		Total	Grain
Dwarf milo maize..........	December 3 5 in.; August 3.14 in.	5050	2000
Dwarf milo maize..........	January 3 5 in.; August 1.32 in.	3865	1340
Early Amber sorghum......	January 3.5 in.; August 1.32 in.	6680	340
White Flint corn...........	February 3.5 in.	1595	350
Pink beans................	February 3.5 in.	....	100
Laguna Mexican June corn..	March 3.5 in.	2915	155
Yellow tepary beans.......	March 3.5 in.	....	750
Etter's Red Dent corn......	April 3.5 in.	1775	None
White tepary beans	April 3.5 in.	....	800
Yellow Aztec corn.........	May 3.5 in.	1585	660
Mexican White Dent corn...	May 3.5 in.	5005	520

In 1910 the milo maize and White Flint corn were very badly damaged by birds, but, in stating yields, allowance was made for this damage as nearly as it could be estimated. There is a chance, therefore, for overstatement of yields in that year, but in 1911 the birds were kept away and the statement of yields represents actual quantities of good clean marketable grain produced per acre.

A comparsion of the yields obtained by means of supplemental irrigation with those obtained by ordinary dry-farming methods reveals very strikingly the superiority of this system for Sulphur Spring Valley. When yields of thirty-five to fifty bushels of milo maize per acre can be obtained by pumping from four to six acre-inches of water upon the land during the winter months, when other work is slack, it is useless to resort to the great amount of labor required by summer fallowing to produce the very meager yields obtained by that method of farming. The increased yields by supplemental irrigation are not so much the result of more water in the soil, as of a small amount of water applied at a critical time. By starting the crops earlier they have time to mature before frost, and the four to six week's growth before the rainy season begins, develops a large root system, which enables them to use practically all the rains that fall, especially on the lighter types of soil. The application of a small amount of water during the hot drouth in August kept crops alive until the later rains of the season were available. Thus, the application of two to three inches of water at a critical time makes the difference between absolute failure and satisfactory success.

The amount of underground water in Sulphur Spring Valley available for pumping has not been determined, but from yields of wells observed by the writer there are indications that small amounts of water, such as we have used, may be secured for a large part of the Valley at depths ranging from a few feet to 200 feet. In considering this question from a business standpoint, it must be remembered that the pumping of forty-eight inches of water on one acre, (the amount that would be required for approximately six tons of alfalfa hay in Sulphur Spring Valley) from a depth of thirty feet would cost as much as the pumping of four inches of water on two acres of milo maize from a depth of 180 feet; while the returns based upon the yields in 1910 at present market prices would be about the same. Experience gained by pumping water for alfalfa on the University Demonstration Farm at Tucson indicates that water could be profitably pumped for this crop from depths of thirty to thirty-five feet in southern Arizona, but could not be pumped profitably at much greater depths. The growing of milo maize, then, in Sulphur Spring Valley by means of supplemental irrigation would greatly expand the area that could be farmed profitably, and the underground water, being used more economically, would be much more likely to hold out.

This supplementary water may often be obtained by deflecting floodwaters. The Indians southwest of Tucson have farmed more or less successfully with floodwater for generations, and their dams for the deflection of such water may be found thrown across the arroyos. By adopting their quick-growing and early maturing crops, along with their methods of using floodwater, there is considerable opportunity in southern Arizona for the white settler to profit by imitation. One of the plots that received a small amount of floodwater each year has produced four paying crops in five years, and the other crop would have been a paying one had there been a good stand. There are many opportunities to secure floodwaters on small areas in Sulphur Spring Valley and in other parts of Southern Arizona.

Three years of our experience and five years of experience by farmers in Sulphur Spring Valley have shown that, with the exception of tepary beans and a few small varieties of corn, yielding too lightly to be profitable, it is impossible to mature crops during the average rainy season. The crops, therefore, must be started ahead of the rainy season, and the only reliable means of doing this is by supplemental irrigation. Fortunately, there are indications that an abundance of water for this purpose may be obtained in the Valley, and this makes prospects for successful farming very bright, when otherwise they would be dark indeed.

The water should be applied by pumping, and a gasoline engine will be found more satisfactory than a windmill as a source of power. Some of the many types of oil engines now being placed on the market may be found even more satisfactory. The water should be applied in quantities of not less than four acre-inches at one time and at a date as near as possible to planting time, to obtain best results; but if a small pumping plant makes it necessary to begin applying water two or three months before planting, in order to cover the land, good results may still be obtained. The water should be applied in rather deep furrows to insure deep penetration. The furrows should be closed as soon as possible after the water is applied, and the land harrowed thoroughly to produce a dust mulch. If possible, the furrows should be laid out in the places to be occupied by the rows of crops, thus insuring the planting of the seeds in moist soil, where the young plants can make the most complete use of the water applied before the rainy season begins. Additional water may be applied at critical periods in amounts indicated by the condition of crops.

EXPERIMENTS WITH DIFFERENT TYPES OF SOIL

It has been shown that moisture was not stored in these experiments and conserved from one season to the next in any considerable quantities in any type of soil by means of summer fallowing, even when the fallow extended over two years. When yields of crops are compared, however, greater differences are seen to exist.

The heavy soil in the south field has not produced a single crop of consequence since the experiments began, except on plots that received floodwater. Its water content is uniformly high when compared with the lighter types of soil, but plants have not been able to make use of this water, probably due to a high hygroscopic coefficient and slow capillary movement.

AMOUNT OF WATER REQUIRED ON LIGHT AND HEAVY SOILS

It is known that in any given soil, plants may extract water until the moisture content reaches a certain percent, after which no further water can be extracted, and the plant dies rather suddenly. The soil moisture content at which common cultivated plants die is to a certain extent, perhaps, a function of the variety of plant, but it is more a function of the soil type. In 1901, during an extreme drouth, the writer made moisture determinations in soil types ranging from loams to rather heavy clays, on which a variety of crops were growing and; in every case the difference in moisture content of soils maintaining living thrifty plants, and those on which the plants were dead, was but one or two percent for the same type of soil; but the moisture content at which the plants died was higher in the heavy soils than in the light ones.

Recent experiments by the Nebraska Experiment Station show less difference between the moisture content of a soil bearing living plants and of the same soil when the plants were dead, than was observed by the writer. They also show remarkable similarity in this respect between plants of widely different nature and habit of growth. Table XXXIII (after Professor Burr*) brings out these facts strongly.

TABLE XXXIII.—PERCENT OF MOISTURE AT WHICH CROPS SUFFER

Depth, in feet	Percent moisture in soil and condition of crops	
	Peas burned beyond recovery	Peas just beginning to fire
1	6 4	7.1
2	6 8	7.8
3	6 8	8.1
	Oats burned beyond recovery	Oats still green
1	6 4	7.3
2	6.8	7.5
3	7.1	8.0
	Lupines badly fired	Lupines still green
1	6.7	7.5
2	7.2	8.0
3	7.3	7.4
	Corn badly fired	Corn not fired
1	7.1	9.0
2	8.0	10.7
3	9.6	11.9
	Russian thistles dead	Russian thistles just beginning to fire
1	6.0	6.7
2	6 3	7.1
3	6.9	7.0

*Hand Book of Dry-Farming, December 1 1911, p. 156.

It is well known that the moisture content at which plants die bears a definite relation to the hygroscopic coefficient of the soil—the percentage of water absorbed by a dry soil from a saturated atmosphere. In light soils plants may extract the water down to a percentage very nearly that of the hygroscopic coefficient, while in heavy soils the limit between the hygroscopic coefficient and the percentage at which plants die is much wider.

On the heaviest soils corn, beans, and sorghum all died during a drouth in August, 1911, when the moisture content was somewhere between 12.08 and 19.35 percent as an average of the first three feet, the average hygroscopic coefficient of which was 9.96 percent; while milo maize was thrifty and green, and finally yielded 29.9 bushels per acre on a light type of soil averaging 8.38 percent moisture in the first three feet, and having an average hygroscopic coefficient of 3.91 percent. In 1909 on this same light type of soil corn did not die until the moisture in the first four feet had been reduced to an average of 6.71 percent, with a hygroscopic coefficient averaging 3.91 percent; while the same variety of corn remained green and finally yielded over fifteen bushels of corn to the acre where the moisture in the first four feet averaged 8.01 percent, and the hygroscopic coefficient averaged 4.39 percent. The difference between the moisture content of the soil bearing thrifty green corn and that on which the corn had died was 1.3 percent, corresponding to less than one inch (.87 inches) of water to the first four feet. The difference between the percent of water and the hygroscopic coefficient was 3.62 where the corn was living and 2.8 where it was dead. It is unfortunate that the exact percent of water in the heavy soil was not determined at the time the crops died, so that similar comparisons might be made. However, it may be assumed that the crops died when the moisture content was comparatively high, probably above 15 percent, because the soil contained 12.08 percent of moisture in the first three feet before the crops were planted and 3.34 inches of penetrating rain fell before they died; while later, after 5.29 inches of penetrating rain had fallen the soil was found to contain an average of 19.35 percent in the first three feet. The complete data are presented in Tables XXXIV, XXXV, and XXXVI, showing moisture content and hygroscopic coefficient as related to plant growth.

TABLE XXXIV.—MOISTURE AND HYGROSCOPIC COEFFICIENT IN THE HEAVY SOIL WHERE CROPS DIED, AUGUST, 1911, AFTER RAINY SEASON IN WHICH 3.34 INCHES OF PENETRATING RAIN FELL

Depth, in feet	Moisture June 10, before crops were planted		Moisture September 15, when total penetrating precipitation, after June 10, had reached 5.29 inches.		Hygroscopic coefficient
	Percent moisture	Inches of water	Percent moisture	Inches of water	
1	14.11	2.24	21.36	3.38	10.06
2	11.66	1.85	21.40	3.39	9.98
3	10.47	1.63	15.30	2.39	9.84
4	10.85	1.72	11.09	1.76	8.23
5	8.00	1.26	10.57	1.66	5.60
6	9.16	1.37	9.41	1.41	5.80
7	11.92	1.83	11.20	1.72	5.53

TABLE XXXV.—MOISTURE AND HYGROSCOPIC COEFFICIENT IN THE LIGHT SANDY LOAM WHERE MILO MATURED IN 1911, AND YIELDED 29.9 BU. OF GRAIN WITH TOTAL PENETRATING PRECIPITATION OF 8.31 INCHES DURING THE GROWING SEASON

Depth, in feet	Moisture June 10, before planting		Moisture September 15		Hygroscopic coefficient
	Percent moisture	Inches of water	Percent moisture	Inches of water	
1	6.99	1.17	9.73	1.63	3.53
2	7.46	1.26	8.57	1.45	3.98
3	7.21	1.31	6.84	1.20	4.23
4	6.43	1.11	5.60	0.95	3.90
5	7.50	1.24	5.57	0.94	3.75

TABLE XXXVI.—MOISTURE AND HYGROSCOPIC COEFFICIENT IN THE LIGHT SANDY LOAM, AFTER CORN HAD GROWN TO MATURITY, 1909

Depth, in feet	Corn green, yield 15.4 bushels per acre			Corn dead, yield 4.5 bushels per acre		
	Percent moisture Sept. 17	Inches of water	Hygroscopic coefficient	Percent moisture Sept. 17	Inches of water	Hygroscopic coefficient
1	7.75	1.30	4.34	5.58	0.97	3.53
2	8.82	1.41	4.91	6.71	1.15	3.98
3	8.49	1.40	4.60	7.40	1.24	4.23
4	6.98	1.26	3.72	7.15	1.24	3.90
5	10.51	1.73	4.48	8.88	1.47	4.24
6	13.24	1.92	6.48	12.00	1.86	5.20
7	14.49	2.19	7.70	17.91	2.65	9.50

Fig. 1.—Dwarf milo maize, October, 1911, grown on 8.31 inches of penetrating rain without supplemental irrigation. Land fallowed in 1910. Yield 29.9 bu. an acre.

Fig. 2.—Dwarf milo maize, August 20, 1910, grown on 9.34 inches of penetrating rain with 4 inches of supplemental irrigation before planting on June 9. Yield 50 bu. an acre.

PLATE IV.—TWO PLOTS OF MILO MAIZE ON LIGHT SANDY LOAM AT McNEAL. THIS TYPE OF SOIL HAS PROVED THE MOST SUITABLE FOR DRY-FARMING IN SOUTHERN ARIZONA.

RETENTION AND EVAPORATION OF WATER IN LIGHT AND HEAVY SOILS

Water does not penetrate heavy soils quickly, consequently, in our most violent storms, much rainfall is lost by flooding. Observations made thirty-six hours after a rain of .78 inches June 11, 1911, showed that the water had penetrated the heavy soil only three inches, the medium soil four to six inches, and the light soil twelve inches. Similar observations in September, three days after rains totaling 1.16 inches, showed a penetration of four inches in the heavy soil, six inches in the medium soil and sixteen inches in the light soil. The heavy soil can hold a much larger percentage of water than the light soil. Thus, samples taken September 15, where the surface appeared saturated from recent rains, showed 29.3 percent moisture in the heavy soil and only 15.52 percent in the medium light soil. This great absorbtive power of the heavy soils is a great advantage in the northern dry-farming regions where the rain falls in the winter and comes in gentle showers, thus giving plenty of time for the water to penetrate by the combined force of gravity and capillary attraction. But in our hot dry climate, with our summer rainfall, a heavy soil is a decided disadvantage, for the water either runs off by flooding or is held near the surface, where it is lost in the creation of the dust mulch, which must be at least five inches deep to be effective.

On the other hand, the light soils allow quick penetration to such depth that comparatively little water is lost by flooding or in creating the dust mulch. Thus, if a dust mulch five inches deep had been created in the heavy soil as soon as possible after each rain, practically all of the 1.16 inches of rain preceding September 15, 1911, would have been lost by evaporation; while in the light soil less than one-third of it would have been lost under like conditions. If the dust mulch had been only two and one-half inches deep, the depth secured by intertillage of crops, five-eights of the rainfall would have been lost in the heavy soil and only about one-sixth in the light soil.

The summer rains of 1911 penetrated the heavy soil three feet, the medium soil four feet, and the light soil seven feet, as shown by samples taken November 2. In 1910 the difference shown between the soil types is not quite so great, owing to the samples in the the medium soil, and some of those in the heavy soil, having been taken from places that undoubtedly received some floodwater. In that year the penetration in heavy soil was four feet where no flooding occurred, and eight feet in the light soil under similar treatment.

Light soils allow more rapid capillary movement, which, no doubt, accounts for the fact that, even with their deeper penetration, when attempts were made to conserve their stored water from one season to the next, practically all of it was lost, the same as in the heavy soil. This more rapid movement, however, would result in a more complete use of the soil water by plants growing on the light soil; and, since intertillage seems to have been quite effective in conserving water during the rainy season, very probably nearly all the rain that fell on the light soils was used by the crops. This, together with the great difference in the hygroscopic coefficient, accounts for the fact that the light soil, with an initial water content of only 7.02 percent in the first four feet, yielded an excellent crop of milo, while, similarly the heavy soil with 11.77 percent produced only crop failures with corn, sorghum and beans.

The writer, therefore, does not recommend the heavy types of soil for purely dry-farming purposes in southern Arizona. They respond readily, however, to the application of additional water and, under a system of supplemental irrigation, may perhaps become the best soils of the Valley. Our tests with heavy soils under this system, however, have been only incidental and due to accidental flooding; they cannot, therefore, be considered conclusive. Where they have been fallowed, the heaviest of them have crusted two and one-half feet deep each year, and it is probable that this crust is never thoroughly softened by the summer rains, although it becomes wet. Subsoiling has been suggested as a means of breaking up and preventing this crust, and deep plowing, with rough, untilled, summer fallow, as a means of securing a more thorough and rapid penetration of rainfall. These problems are subjects for further experimentation.

OTHER CONSIDERATIONS IN SELECTING DRY-FARMING SOILS

Soils containing alkali should be avoided for dry-farming. The small amount of water available will result in highly concentrated soil solutions which will do the maximum amount of damage to crops. In certain sections of the Valley there is considerable alkali, especially black alkali, which does the most serious injury. Soils in Sulphur Spring Valley should be analyzed for alkali before being selected for dry-farming. Also, soils underlaid with caliche, or any other form of hard-pan within five or six feet of the surface, should be avoided. They will not allow moisture to penetrate deeply enough to become of the most benefit to plants, and such formations nearer the surface than four feet will interfere with normal development of plant roots, without which they cannot make complete use of the summer rains.

THE DRY-FARM CROPS FOR SULPHUR SPRING VALLEY

From observations and limited experience, and from a knowledge of the character of the rainfall and the season in which it occurs, settlers in the Valley had formed the opinion that summer-growing crops would have a better chance of success than winter grain crops. Therefore, we planned quite an extensive test of varieties of corn, beans and sorghum. These crops were grown for three successive summers on three distinct types of soil, by both continuous cropping, and alternate cropping and fallowing. The manner of planting, cultivation, harvesting, and yields will be described under the separate discussions of each crop.

CORN

Eighteen varieties of corn have been grown on the dry-farm during the three years. Some were grown only one year, others two, and a few the full three years. The following descriptions may serve to identify them:

Minnesota No. 13. Yellow dent; grains medium; stalks short and rather sturdy; developed by the Minnesota Experiment Station and said to be very early. Seed obtained from the Fort Hays Branch of the Kansas Experiment Station.

Pride of Saline. White dent; grains large; stalks short and thick; said to be earlier than ordinary large varieties of dent corn. Seed obtained from the Fort Hays Branch Station.

Mexican June. White dent; grains medium; stalks tall and thick; originated in Mexico and described as very early. Seed obtained from Mr. E. L. Crane of Yuma, Arizona; had been grown on Colorado River bottom land after an overflow and without further irrigation.

Laguna Mexican June. White dent; similar to Mexican June except that it has a very tight husk. Seed obtained from Mr. Ed. Bower of McNeal, Arizona, who obtained it from the Texas Seed and Floral Co., Dallas, Texas.

Mexican White Dent. Ears medium; grains small; stalks tall and slender; early. Seed obtained from the province of Zacatecas in central Mexico, where it is grown without irrigation at elevations of about 6,000 feet.

Funk's Ninety Day. Yellow dent, ears and grains medium small; stalks short and medium slender; husk loose; one of the earliest varieties of dent corn. Seed grown in 1908 on the dry-farm by Mr. Bower.

Cream Dent. Cream colored dent; ears short and thick; grains medium to small; stalks short and thick; very early. Grown by farmers for many years in Navajo and Apache Counties by irrigation, and also grown in the mountainous regions of the same counties without irrigation; seems well adapted to dry-farming in northern Arizona.

Etter's Red Dent. Ears small and compact; grains dark red, deep, and narrow; stalks tall and slender; early. Seed obtained from Mr. C. M. Etter of Phoenix, Arizona, who brought it from Kansas about twelve years ago, and adapted it to conditions existing in Salt River Valley. The original name could not be obtained.

North Dakota Special. Yellow dent; ears and grains medium; stalks short. Developed by the North Dakota Experiment Station, and said to be very early and very drouth resistant. Seed obtained from a North Dakota seedsman.

White Flint. Long, slender, cylindrical ears; grains broad and shallow; stalks short, slender, and many eared; inclined to sucker; very early. Grown by farmers in northern Arizona for thirty years, both with and without irrigation. Seed brought by them from Utah. Our seed obtained from Snowflake.

Australian White Flint. Similar to White Flint. Seed obtained from the Barteldes Seed Company, Denver, Colorado.

Mexican Flint. Ears much larger than White Flint and tapering; grains small and very hard, slight creamy under-color due to the corneous nature of the grain; stalks medium large and many eared; inclined to sucker. Seed obtained from a farmer in San Simon Valley, who obtained it from Mexico.

Montezuma. A variety of Flint corn similar to the above. Seed obtained from a farmer in Sulphur Spring Valley, who obtained it from Mexico.

Blue Aztec. The common, blue soft corn grown by the Indian tribes in northern Arizona; ears short and thick; grains shallow and sometimes dented; stalks very short; many ears and many suckers.

Yellow Aztec No. 1. Yellow soft corn; ears small and short; grains small and shallow; stalks short and slender; often two eared. Grown by Indian tribes seventy-five miles southwest of Tucson, without irrigation. Seed obtained from them.

Yellow Aztec No. 2. A yellow variety of soft corn grown by irrigation by the farmers in the vicinity of Tucson. Very similar to, and probably originally the same as the variety described above. Seed obtained from a Tucson seedsman.

White Aztec. A white variety of soft corn, similar to the yellow variety and obtained from a Tucson seedsman.

In 1909 twelve of these varieties were planted on land that had grown two previous crops of corn and was to be cropped continuously during our experiments. It had not been plowed since the previous season, but had been disced several times. A crust varying from four to nine inches in thickness had formed under the dust mulch. The seed was planted with a combined lister and drill of the sulky type, which did not penetrate more than four inches, and, consequently, did not break through the crust. The seed was covered with perfectly dry soil about two and one-half inches deep in the bottom of these shallow furrows.

The plots were 48 feet wide and 230 feet long, each containing one-fourth of an acre. Fourteen rows were planted to the plot, giving an average distance of three feet and five inches between the rows. All varieties were planted thickly to insure a perfect stand, and thinned later to what was believed to be the proper distance for each variety, which was one stalk and occasionally two every nineteen inches for the small ones, such as Aztec corn, and one stalk every thirty-two inches for the larger ones. The plantings were made July 1 and 2, and on July 5 and 6 there was a total precipitation of .73 inches. This moisture penetrated the soil sufficiently to bring up all the plantings and to maintain the crops in fairly good condition until the latter part of July, when the summer rainy season opened fully and continued with rather frequent light showers until September 5, after which no more rain fell. On October 8 harvesting was begun. A few plots unharvested October 10 were killed by frost, but were harvested immediately thereafter. This gave a growing season of ninety-seven days. Observations made September 15, and again October 7 showed some interesting facts regarding the adaptations of the different varieties to our short growing seasons. These observations are recorded in Table XXXVII.

The following year, 1910, the Yellow Aztec No. 2 was discarded because of its similarity to Yellow Aztec No. 1, and to the White Aztec in yield, length of growing season, and habit of growth, the name "Yellow Aztec" being adopted for the variety retained. Pride of Saline, was discarded because of its lateness; Funk's 90 Day,

TABLE XXXVII.—OBSERVATIONS ON CONDITIONS OF DIFFERENT VARIETIES OF CORN AT DIFFERENT DATES, 1909

Variety	Observed September 15 at 72 days	Observed October 7 at 95 days
Minnesota No. 13	Just silking	Ears not quite ripe
Pride of Saline	Beginning to tassel	Stalks dried up; no ears
Blue Aztec	In good "roasting ear"	Ripe and fodder dried up; well eared
Yellow Aztec No. 1	Ears hardening	Ripe and fodder dried up; every stalk eared
Yellow Aztec No. 2	In "roasting ear"	Ripe and fodder dry; well eared
White Aztec	In "roasting ear"	Ripe and fodder dry, well eared
Mexican June	Not tasseled or silked	Green; no ears
Laguna Mexican June	Not tasseled or silked	Green, only a few ears
Funk's 90 Day	Tasseling and silking	Green; ears not mature
Mexican White Dent	Beginning to tassel and silk	Damaged by drouth; ears not mature
Cream Dent	Poor stand; ears half filled	Green; well eared; ears not mature
White Flint	In full "roasting ear"	Ripe; ears mature; fodder ready to cut; one or two ears to every stalk

because of its liability to smut, 90 percent of the crop of 1909 being smutted; also Mexican June, because of its similarity to Laguna Mexican June. In place of the discarded varieties, Etter's Red Dent, North Dakota Special, White Australian Flint, and Montezuma were added to the list. The revised selection of varieties was planted about the middle of June in the same manner as in 1909, except that an attempt was made to penetrate the bottom of the crust and plant the corn in moist soil. This resulted in poor stands on nearly all the plots, due to clods of broken crust falling back into the furrows, where they were broken down by rain, increasing the deep covering and preventing the corn from coming up. The first rain sufficient to sprout seeds occurred July 22, and the first killing frost October 17, giving a growing season of eighty-seven days. The Yellow Aztec corn was ripe by September 22. White Aztec and Blue Aztec were ripe when harvested. The Flint varieties made some immature grain, but none were thoroughly ripened. The remainder of the varieties failed to mature grain, although a small amount of immature grain is credited to a few of them in the table giving yields.

The conditions under which the varieties were grown were not uniform. There were at least three distinct types of soil; and some were grown on land that had grown three successive crops previously, while others were grown on land that had been fallowed in 1909. However, in most cases, there were plots enough of each variety to test it under all these conditions.

In 1911 all but seven of the varieties grown in 1910 were discarded, and Mexican Flint corn was added to the list. On June 11 a rainfall of .78 inches occurred, and, immediately thereafter, the north field (medium and light types of soil) was planted, by means of a Hoosier double-disk press drill, covering the seed two inches deep in from four to six inches of moist soil. The same method of planting was tried in the south field (heavy type of soil) but the plantings failed to come up. The ground was harrowed with a spike-tooth harrow immediately after planting. In the north field all plantings came up soon, and the crops maintained themselves in fair condition until the ainy season opened July 9. However, after a short rainy season of ten days, five week's drouth, accompanied by excessive heat, during the latter part of July and August, burned the tassels and silks beyond recovery, and most of the plots were complete failures. The remainder of the south field was planted with a lister, and the corn on these plots, together with that planted earlier with the press drill, failed to come up until after the rains, July 9. Thus, it passed the drouth without tasseling and silking. After August 26 the rainy season extended through both September and October, and killing frost did not occur until October 23. This afforded a growing season long enough to mature grain on such plots as were not already destroyed by the heat and the drouth.

All plots were cultivated once with a two-horse cultivator and three times with a 14-tooth harrow. A comparison of the yields obtained will not allow any safe conclusions to be drawn regarding drouth resistance of the different varieties, since those varieties that came through the drouth were either up later, or were on plots having a higher moisture content; and, in some instances, the same variety failed on one plot and made considerable grain and forage on another. All crops were cultivated six times in 1909, one to three times in 1910, and four times in 1911.

In determining yields an account was kept of the total crop as well as of the grain in order to determine the value of the different varieties for forage or silage. The crop was cut and shocked, and, after standing for thirty days, the total weight determined. It was then husked and the weight of grain determined separately. This method of weighing gave as nearly uniform moisture conditions at the time of weighing as it was possible to attain, and the results are comparable in that respect. Table XXXVIII shows the results obtained.

TABLE XXXVIII.—YIELDS OF VARIETIES OF CORN AT MCNEAL

Variety	Year	Pounds per acre		Stand	Soil type	Previous treatment of soil
		Total crop	Grain			
White Flint.	1909	2783	900	Thin	Light	Part corn, part fallow 1908
White Flint.	1910	948	80	Good	Heavy	Prairie1908; fallow1909
White Flint.	1910	1300	180	Medium	Medium	Prairie1908; fallow1909
White Flint	1910	600	150	Half	Medium	Crop 1907, 1908; fallow 1909
White Flint ..	1910	1200	405	Half	Medium	Crop 1907-1909 incl.
White Flint..	1911	1508	736	Good	Light	Prairie 1908; fallow 1909, 1910
White Flint.	1911	680	140	Good	Medium	Crop 1907-1910 incl.
White Flint ...	1911	Failed	...	Good	Heavy	Prairie 1908; fallow 1909, 1910
White Flint....	1911	Failed	..	Good	Medium	Crop 1907, 1908, 1910; fallow 1909
Yellow Aztec...	1909	1016	408	Good	Light	Crop 1907, 1908
Yellow Aztec...	1910	880	176	Medium	Heavy	Prairie1908; fallow1909
Yellow Aztec...	1910	1472	501	Good	Light	Crop 1907, 1908; fallow 1909
Yellow Aztec...	1910	880	421	Good	Medium	Crop 1907, 1908, 1909
Yellow Aztec...	1911	1184	340	Good	Medium	Prairie 1908; fallow 1909, 1910
Yellow Aztec (No. 2)...	1909	1400	336	Good	Light	Crop 1907, 1908
White Aztec...	1909	1400	400	Good	Light	Crop 1907, 1908
White Aztec...	1910	980	403	Medium	Light	Crop 1907, 1908; fallow 1909
White Aztec...	1910	768	214	Poor	Medium	Crop 1907, 1908, 1909
Blue Aztec....	1909	1428	296	Good	Medium	Crop 1907, 1908
Blue Aztec....	1910	1572	220	Medium	Heavy	Prairie1908;fallow1909
Blue Aztec....	1910	1560	588	Medium	Light	Crop 1907, 1908; fallow 1909
Blue Aztec....	1910	1280	330	Medium	Medium	Crop 1907, 1908, 1909
Blue Aztec....	1911	Failed	...	Good	Heavy	Prairie1908; fallow1909 winter grain 1910
Blue Aztec....	1911	Failed	...	Good	Medium	Crop 1907-1910 incl.
Mexican White Dent.......	1909	2664	120	Good	Medium	Crop 1907, 1908
Mexican White Dent......	1910	1440	None	Medium	Heavy	Prairie1908; fallow1909

TABLE XXXVIII.—*Continued*

Variety	Year	Pounds per acre		Stand	Soil type	Previous treatment of soil
		Total crop	Grain			
Mexican White Dent. ...	1910	2900	200	Good	Light	Crop 1907, 1908, fallow 1909
Mexican White Dent.	1910	1492	58	Good	Light	Crop 1907, 1908, 1909
Laguna June	1909	1936	66	Good	Light	Crop 1907, 1908
Laguna June .	1910	2268	None	Good	Heavy	Prairie1908; fallow1909
Laguna June	1910	2800	50	Good	Medium	Crop 1907, 1908; fallow 1909
Laguna June	1910	800	None	Poor	Medium	Crop 1907, 1908, 1909
Laguna June	1911	1024	192	Good	Heavy	Prairie 1908, fallow 1909, 1910
Laguna June	1911	2480	332	Good	Medium	Prairie 1908; fallow 1909, 1910
Laguna June	1911	1600	168	Medium	Medium	Prairie 1908; fallow 1909, 1910
Laguna June.	1911	1870	338	Good	Light	Crop 1907-1910 incl.
Etter's Red Dent. . .	9110	2764	None	Good	Heavy	Prairie1908;fallow 1909
Etter's Red Dent...	1910	2800	124	Good	Medium	Crop 1907, 1908; fallow 1909
Etter's Red Dent.	1910	1120	42	Half	Medium	Crop 1907, 1908, 1909
Etter's Red Dent......	1911	1838	354	Good	Light	Crop 1907-1910 incl.
Australian Flint	1910	764	160	Half	Heavy	Prairie1908;fallow 1909
Australian Flint	1910	600	244	Half	Light	Crop 1907, 1908; fallow 1909
Australian Flint	1910	300	63	Poor	Light	Crop 1907, 1908, 1909
Australian Flint	1911	Failed	...	Good	Light	Crop 1907-1910 incl.
Minn. No. 13. .	1909	828	160	Good	Medium	Crop 1907, 1908
Minn. No. 13. .	1910	1540	100	Medium	Heavy	Prairie1908;fallow 1909
Minn. No. 13. .	1910	1252	148	Good	Light	Crop 1907, 1908; fallow 1909
Minn. No. 13. .	1910	280	None	Poor	Medium	Crop 1907, 1908, 1909
Cream Dent...	1909	491	117	Poor	Medium	Crop 1907, 1908
Cream Dent...	1910	800	None	Half	Half	Prairie1908;fallow 1909
Funk's 90 Day.	1909	1570	124	Good	Medium	Crop 1907, 1908
Pride of Saline.	1909	1172	None	Good	Medium	Crop 1907, 1908
Mexican June. .	1909	1520	None	Good	Light	Crop 1907, 1908
Montezuma....	1910	600	None	Half	Medium	Prairie1908;fallow 1909
Mexican Flint. .	1911	3840	528	Good	Light	Prairie 1908; fallow 1909, 1910
N. Dak. Special	1910	480	None	Poor	Medium	Prairie1908; fallow1909

None of the varieties of corn show great promise as grain crops for Sulphur Spring Valley. Aztec varieties of soft corn persistently produced considerable quantities of grain, even under the most adverse conditions, but the ears are too small and the labor of husking too great to make them profitable as marketable grain crops. It required about one hour to husk a bushel of grain. They might be used with profit to enrich silage made from other varieties, or as feed, if animals were allowed to do the harvesting, a practice common in the East with hogs, and which could be adapted to poultry feeding under our conditions. These corns have ripened in seventy days after planting, which insures some grain even in the shortest growing seasons within our knowledge of the Valley.

The blue variety of Aztec corn has somewhat larger ears than the yellow and white varieties, which are husked more easily; but, on account of its shorter stalks, it could not be recommended instead of the other two. The failure of Blue Aztec in 1911 was due more to the kind of soil in which it was grown, and to the manner of cultivation, than to any weakness in the variety.

White Flint has been the best producer of grain, and is worthy of further trial. It produces a long ear, which is easily husked, and it seems to withstand smut better than the larger varieties. White Flint is only a few days longer in maturing than the Aztec corn. It may also be used in enriching silage. The variety purchased as Australian White Flint did not do so well as the common variety.

Mexican Flint, the one season it was grown, gave promise of being equal to the White Flint. It has a larger ear and stalk, and matures at about the same time.

Laguna Mexican June, Etter's Red Dent, and Mexican White Dent have led all varieties in the production of forage; and, since they have been quite persistent in the production of small quantities of grain, they are recommended for silage. They did not equal the White Flint in the production of grain even when supplemental water was added to the rainfall. The tight shuck of the Laguna makes it especially resistant to smut, to which the other two varieties are susceptible, but less so than Funk's 90 Day.

Funk's 90 Day was the earliest of the Dent varieties tested. It would have produced a fair amount of grain had it not been for the ravages of smut, with which at least ninety percent of the ears were affected in 1909. As it had been similarly damaged the two preceding years when grown by Mr. Bower, we discarded it after one season's test.

None of the other varieties tested showed characteristics worthy of discussion. All the larger varieties, except Laguna Mexican June, were more susceptible to smut, which seemed very prevalent, than the smaller varieties, but these, on the other hand, were damaged badly by birds. White Flint seemed to be their favorite, nearly half the crops being taken by them in 1909. Several plots were badly damaged in 1910; but, in 1911, the birds were kept away and no damage occurred In recording yields, this damage was estimated as closely as possible and corrections made for it, so that Table XXXIX shows, as accurately as possible, the actual yields that would have been obtained had there been no damage by birds.

THE SORGHUMS

One variety only of saccharine sorghum has been tested; namely, Early Amber. Of the nonsaccharine varieties we have tested Black Hulled White Kafir, Red Kafir, Standard and Dwarf milo maize, and broom corn of the Oklahoma dwarf type.

Kafir corn proved to be too late maturing for our short growing season and was discarded in 1911. Milo maize and sorghum matured considerable seed in 1909, but none in 1910, the season being too short. In 1910 low yields of milo maize forage were obtained. This was due to the extremely poor stands caused by attempting to plant deeply enough to reach stored moisture, which was insufficient to sprout the seeds; while the deep covering, increased by soil washed into the furrows by the first rain of the season, formed a crust which prevented the young plants from coming up. Milo maize, therefore, is a much better forage crop than is indicated by the table of yields.

In 1909 and 1910 plantings were made with the lister in the manner described under the discussion of corn varieties. In 1911 the double-disc press drill was used in planting part of the plots, and the lister for the balance. With sorghum our best results were obtained by planting with the lister, but this was due, probably, to soil type and moisture content rather than to the method of planting. With milo maize the best results by purely dry-farming methods were obtained with the press drill, seeding at the rate of eight pounds to the acre, and thinning to one stalk every six inches. Special plates were prepared for seeding which dropped from seven to thirty-two pounds of seed to the acre, and the plots were thinned to any stand desired.

All plots were cultivated in the same manner as described for corn—six times in 1909, one to three times in 1910, and four times in 1911. One plot of sorghum in 1910 was broadcasted at the rate

TABLE XXXIX.—YIELDS OF SACCHARINE AND NONSACHARINE VARIETIES OF SORGHUM, WITHOUT IRRIGATION, AT MCNEAL

Variety	Year	Pounds per acre		Stand	Soil type	Previous treatment of soil
		Total crop	Grain			
Early Amber sorghum	1909	3528	None	Good	Light	Crop 1907, 1908
" "	1909	3056	268	Good	Medium	Crop 1907, 1908
" "	1909	1000	None	Good	Light	Prairie 1908
" "	1910	5120	None	Good	Medium	Crop 1907, 1908; fallow 1909
" "	1910	2520	None	Medium	Medium	Crop 1907, 1908, 1909
" "	1910	6556	None	Good	Heavy	Prairie1908,fallow1909
" "	1911	1048	None	Good	Heavy	Prairie 1908, fallow 1909, 1910
" "	1911	1416	None	Good	Heavy	Prairie 1908; fallow 1909, 1910
" "	1911	4904	None	Good	Medium	Prairie 1908; fallow 1909, 1910
" "	1911	2730	None	Good	Medium	Crop 1907-1910 incl.
Average		3188				
Milo, dwarf...	1910	1312	None	Very poor	Heavy	Prairie1908;fallow1909
Milo, dwarf...	1910	400	None	Very poor	Heavy	Prairie1908;fallow1909
Milo, dwarf...	1910	1780	None	Very poor	Medium	Crop 1907, 1908; fallow 1909
Milo, dwarf...	1910	320	None	Very poor	Medium	Crop 1907, 1908; fallow 1909
Milo, dwarf...	1910	1880	None	Very poor	Medium	Crop 1907, 1908, 1909
Milo, dwarf ..	1910	100	None	Very poor	Light	Crop 1907, 1908, 1909
Milo, dwarf...	1911	2192	460	Good	Medium	Prairie 1908, fallow 1909, 1910
Milo, dwarf ..	1911	1844	None	Good	Medium	Crop 1907-1910 incl.
Milo, dwarf ..	1911	4285	1675	Good	Medium	Prairie1908;crop 1909 fallow 1910
Milo, dwarf...	1911	2036	None	Good	Medium	Prairie 1908; fallow 1909, 1910
Milo, standard	1909	2760	280	Good	Light	Crop 1907, 1908
Milo, standard	1909	4780	240	Good	Medium	Crop 1907, 1908
White Kafir ..	1909	1976	None	Good	Medium	Crop 1907, 1908
Red Kafir	1909	1744	None	Good	Medium	Crop 1907, 1908
Red Kafir	1910	4116	None	Half	Medium	Prairie1908;fallow1909
Broom corn, dwarf....	1910	1520	...	Good	Medium	Prairie 1908; fallow; 1909
" "	1910	1280	...	Good	Light	Crop 1907, 1908; fallow 1909
" "	1910	2300	...	Good	Medium	Crop 1907, 1908, 1909

of thirty-eight pounds to the acre, and given no cultivation. The yields obtained during three years are shown in Table XXXIX.

From the table it will be seen that Early Amber sorghum has proved to be a persistent and profitable yielder of forage. It yields best when planted in rows and cultivated, and the small yield of the plot seeded broadcast corroborated the experience of neighboring farmers in that respect. It may be seeded with a combined lister and drill, or with a press drill, or it may be sown by hand in the bottom of lister furrows and covered with a harrow, or it may be seeded in similar furrows with a corn drill. The corn drill may be converted into a sorghum drill by boring holes five-sixteenths of an inch in diameter in a blank plate at intervals that will drop every four inches. In our drill this required twenty holes in the plate. Sorghum seed may be sown at any time preceding the rainy season. It will lie in the ground unharmed until the rains begin, when it will sprout at once and come up. The seed should be covered not more than one and one-half inches deep. When seeded thickly in the rows, it makes hay of good quality, the stalks being small, while the yield is fully as great as with thinner planting, allowing larger stalks. Sixteen pounds of seed to the acre is sufficient.

Standard milo maize produced larger yields of forage than did sorghum in 1909, the only year in which they were compared. It also produced considerable grain and would be fully equal to sorghum for use in the silo, though not considered as good a hay crop. The dwarf form of milo has been the best producer of grain, and for this purpose it far outranks any of the varieties of corn that we have tested. Ordinarily, the season is a few days too short to mature the grain fully; but, if the plants can be started a few days ahead of the season, the crop can be relied upon to produce remunerative crops of grain. Its dwarf habit of growth is a great advantage, as the grain may be harvested with the header or self-binder, and threshed with an ordinary wheat thresher.

For forage, milo maize should be planted and cultivated in the same manner as sorghum, but for grain the stalks should stand every six inches in rows three feet and six inches apart. Planted in this way, it will stool to about three stalks in a place, if moisture conditions are favorable. It should be cultivated after every rain.

The season was not long enough to mature Kafir corn; and, after two season's trial, it was discarded in favor of milo maize.

The one season's trial of dwarf broom corn was rather favorable, but further testing is needed before it can be recommended. Its successful culture would require a broom factory in the Valley to insure a market for the crop.

German millet was tested on three different plots in 1910, but, as all were failures, the crop was discarded. In especially favored locations good crops of this variety of millet have been grown in the Valley. We do not recommend it, however, for general planting, because the sorghums are so much better.

BEANS

Six varieties of beans have been tested. The seed originated as follows: The common Pink bean was purchased in a grocery at Douglas. A wax bean, identified as Leopard Wax, was obtained from S. F. Smith of Snowflake, Arizona, where it had been tested by dry-farming methods with reported success. Four varieties—Yellow Tepary, White Tepary, Red Indian and Hansen, came originally from the Papago Indians about seventy-five miles southwest of Tucson.

In 1909 Pink beans made a very good showing on a plot situated in a depression which received some floodwater during the heaviest rains. In 1910 and 1911 this variety was not so successful; and, while many reports came to the writer of good yields obtained by various farmers, his own results during the three years do not allow of any unqualified endorsement of this variety for general planting.

The Red Indian and the Hansen were quite similar in growth and yield to the Pink bean, and were discarded in 1911.

The Leopard Wax made a good yield in 1909, considering that there was a very poor stand on the single plot grown. In 1910 there were continued poor stands, and in 1911 this bean also was discarded.

Tepary beans proved to be far the best yielders of all varieties tested. In 1909 only the yellow variety was grown, and we had seed for only one-ninth of an acre. This seed was planted on a plot of ground having a gravel streak 90 feet across in a total length of 242 feet. The teparies did not do so well on the gravelly part of the plot, and the stand was much poorer than where there was no gravel, but the average yield of the whole plot was 457 pounds per acre.

NOTE Professor Clothier s records show that yellow teparies were grown at McNeal in 1909. Bulletin 68, at the bottom of page 612 therefore contains an error stating that no teparies were grown at McNeal in 1909 On page 613 *Bayou beans* listed as yielding 457 pounds per acre, should be corrected to read *yellow teparies* —R H FORBES

Fig. 1.—Dwarf milo maize at McNeal dry-farm, yielding 35.7 bu. an acre in 1911, when brought up by supplemental irrigation.

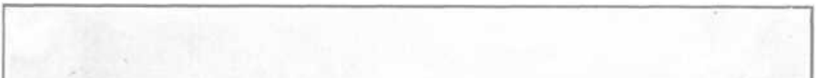

Fig. 2.—Yellow tepary beans at McNeal dry-farm, yielding 739 lb. an acre on land that had been cropped every year for five years.

PLATE V.—TWO SUITABLE DROUTH-RESISTANT CROPS FOR SULPHUR SPRING VALLEY.

When this yield was compared with 496 pounds per acre of Pink beans on a plot having no gravel and receiving some floodwater, and with a better stand than the teparies, the new bean impressed the writer very favorably as a dry-farming crop. Consequently extensive experiments with it were planned for the following season.

In 1910 the white tepary was tested for the first time and yielded fully as well as the yellow variety. The stand on all plots that year was poor, however, due to heavy storms which partly filled the furrows in which the beans were planted. The seeds were covered so deeply and the ground above them was baked so badly that the young plants could not come up. For this reason, the bean plots grown in 1910 are not strictly comparable. In 1911 uniformly good stands were obtained on all plots and the differences in yield that year were due to differences in variety.

The teparies proved their superiority over other species in 1911 more fully than in 1909 or in 1910. They also displayed a recuperative quality not shown by Pink beans when injured by a hot dry spell during the growing season, and were more resistant against both heat and drouth than Pink beans.

Tepary beans brought up by the rains on June 11, supplemented by light rains on July 9, 14, 16, and 20, set and matured 140 pounds of seed per acre by the end of the August drouth, which lasted from July 20 to August 25. No seed was produced by the Pink beans under similar conditions. After the drouth the teparies made a second growth, and set and matured an additional 387 pounds of beans to the acre before the end of the growing season, making a total yield of 527 pounds an acre as an average of four plots. Four plots of Pink beans averaged only 96 pounds an acre under the same conditions.

Nine plots of Pink beans grown during the three years without irrigation averaged 135 pounds per acre. Six plots of yellow teparies grown in the same manner averaged 409 pounds per acre, and four plots of white teparies averaged 372 pounds per acre. The ten plots of teparies averaged 387 pounds per acre against only 135 pounds per acre for the nine plots of Pink beans. These averages were taken from yields of plots grown on all types of soil, and they represent fairly the productivity of the two types of beans when compared with each other. While the yellow variety of teparies yielded on an average a little higher than the white variety, the difference was so slight that we recommend the white variety for planting, because its superior flavor and white color will be more likely to insure a market for it.

Teparies germinate and grow very promptly. Plants from seed sown in moist soil on Monday evening were showing through the ground Thursday evening, and the rows could be distinctly seen Friday morning, although the seed was covered three inches deep. It was several days longer before Pink beans planted in a similar manner were showing through the ground. Teparies also bloom and begin bearing earlier than Pink beans.

When given small amounts of supplemental irrigation, teparies showed even greater superiority over Pink beans than under purely dry-farming conditions. Three plots of teparies grown by supplemental irrigation in 1910 and 1911 averaged 761 pounds of beans per acre, while three plots of Pink beans under similar conditions averaged only 155 pounds per acre.

The yields obtained with all varieties of beans tested by purely dry-farming methods during the three years of our experiments are presented in Table XL. The yields obtained by supplemental irrigation have already been presented in Tables XXX and XXXII.

CULTURE OF BEANS

In 1909 and 1910 all beans were planted with a combined lister and drill, the beans being covered two to three inches deep in the bottoms of furrows four inches deep. The first rain came nearly three weeks in advance of the general rainy season, and occurred in two showers on consecutive days, the total precipitation being .73 inches. The furrows concentrated this scanty rainfall upon the seeds, resulting in fairly good stands nearly three weeks earlier than could have been obtained by level planting. In 1910 the same method was followed, but in attempting to reach stored moisture the furrows were made much deeper, and the beans were covered four inches deep in the bottoms of the furrows. The stored moisture was not sufficient to bring the plants up, and the seeds lay in the ground nearly six weeks before rain occurred. The first rain was again a light one, but the water was concentrated in the bottoms of the furrows and started young plants. Just as they were coming through, a heavy storm occurred which washed large quantities of soil into the furrows, burying nearly all the young plants and sprouted seeds beyond hope of recovery, and resulting in extremely poor stands. In 1911 part of the plots were planted with the lister, and the seed covered as shallow as possible—in most cases not more than one and one-half inches. Other plots were planted with a press drill immediately after a rain of .78 inches, which occurred June 11. Both meth-

TABLE XL.—YIELDS OF BEANS, WITHOUT IRRIGATION, AT MCNEAL

Variety	Year	Pounds per acre	Stand	Soil type	Previous treatment of soil
Pink beans.......	1909	496	Medium to good	Medium	Crop 1907, 1908. Received some floodwater
Pink beans.......	1910	64	Half	Heavy	Prairie1908; fallow1909
Pink beans........	1910	84	Twothirds	Heavy	Prairie1908; fallow1909
Pink beans.......	1910	52	Very poor	Medium	Crop 1907, 1908, 1909
Pink beans.......	1910	Failed	None	Medium	Crop 1907, 1908; fallow 1909
Pink beans...	1911	48	Good	Heavy	Prairie 1908; fallow 1909, 1910
Pink beans........	1911	128	Good	Heavy	Prairie 1908; fallow 1909, 1910
Pink beans........	1911	144	Good	Medium	Prairie 1908; fallow 1909, 1910
Pink beans........	1911	66	Good	Light	Crop 1907-1910 incl.
Red Indian........	1909	161	Poor	Light	Crop 1907, 1908
Red Indian........	1910	88	Very poor	Light	Crop 1907, 1908; fallow 1909
Red Indian........	1910	175	Medium	Heavy	Prairie1908; fallow1909
Red Indian........	1910	Failed	None	Light	Crop 1907, 1908, 1909
Hansen...........	1909	126	Very poor	Light	Crop 1907, 1908
Hansen...........	1910	88	Very poor	Light	Crop 1907, 1908; fallow 1909
Hansen...........	1910	Failed	None	Light	Crop 1907, 1908, 1909
Leopard Wax.....	1909	135	Very poor	Light	Prairie 1908
Leopard Wax......	1910	104	Half	Medium	Prairie1908; fallow1909
Yellow tepary......	1909	457	Medium	Light	Crop 1907, 1908
Yellow tepary......	1910	160	Medium, uneven	Heavy	Prairie1908; fallow1909
Yellow tepary......	1910	370	Good	Heavy	Prairie1908; fallow1909
Yellow tepary......	1910	Failed	None	Light	Crop 1907, 1908, 1909
Yellow tepary......	1910	232	Less than half	Medium	Crop 1907, 1908; fallow 1909
Yellow tepary......	1911	730	Good	Medium	Crop 1907-1910 incl. Some floodwater
Yellow tepary......	1911	506	Good	Medium	Crop 1907, 1908, 1910; fallow 1909
White tepary......	1910	248	Medium	Heavy	Prairie1908; fallow1909
White tepary......	1910	296	Very poor	Light	Crop 1907, 1908; fallow 1909
White tepary......	1910	Failed	None	Light	Crop 1907, 1908, 1909
White tepary......	1911	480	Good	Medium	Prairie 1908; fallow 1909, 1910
White tepary......	1911	392	Good	Medium	Crop 1907-1910 incl.

ods resulted in good stands, but in the lighter types of soil beans planted with the press drill came up at once, while in the heavy type they did not come up until further rains in July. Those planted with the lister were planted several days after the rain of June 11, and also failed to come up until the July rains. These experiments are not conclusive as to the best method of planting. The lister method has the advantage of concentrating the water of the first rain, usually a light one, into the bottoms of the furrows, thus often insuring an earlier stand than could be obtained by level planting; but it will be necessary to break up any crusts that form in these furrows before the young plants come through. The danger in the lister method is from violent rains before the plants are out of the ground, which cover the seeds too deeply and form thick crusts in the bottoms of the furrows, which are difficult to break successfully. Planting by this method should be done before the rains, and the covering of the seeds should be as shallow as possible.

The press drill gave excellent results in the one season's test. With shallow planting it is also quite probable that the seeds would come up after the first rain, even though a light one, and by this means danger from deep covering and crusting would be avoided. The writer is inclined to recommend the press drill instead of the lister as the implement with which beans should be planted. Holes in the seed box may be left open to correspond with the distances between the rows, and, by stopping all others, an eight-hoed drill may be made to plant two rows of beans at one time. The drill may be adjusted to plant beans of any size and at any desired distance in the row.

The distance between rows should be from three to three and one-half feet, which is wide enough to allow thorough cultivation with a horse implement, and close enough to insure economical use of all rainfall. The distance apart in the rows will depend on the variety. Pink beans, Hansen beans, and Red Indian beans should be planted one in a place six inches apart, or two beans in a place twelve inches apart. Tepary beans do best when planted singly four inches apart. On one plot good results were obtained by planting two inches apart, but four inches gave just as good results and required less seed. These distances require sixteen pounds per acre of teparies and thirteen pounds of Pink beans and others of the same type. Larger beans would require more seed per acre for the same distances apart. Beans should be cultivated after every rain throughout the season. If weeds get a start, they should be removed with a hoe. The harvesting of beans is generally understood and need not be discussed here.

Our yields with tepary beans have been sufficiently large to be profitable, if a market for them can be obtained at about three cents a pound, and in the opinion of the writer such a market will be found when the bean becomes better known. Horses eat and relish both the seed and the dry vines; while jackrabbits will pass by Pink beans to eat teparies. This indicates, probably, that the tepary will be found adapted to stock feeding, in which case it will be worth more than three cents a pound to combine with milo maize for fattening swine, or for balancing rations for dairy cows. We therefore recommend this bean as a new and valuable dry-farming crop, especially for the Southwest. While the quality of the Pink bean is decidedly superior to the tepary, our yields of the Pink bean have been so meager that we cannot recommend it as a purely dry-farming crop, although it may be successfully grown where supplementary irrigation can be applied. Other beans tested have not proven superior to the Pink bean.

WINTER GRAIN CROPS

The following varieties of winter grains were tested on the heavy soil in 1909 and 1910: Wheat; Sonora, Gold Coin, Turkey Red, Kharkov, Kubanka, and Emmer. Barley; White Hulless and California. The crops failed to come up in 1909 owing to late planting, which was delayed until November in order to save as much moisture as possible until the following spring. It was believed, at that time, that summer fallowing would conserve the moisture.

In 1910 the plots which were planted September 12 to 14, all came up well, beginning to show above the ground September 17. Planting was done with a Hoosier double disk press drill, and the seeds were placed five and one-half inches deep, reaching moist soil below the dust mulch. The ground was broken first in January 1909, and had been in fallow twenty-one months. Moisture conditions were good. On December 17 the plots were reported to be in fair condition, and were expected to pass the winter safely. On March 22 they were reported to be suffering for water. By May 1 they were dead, and on June 10, when first observed by the writer, very little evidence remained that there had been any living grain on the plots. The soil was badly crusted and cracked open, although the ground had been harrowed several times during the winter. Moisture determinations were made at two locations in the plots, September 17, 1910, and at one location, June 10, 1911, with results shown in Table XLI.

TABLE XLI.—MOISTURE IN WINTER GRAIN PLOTS IN SEPTEMBER AT PLANTING TIME, AND IN JUNE AFTER CROPS HAD DIED FROM DROUTH

	September 17, 1910				June 10, 1911	
	Location No. 1		Location No. 2		Location No. 2	
Depth feet	Percent moisture	Inches water	Percent moisture	Inches water	Percent moisture	Inches water
1	20.42	3 23	24 92	3 95	15.60	2.47
2	17.32	2.74	19 43	3.08	15.35	2.43
3	15.17	2.37	16.10	2.51	14.98	2.34
4	10.14	1.61	12.78	2.02	12.72	2.01
5	6.40	1 01	9.29	1 46	10.57	1.56
6	6.20	0.93	10 54	1.58	10.16	1.52
7	7.19	1.10	10.11	1.55	10.94	1.68
8	7.25	1.17	13.68	2.20	9.41	1.51
Totals..		14.16		18.35		15.52

At planting time these plots contained all the moisture that it had been possible to conserve from two summer rainy seasons and one winter season, by our method of summer fallowing. It is seen that the amount was small, and that it was lost before the following June. The writer believes this will be the general result of attempts at growing winter grains. Occasionally, late fall rains with abundant winter rains, such as occurred in the fall and winter of 1911, may make it possible for grain crops to live through the season, but usually the dry winds of March, April, and May will dry out the soil and destroy the crops. Even if such crops could be brought to maturity, there is no hope of yields sufficient to compete with those obtained with milo maize by summer cropping, and for that reason the writer advises against winter grain crops in this Valley.

METHOD AND DATE OF PLANTING DRY-FARM CROPS

When the experiments were begun in Sulphur Spring Valley, the writer noticed that settlers had been waiting until after the rains began before planting their crops. This resulted in considerable delay and further shortened the growing season. In 1909 neighboring farmers delayed their planting until after the rain of July 22, with resultant crop failures, while some fairly satisfactory crops were produced on our dry-farm by plantings made before the light rains of July 5 and 6, which brought the crops up three weeks in advance of those planted after July 22.

The writer, therefore, adopted as a general system the planting of all crops before the summer rains, so that their growth would not be delayed a moment longer than necessary after sufficient water penetrated the soil to reach the seeds. The results obtained during the three years, when compared with results on adjoining farms, where planting was delayed until after the rains, abundantly justify the method. In order to secure the help of steep ridges in concentrating the water from the first light rains upon the seeds, systems of planting in the bottom of furrows by means of a combined lister and drill were adopted, and gave good results in 1909. The results in 1910 were so disastrous to the stand, that in 1911 a few plots were laid off to test the efficiency of various methods of planting: (1) on level land before the rains, with a Hoosier double-disc press drill, (2) of shallow planting in furrows with the lister before the rains, and (3) of planting after the rains began, in the bottoms of furrows made before the rains. Pink beans, Laguna Mexican June corn, and Early Amber sorghum were the crops selected for the test. The crops did not come up until after the rain of July 9. The stands obtained by the three methods were generally good, but the plots planted in furrows before the rains, made the largest yields. However, it was discovered at the beginning of the season and during the season that these plots had better moisture conditions than the others,—at least two of them having received floodwater—so these results cannot be considered conclusive. As stated elsewhere other plots were planted with the press drill after the June rains with resultant success.

In 1910 good stands were obtained on medium soil by shallow planting with the lister, and fair to good stands on heavy soil by the same method. In 1911 a rainfall of .78 inches, which penetrated the level heavy soil only three inches, wet the soil from four to twelve inches deep in the bottoms of the furrows, the average of all observations being eight inches. The writer is therefore inclined to recommend this method of planting for corn, provided the seeds are covered very shallow, and level planting with a press drill for beans and milo maize. All crops should be planted before the rains begin, if pure dry-farming is attempted. Seeds will lie in the dry soil six weeks without injury, and come up as soon as moisture strikes them. Where supplemental irrigation is used, the planting usually will be done before any rains occur. The lister was used with all crops in this method of planting; but in 1911 a crust was formed over beans by a rain of .78 inches and had to be broken before they could come up. The press drill, therefore, would give better results with beans and probably also with milo maize. Beans and milo maize should be planted not over two inches deep in moist soil, and not over one and one-half inches deep in dry soil before the rains. Corn may be planted in moist soil as deep as three or four inches, but two and a half inches will give the best results. In dry soil it should not be planted deeper than beans or milo maize.

CONCLUSION

A SUGGESTED SYSTEM OF FARM PRACTICE FOR SULPHUR SPRING VALLEY

Provision should be made for supplementing the rainfall either by using floodwaters or by pumping. Pumping is to be preferred, because water can then be applied when needed to start or save the crop. Incidentally, it will afford a sure means of having a good garden in which much of the living for the family may be grown. The live stock business should prove profitable, making use of the land lying beyond the available groundwater zone for grazing purposes, supplemented in times of shortage by forage grown upon the farm. The fodder from the production of milo maize as a grain crop will answer for this purpose; and, if insufficient in amount, it may be supplemented with sorghum grown for the purpose. The dairy business should also prove profitable, as dairy products are always in demand at high prices in Arizona. The chief feed should be silage which could be made profitably from the larger varieties of corn, such as Etter's Red Dent, Laguna Mexican June, or White Mexican Dent, enriched, if necessary, with smaller varieties, such as Flints or Aztec, all of which can be depended upon to produce some grain even under the most unfavorable conditions. It might be possible to furnish some grazing for the dairy herd during the summer months, if the range were not overstocked with other cattle.

Milo maize grown for grain should prove a profitable money crop; and, if the dwarf variety is grown, it may be harvested with a header and threshed with an ordinary wheat thresher, or it may be cut with a self-binder and threshed in the same manner. It will furnish grain for work horses, poultry, and pigs, and also may be converted into silage of good quality, if cut when the grain is in the dough.

White tepary beans should be a good money crop; and, if grown in large quantities, probably a good market in the East could be developed for them. This crop, with milo maize and sorghum, and corn for silage, should be the principal field crops grown. All crops should be grown in rows not less than three feet apart and should be given thorough intertillage. Loams and sandy loams should be selected as far as possible for cultivation; gravel banks and coarse sands should be avoided. The soils will need strengthening, and this can be done by means of barnyard manure and the plowing under of an occasional green cover crop.

The climate in Sulphur Spring Valley is superb, and with a rational system of farming, such as has been outlined above, it should become the home of many happy and prosperous people.

SUMMARY

1. Summer fallowing by the ordinary methods has not been successful in permanently accumulating water in the soil, even after a two-year fallow.

2. Supplemental irrigation has been much cheaper than summer fallowing, and has supplied the moisture necessary to bring up crops six weeks ahead of the season; while summer fallowing has proved a complete failure in this respect. The growing season is so short that crops cannot be produced successfully unless they are started ahead of the rainy season.

3. Thorough intertillage of summer grown crops always pays. It destroys weeds, keeps the soil mellow and in condition to absorb rainfall more readily, and undoubtedly checks evaporation during the rainy season. Intertillage should not be over three inches deep.

4. The light types of soil have proved to be more valuable for dry-farming than the heavier types, though the latter respond readily to the application of additional water.

5. Winter grain crops have not been successful during our experiments, and from the rainfall records it is very probable that they will not become so. The grain-bearing sorghums should be substituted for them as a source of grain.

6. Milo maize has been the best grain crop tested, and very probably will prove to be the best money crop for the Valley. Paying crops have been produced two years in succession on the same land by the application of from four to six inches of water in addition to the natural rainfall.

7. Tepary beans may become a close second to milo maize as a money crop where supplemental water is used; while they are practically the only seed crop that can be produced in anything like paying quantities without the addition of supplemental water.

8. Early Amber sorghum is a sure producer of forage even without the use of supplemental water, and it responds readily to the addition of small quantities of water. It should always be grown in rows and intertilled, and, if planted thickly enough, may be cut and cured into hay of good quality, or converted into silage.

9. Corn is not a paying grain crop when grown by the methods used in our experiments, though it may be grown for silage. Etter's Red Dent, Laguna Mexican June, and Mexican White Dent are the best silage varieties. White Flint, Mexican Flint, and the varieties of Aztec corn are persistent in the production of grain under adverse conditions, and may be planted for the purpose of supplying grain to enrich silage; but none of them, with the possible exception of White Flint, shows promise of being successful in the production of grain for the market.

10. The silo should find a place in the Valley. Stock raising and dairying, combined with the raising of milo maize and beans for the market, should constitute a system of farming that would insure a fair degree of success to the Sulphur Spring Valley settler.