EXPERIMENTS WITH IRRIGATED ROTATIONS IN THE SOUTHWEST

by

ARTHUR THEODORE BARTEL

B. S., University of Idaho, 1928

A THESIS

submitted in partial fulfillment of the requirements

for the degree of

MASTER OF SCIENCE

KANSAS STATE AGRICULTURAL COLLEGE

1930

TABLE OF CONTENTS

Page

Page

EXPERIMENTS WITH IRRIGATED ROTATIONS IN THE SOUTHWEST

INTRODUCTION

Rotations are of special benefit to newly organized irrigation projects. It is highly important that the farmers in such a project receive the earliest assistance in establishing a desirable and profitable rotation system. It was with this object in mind that the rotations discussed in this paper were started. Before a system of rotation is established it is essential to know the productiveness of the different crops and the market demand of these crops. But even after we know the productiveness and market demand of these crops, we cannot yet make out a system of rotation that is to be permanent. A rotation system is seldom permanent -- it has to change with the times. For in this rapidly progressing period new crops are constantly being developed and grown. These new crops replace the older ones and enter into the rotation system. Thus a rotation has to change with the scientific advances that are being made. Many times, however, these new crops can be interchanged with the older ones because the basis of the crop is the same.

THE YUMA RECLAMATION PROJECT

The rotations that are to be discussed were started at the United States Yuma Field Station, Bard, California, in 1923. This station is situated on the northwest end of the Yuma Reclamation Project. The Yuma Reclamation Project consists of 110,000 acres of land located in the states of Arizona and California; 65,000 acres of this area is valley land and is irrigated by water from the Colorado river.

The entire Yuma Valley soil is made up of sediments, and consists of a great bed of sand overlain and interstratified with layers of finer material left by the river as it shifted its course from one side of the valley to the other. Thus the soils all have a common origin and differ mainly in texture. Even the heaviest soils are underlain at a few feet by sand which extends to unknown depths. This sand is often rather coarse but the greater part is very fine. When this very fine sand is found at the surface it forms with the silt in the irrigation water a fine sandy loam.

The Yuma Reclamation Project was started in 1910, but it was not long before it was face to face with many problems.

Of primary importance is one concerning the sediment that is brought down by the Colorado river and deposited on the lands. This sediment is spoken of as silt and consists mainly of clay particles so finely divided at times as to be largely colloidal. The amount of silt carried by the Colorado river varies from month to month and also from year to year. The river starts its maximum silt deposit during the early summer months. At this time the water often carries 2 per cent of silt. During the winter and early spring the river carries much less silt and is often as low as 0.01 per cent. Forbes (1902) determined the amount of silt deposited in 1900 to be about 61,000,000 tons, or enough to make 53 square miles of alluvial soil one foot deep.

It can easily be seen how this deposit of silt affects agriculture on this Reclamation Project. Ditches require continual dredging and cleaning. Oftentimes certain ditches are dredged three times during one single summer. This work causes an enormous expense to be shouldered by the project. The effect of the silt upon the soil and crops is also of importance. To a sandy soil a certain amount of silt is beneficial, but as the silt accumulates it soon becomes so thick as to make cultivation difficult and penetration of water very slow. There is also some danger of using the

silty water during the hot summer months. This is especially true with alfalfa. The alfalfa is watered and the sediment almost immediately settles and forms a layer of soil so dense that the water stands on the surface of the ground for a long period of time. With the aid of the intense summer heat the alfalfa plants are soon smothered. Alfalfa on this account is not irrigated on the heavier lands of the project during the summer months. In the fall it is occasionally difficult to start young alfalfa when a large amount of silt is carried in the irrigation water.

The varying water table throughout the Yuma valley is another factor of interesting importance. Levees have been constructed on the banks of the Colorado river, thus protecting the farming lands from overflow by the river. This might tend to increase the water pressure and raise the water table in the surrounding territory. Test wells have been put down on the Yuma Reclamation Project and are situated so as to cover the entire valley. The depth of the water in these wells is measured every month. The readings show that the water table varies with the amount of water in the Colorado river. When the river is high the water table rapidly rises and when the river lowers the water table also lowers. In areas close to the river the water table

responds very rapidly to variations in the water in the river. In areas away from the river the rapidity of water table response to river variations depends on the distance away from the river, the type of soil, the general lay of the land and perhaps other factors. A water table at one place may vary from three to four feet during one single year. The water table often gets within four feet from the surface of the ground in certain sections of the project. It would seem that alkali would be more prevalent because of the high water table, but this high water table is only during the summer months when irrigation is practiced very frequently. This tends to leach the alkali salts back into the subsoil. A few large drainage ditches have been constructed to take care of the excess ground water.

REVIEW OF LITERATURE

It seems that the problem of obtaining a desirable rotation system is universal. Everywhere farmers are practicing rotation of crops in some form or other. Many years ago a crop rotation was looked upon as only a method of securing higher yields. Now numerous other factors are involved as weed control, moisture conservation, disease

control, insect control, erosion control, equal division of labor throughout the entire year, a larger amount of cash crops, and a larger diversification of crops. All these factors mean much to the financial success of the farmer and although they are all important, the main object of rotation is still generally higher yields when a long-time period is considered.

The relative importance of the rotation factors mentioned above varies with the locality. It is seldom that conditions at one place are comparable with those of another and therefore the rotations would be different. Conditions that prevail on dry-land rotations are of little value when irrigated rotations are being considered. Even an irrigated rotation in the north would be impracticable to an irrigated region in the south. Each system of agriculture is more or less independent as far as rotation problems are concerned. It is for these reasons that this review of literature will deal only with irrigated rotations, and particularly stress the publications that are of special value to this section.

Among the early rotation experiments were those discussed by Pittman (1924). These rotations were started in 1908 at the Greenville Experiment Farm, Greenville, Utah. The rotations can be termed as short rotations in that they

cover but a short period of years. Most of the experiments have to do with the effect of manure on the yield of the different crops. The continuously cropped plats of each crop were divided into untreated and manured plats. Manure was also applied to longer rotations in which several crops occur.

More conclusive results were obtained from the effect of manure on the yield of sugar beets than with any other crop. In continuously cropped plats where no manure was applied the yields of sugar beets showed a lower decline in yield than did the other crops when grown under the same conditions. Pittman also found that manure was very effective in enabling the sugar beets to resist blight (Phoma boetae).

Potatoes were second in responding to the applications of manure. The average yield of all the unmanured plats was only 62 per cent as high as the average yield of the manured plats. A four-year rotation of oats, corn, beans, and potatoes showed the second highest yield of potatoes when compared with the manured plat.

The yields of wheat and oats were increased by lighter applications of manure but decreases occurred when 40 tons of manure were applied. This was due to the straw growing too rank, thus lodging the grain and causing it to mature

improperly and increasing the difficulty in harvesting. The corn was continuously cropped with and without manure. The increase in yield due to the manure was much greater with the 5-ton application than with the 10-ton application. In conclusion, Pittman states that it is possible to maintain the nitrogen content of their soil by a rotation system in which one-third of the land is kept in alfalfa and the manure produced by feeding this alfalfa is returned to the soil.

Scofield (1918) discussed the effects of farm manure upon the yields of potatoes and sugar beets at three different stations, namely: Scottsbluff Field Station near Mitchell, Nebraska; Belle Fourche Field Station near Newell, South Dakota; and the Huntley Field Station, Huntley, Montana. These results were obtained from the rotation experiments from each of these stations. The rotations to be compared had exactly the same crop sequence except in one rotation manure was applied and the other received no manure. At Scottsbluff, Nebraska, the manure increased the yield of potatoes 40 bushels per acre and the yield of sugar beets 4.3 tons per acre. The proportion of marketable potatoes was increased 8.per cent by the application of the barnyard manure.

The application of manure at the Belle Fourche station increased the yields of potatoes 34 bushels per acre and the yield of sugar beets 1.9 tons per acre. The proportion of marketable potatoes was increased about 7 per cent. The results at the Belle Fourche station are not as outstanding as they are at the Nebraska station. Still less increases were found at the Huntley Field Station where the manure increased the yield of potatoes by 26 bushels per acre and sugar beets by 2.6 tons per acre. The proportion of marketable potatoes was not influenced at this station. The author gave no results on the comparison of manure on rotated and non-rotated lands. It is therefore impossible to say just what effect the rotations had in influencing the yields.

Scofield (1920) summarized the results obtained on the effects of alfalfa on the subsequent yields of certain irrigated crops. These results were obtained from the same three experiments as have just been discussed. These stations are located so as to represent the conditions of much of the irrigated lands in the Northern Great Plains area and it was believed that the results secured were generally applicable to that region.

The effects of alfalfa on the yields of Irish potatoes,

oats, and sugar beets have been tested at the three different stations for three years. Comparison is made between the yields of these crops when grown in the same sequence but without alfalfa. At Scottsbluff, Nebraska, the alfalfa increased the yields of the crops as follows: Potatoes 100 bushels per acre, proportion of marketable potatoes 12 per cent; oats 6 bushels per acre; and sugar beets 3.4 tons per acre. The results at the Huntley Field Station are not quite as outstanding. Alfalfa increased the yields of potatoes 50 bushels per acre, but did not increase the proportion of marketable potatoes. The yield of oats was increased 11 bushels per acre and of sugar beets 1.5 tons per acre. The soils at the Nebraska station are of a light sandy loam, and a clay loam at the Huntley station in Montana. At the Belle Fourche Field Station, however, the soil is a heavy clay loam rich in organic matter and here the beneficial effect of alfalfa was too slight to be regarded as significant.

In 1912, irrigated rotation experiments were started at the Belle Fourche Field Station, Newell, South Dakota. These rotations include 129 one-quarter acre plats. After having 14 years of results Aune (1927) makes the following summary: (1) Crops following alfalfa have not shown any

marked increase in yield except where the alfalfa is pastured by sheep or hogs; (2) the application of manure has given marked increase in the yields of sugar beets, alfalfa, and potatoes, and a slight increase in the yield of corn; (3) sugar beets following a cultivated crop have given fairly uniformly good yields, and sugar beets following a grain crop without manure or after red clover or alfalfa have given uniformly poor results; (4) potatoes in rotations which include manure or alfalfa have given better yields than without these treatments; the same was true with corn; (5) harvesting certain field crops by pasturing with live stock results in higher net returns per acre than harvesting the usual way. A marked increase in the yield of the crops that follow is also obtained. Aune states that the crops in a rotation should be so planned that the previous crop is a preparation for the crop that is to follow.

Hastings and Hansen (1929) report a series of rotation experiments begun in 1912 at the Huntley Field Station at Huntley, Montana. These rotations were 29 in number but in 1916 ten additional ones were started. The crop sequences vary from continuously cropped plats to six-year rotations. The crops grown include alfalfa, sugar beets, potatoes, oats, wheat, and corn. The alfalfa was grown in most of the

rotations in an effort to maintain the productivity of the soil.

The highest yields of sugar beets were obtained in a six-year rotation of three years alfalfa, corn (harvested with hogs), flax, sugar beets. The average yield here was over 15 tons per acre. The lowest yield occurred in a three-year rotation of potatoes, oats, and sugar beets. The average yield here was only 8 tons per acre. Very good results were obtained when the potatoes were manured and the land planted to sugar beets the second year.

Relatively low yields of potatoes were obtained in a rotation in which potatoes follow oats with rye weeded in the fall in the oats stubble and plowed under as a green manure immediately preceding the planting of the potatoes. A two-year rotation of oats and potatoes in which the potatoes were manured produced an average of 322.6 bushels per acre. This was the highest yield of potatoes in any of the rotations.

Oats was one of the major crops in the rotation systems. The lowest average yield was obtained in a continuously cropped plat. The average yield here was only 37.9 bushels per acre. An average yield of 94.5 bushels per acre was obtained in a rotation of three years alfalfa, potatoes,

oats, and sugar beets (manured).

The yields of wheat were rather low for irrigated lands. The highest average yield was only 33.8 bushels per acre. This was obtained in a two-year rotation of wheat and sugar beets. The lowest average yield of 20.7 bushels per acre was obtained in a rotation of wheat and oats. These low yields may be due to the fact that none of the wheat plats had any source of fertilizer. The highest yield of corn was found in a rotation of potatoes and corn while the lowest occurred where the land was continuously cropped to corn.

The comparative financial value of the different rotations was emphasized. Large yields are highly desirable, but it is of equal importance to know the expenses incurred in obtaining these yields. The production costs per acre of each of the crops was determined. It was found that the highest net value per acre was obtained in a two-year rotation of potatoes and sugar beets (manured). As a rule the highest returns in the rotations where manure was used as a source of additional plant food. The continuously cropped plats of corn, oats, wheat, and potatoes resulted in a loss in the net value per acre.

The effect of soil treatments on sugar beets in the rotation experiments at the Huntley Field Station are more

fully discussed by Savage and Powers (1928). They found that manure increased the average yield of sugar beets 32.4 per cent or 3.4 tons per acre. Alfalfa, on the other hand, only increased the yield 20 per cent or 2.09 tons per acre. By using manure in the alfalfa an increase of 2.34 tons was noted. Sugar beets yielded better when grown a year after alfalfa than when it directly followed alfalfa. The yields of beets in all the rotations were consistently higher following potatoes than following oats or wheat. The authors also state that sugar beets improve the physical condition of the soil for subsequent crops.

According to Holden (1923) every crop rotation should include either alfalfa, sweet clover, or some other legume crop, and the application of barnyard manure to increase or keep up the productiveness of the land. No rotation is complete without a cultivated crop. Holden states that the advantages of crop rotation are as follows: (1) Saves labor, (2) better use of water, (3) less disease, (4) less risk from hail, (5) lessens effects of low markets, (6) it is easier to keep live stock, (7) increases yields. In 1912, thirty-two different rotations were started at the Scottsbluff Experiment Station near Mitchell, Nebraska. The different crops used were potatoes, sugar beets, corn, oats,

and wheat. Manure was applied to numerous rotations. Alfalfa, however, increased the yields of potatoes, corn, oats, and wheat more than did applications of manure. Sugar beets yielded slightly higher on manured ground. Holden compared the rotations as to cash loss or gain per rotation. All rotations not having alfalfa showed a loss except one two-year rotation of oats and sugar beets manured. Every rotation having alfalfa shows a profit even though the alfalfa crop itself shows a loss in the shorter rotations. When corn is given proper care and fed to hogs on alfalfa pasture it is a profitable crop.

Fertilizer experiments with alfalfa were conducted at the United States Yuma Field Station at Bard, California. In these tests Westover and Noble (1926) found that applications of superphosphate were the most economical and practical method of increasing the alfalfa yields in that region. Applications of 500 pounds of 16 per cent superphosphate per acre showed a maximum increase of 3.52 tons per acre over the check plat. Decreases in yield often resulted when sulphur was applied. The authors recommended applications of 300 to 500 pounds of superphosphate per acre to the alfalfa every other year.

Creighton (1930) states that every year about 30,000 acres of milo are grown in the Imperial Valley, California, as a filler crop in the rotation with vegetables. There are instances where land has produced within a year one crop of early lettuce, followed by canteloupes, and followed by late milo. The author writes: "It is a common experience that milo follows wheat or barley very well, but the reverse is usually disastrous. The generally accepted explanation is that milo roots and stalks are high in sugars which, during the decaying process, nourish millions of bacteria. When this sugary solution is finally used up, these bacteria must seek food elsewhere and a competition for plant food between the yellowing grain and the bacteria takes place -- a losing battle for both. Alfalfa following milo is able to secure some nitrogen from the air, and appears not to be handicapped to any extent." Other explanations can doubtless be found in other publications.

CLIMATIC CONDITIONS

The meteorological data since the rotations were started in 1923 are given in Table I. The data given here are quite representative of the conditions that prevail throughout the valley sections of the Yuma Project.

From the maximum and mean maximum temperatures, it will be seen that quite often it gets rather warm. In every case the maximum for the year is 113 degrees or above, with an absolute maximum of 117.5. The average monthly maximum is over 100 degrees for seven months out of the year and over 110 degrees for five months out of the year. The highest mean maximum temperature seems to occur in July and August of each year, the same months in which the highest maximums are found.

It will be seen that the mean temperatures from year to year vary but slightly. The highest mean is found in 1926 and the lowest in 1923. The highest monthly mean is found during July and August.

There are no mean monthly minimum temperatures which are below 32 degrees, although in January, 1929, it was very close. The average lowest mean minimum temperature is found in January and the highest in August. The mean temperature

for August, 1929, was higher than any other from 1923 to 1929. The absolute minimum for the period was 20 degrees. This occurred in January, 1929, the same month the mean minimum was so low. In August, 1929, the minimum was 70 degrees which is exceptionally high for this period.

The amount of evaporation corresponds rather closely with the temperature variations. The least average evaporation occurs in January and the highest in June and July. Although the temperatures are high in August and September, a falling off in the evaporation is noted. This is probably due to the fact that during these months the relative humidity is high. The combination of high relative humidity and temperature makes August and September very disagreeable.

The daily wind velocities are divided into the highest, lowest, and mean. It seems as if the greatest amount of wind is found during the months of April and March. The least amount occurs during the late fall months. No days occurred when there was not at least a trace of wind.

The precipitation is very small and rarely beneficial to any of the crops. In 1928 even less than one-half an inch of rainfall fell during the entire year. The year 1926, on the other hand, leads the yearly precipitation with 8.73 inches. Most of the rainfall occurs in December

while May and June are the months of greatest drought. For five out of the seven years, no rainfall occurred during these months. The seven-year average for May and June is 0.01 inch and is almost negligible. The average yearly precipitation amounts to 3.64 inches.

The average first killing frost in the fall is found on November 24. The average last frost in the spring is on March 4. This leaves an average of 264 frost-free days each year. In 1929, the last frost in the spring was on April 8 which is considered very late for this region. During that year there were only 219 frost-free days. It seems that almost twice as many frosts occur in the spring as in the fall. In 1927,there were 12 days in which the temperature went below 32 degrees. In 1924, this number went up to 29 days.

Table I. A Summary of the Meteorological Data From the United States Yuma Field Station, Bard, California, 1923 to 1929

Year	Jan.	Febr.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	For Year
Temperature -- Maximum													
1923	84.0	90.0	89.0	97.0	108.0	113.0	110.0	107.0	111.0	97.0	84.0	73.0	113.0
1924	77.0	86.0	85.0	91.5	106.5	113.0	111.0	110.0	110.0	107.0	99.0	82.0	113.0
1925	83.0	86.0	94.0	104.0	104.0	114.0	117.0	108.0	104.0	100.0	87.0	79.0	117.0
1926	76.0	87.0	91.0	100.0	104.0	113.0	109.0	111.0	105.0	102.0	93.0	80.0	113.0
1927	80.0	88.0	94.0	104.0	113.0	111.0	113.5	117.5	108.0	104.5	88.0	80.0	117.5
1928	84.0	83.0	97.0	97.0	106.5	112.0	115.0	115.0	114.0	103.0	89.0	78.0	115.0
1929	78.0	86.0	93.5	94.5	102.0	116.0	113.0	114.5	111.0	106.5	89.0	83.0	116.0
Ave. 7 years	84.0	90.0	97.0	104.0	113.0	116.0	117.0	117.5	114.0	107.0	99.0	83.0	117.5
Temperature -- Mean Maximum													
1923	73.3	72.7	76.9	83.2	96.1	96.9	103.0	103.7	96.8	87.7	77.6	66.1	86.2
1924	67.5	78.7	64.6	79.6	93.4	105.0	104.9	104.5	101.9	89.6	81.7	68.7	86.7
1925	68.4	78.7	82.0	87.4	95.9	100.2	106.6	104.0	99.7	84.0	75.9	70.7	87.8
1926	68.3	77.2	81.5	87.3	93.7	104.0	105.5	104.4	100.3	93.8	82.9	65.1	88.6
1927	70.9	75.8	78.4	87.2	96.8	101.2	106.6	104.8	99.8	92.8	79.7	66.4	88.3
1928	71.6	74.2	82.6	86.9	94.9	101.8	106.4	104.5	104.2	92.2	78.4	68.6	88.9
1929	67.2	70.9	79.1	83.3	96.1	101.8	106.4	104.8	98.4	93.7	78.1	76.3	88.0
Ave. 7 years	69.7	75.5	77.9	85.0	95.1	101.6	105.6	104.4	100.2	90.5	79.2	68.8	87.8

Temperature -- Mean

1923	56.2	56.9	59.2	65.9	75.7	66.4	88.6	87.1	79.4	67.8	62.0	53.5	68.2
1924	52.3	57.0	57.0	63.4	70.7	84.4	87.2	85.9	82.9	67.4	61.3	51.6	68.4
1925	50.8	59.1	62.9	67.8	76.4	81.8	89.9	87.5	79.5	68.2	58.4	55.1	69.8
1926	50.7	59.3	64.1	70.5	74.3	82.7	87.9	87.3	82.9	73.0	62.5	51.6	70.6
1927	55.2	60.1	59.7	66.9	74.3	81.1	89.5	89.0	81.6	72.1	62.9	52.1	70.4
1928	54.4	56.2	63.4	66.7	71.1	81.4	87.4	87.9	83.6	71.9	60.7	53.8	69.9
1929	49.7	53.5	60.8	64.3	75.2	81.3	89.9	89.8	82.5	74.2	57.2	57.8	69.7
Ave.7 years	52.8	57.4	61.0	66.5	73.9	79.9	88.6	87.8	81.8	70.7	60.7	53.6	69.6

Temperature -- Minimum

1923	25.0	25.0	30.0	39.0	48.0	48.0	58.0	60.0	45.0	36.0	31.0	32.0	25.0
1924	23.0	32.0	30.0	34.5	49.0	54.0	58.0	55.0	49.0	34.0	30.0	27.0	23.0
1925	23.0	32.0	30.0	35.0	52.0	48.0	60.0	61.0	47.0	45.0	28.0	28.0	23.0
1926	24.5	35.0	30.0	45.0	45.0	53.0	59.0	58.0	52.0	41.0	35.0	22.0	22.0
1927	31.0	34.0	33.0	36.0	44.0	51.0	60.0	65.0	45.0	42.5	29.0	28.0	28.0
1928	27.0	26.0	35.0	36.5	47.0	53.0	54.0	61.0	51.0	37.5	31.0	26.5	26.0
1929	20.0	27.5	31.0	30.5	39.0	49.0	66.0	70.0	55.0	35.0	27.0	29.0	20.0
Ave.7 years	20.0	25.0	30.0	30.5	39.0	48.0	54.0	55.0	45.0	34.0	27.0	22.0	20.0

Temperature -- Mean Minimum

1923	39.2	44.1	41.5	48.9	57.0	56.1	71.4	70.7	62.4	48.0	46.1	41.7	52.0
1924	34.7	39.5	39.7	45.4	54.8	63.9	69.7	67.3	63.9	45.3	41.9	38.8	50.4
1925	33.1	39.5	43.7	47.5	56.9	63.4	73.2	70.9	59.3	51.9	40.8	39.4	51.6
1926	33.2	41.4	46.8	53.7	55.0	62.4	70.3	70.3	65.6	52.3	42.1	38.2	52.5
1927	39.5	44.4	40.9	46.7	52.8	60.9	72.3	73.2	63.3	51.4	46.2	37.7	52.4
1928	37.2	38.1	44.1	46.1	57.2	60.9	68.3	71.2	63.0	51.6	43.0	38.9	51.6
1929	32.1	36.0	42.5	45.3	54.2	60.7	73.4	75.4	66.1	54.2	40.0	38.9	51.6
Ave.7 years	35.6	40.0	42.7	47.7	55.4	61.2	71.2	71.3	63.4	50.7	42.9	39.1	51.7

Average Daily Wind Velocities
(Miles per Hour)

Maximum

1923	3.0	6.7	5.6	6.6	3.7	3.3	2.1	2.3	4.0	4.8	6.1	8.3	8.3
1924	4.5	6.2	6.8	7.6	2.3	3.3	2.4	2.1	1.9	3.4	5.3	6.1	7.6
1925	4.1	6.6	4.5	5.0	4.0	4.2	2.8	2.2	1.8	3.4	4.5	3.3	6.6
1926	3.4	4.2	3.8	2.8	4.3	1.2	4.0	1.2	1.2	3.2	3.4	4.0	4.3
1927	4.0	3.6	4.2	3.7	5.3	2.8	2.0	2.6	3.8	2.2	1.6	5.5	5.5
1928	3.3	3.7	5.4	5.7	3.2	2.8	2.2	3.1	1.9	6.3	3.8	4.0	6.3
1929	2.5	6.3	5.6	4.2	5.3	2.1	1.6	1.3	1.5	2.4	3.6	1.9	6.3
Ave.7 years	4.5	6.7	6.8	7.6	5.3	4.2	4.0	3.1	4.0	6.3	6.1	8.3	8.3

Minimum

1923	0.17	0.33	0.42	0.83	0.46	0.63	0.13	0.71	0.29	0.42	0.29	0.25	0.17
1924	0.54	0.50	0.58	0.71	0.58	0.50	0.29	0.54	0.17	0.25	0.33	0.25	0.17
1925	0.46	0.58	0.50	0.46	0.79	0.67	0.38	0.63	0.42	0.08	0.25	0.17	0.08
1926	0.21	0.38	0.38	0.54	0.54	0.38	0.33	0.04	0.21	0.17	0.13	0.08	0.04
1927	0.08	0.21	0.29	0.25	0.54	0.33	0.46	0.46	0.21	0.08	0.08	0.21	0.08
1928	0.25	0.29	0.29	0.33	0.46	0.50	0.17	0.33	0.25	0.17	0.17	0.17	0.17
1929	0.21	0.28	0.46	0.67	0.54	0.46	0.29	0.10	0.20	0.10	0.10	0.10	0.10
Ave.7 years	0.08	0.08	0.29	0.25	0.46	0.33	0.13	0.04	0.10	0.08	0.08	0.08	0.04

Mean

1923	1.1	2.1	2.0	2.2	1.7	1.3	1.2	1.1	1.3	1.4	1.3	1.8	1.5
1924	1.9	1.5	2.3	2.0	1.2	1.4	1.0	1.0	0.71	1.0	1.4	1.9	1.4
1925	1.3	1.5	1.8	1.8	1.6	1.8	1.2	1.2	0.94	0.71	1.3	1.1	1.4
1926	1.2	1.3	1.2	1.2	1.4	0.8	1.2	0.67	0.52	0.65	0.64	0.91	0.97
1927	0.9	1.0	1.5	1.3	1.6	1.0	1.0	0.89	0.95	0.55	0.67	1.1	1.0
1928	0.9	1.3	1.5	1.7	1.2	1.2	0.93	0.96	0.71	0.77	1.0	1.3	1.1
1929	0.8	1.7	1.8	1.5	1.2	1.0	0.75	0.5	0.5	0.5	0.8	0.5	1.0
Ave.7 years	1.2	1.5	1.7	1.7	1.4	1.2	1.0	0.9	0.8	0.8	1.0	1.2	1.2

Evaporation -- Inches

1923	2.61	3.75	5.36	6.94	9.35	9.08	8.69	8.67	7.28	5.53	2.83	2.09	72.19
1924	2.76	3.68	5.25	6.46	8.21	9.21	9.66	8.95	6.74	5.18	3.91	2.75	72.65
1925	2.56	3.45	5.37	6.42	9.69	9.62	9.46	9.05	7.94	3.96	3.20	2.33	72.15
1926	2.30	3.20	4.97	5.75	9.67	9.11	9.94	7.71	6.27	4.92	3.00	6.19	73.03
1927	2.08	2.44	4.63	6.18	9.16	9.02	9.03	8.73	6.99	4.44	2.79	2.21	67.70
1928	2.27	3.00	4.90	6.92	8.22	9.24	9.41	8.43	6.86	4.74	3.15	3.29	70.43
1929	2.40	3.49	5.37	6.48	8.49	9.09	8.59	7.11	5.77	4.71	3.09	3.24	66.83
Ave. 7 years	2.43	3.29	5.12	6.45	8.97	9.19	9.25	8.38	6.72	4.78	3.14	3.01	70.72

Precipitation -- Inches

1923	0	0.02	0.42	0.13	0	0	0.34	0.39	0.25	0	0.49	1.63	3.67
1924	0	0	0.30	0.09	0	0.02	0	0	0.21	0	0	0.23	0.85
1925	0	0.01	0.38	0.46	0	0.08	0.81	0.02	0.02	1.64	0.21	0.63	4.28
1926	0.06	0.01	0.17	0.38	0.05	0	0.04	2.27	1.23	0	0	4.52	8.73
1927	0.48	0.25	0.24	0.17	0	0	0.63	0.18	0	0.43	0.55	1.48	4.41
1928	0	0.18	0.06	0	0.01	0	0	0	0	0.22	0	0	0.47
1929	0	0	0	0	0	0	0.16	0.96	1.85	0	0	0	2.97
Ave.7 years	0.08	0..07	0.22	0.18	0.01	0.01	0.28	0.55	0.51	0.33	0.18	1.21	3.63

Killing Frosts

Year	Last in Spring: Date	Last in Spring: Minimum Temperature	First in Autumn: Date	First in Autumn: Minimum Temperature Degrees F:	Frost Free Period (Days)	Number of days 32 degrees or below: Spring	Number of days 32 degrees or below: Autumn
1923	Mar. 22	32	Nov.29	31	251	16	3
1924	Mar. 22	31	Nov. 7	30	229	18	11
1925	Mar. 13	30	Nov.16	28	247	17	7
1926	Jan. 30	32	Dec.16	31	319	15	8
1927	Jan. 25	31	Dec. 6	32	314	3	9
1928	Febr.21	32	Nov.17	31.5	269	12	13
1929	Apr. 8	30.5	Nov.14	27	219	26	6
Ave.7 years	Mar. 4	31.1	Nov.24	30.0	264	15.3	8.1

ACREAGE OF CROPS GROWN ON THE YUMA RECLAMATION PROJECT

The crops grown in the rotation experiments were largely determined by the crops grown on the Yuma Reclamation Project. If it is expected that these rotations are to benefit the farmers in this project the different crops should be very nearly the same. The yearly amount of land in cultivation averages about 53,000 acres. The per cent of land devoted to the growing of each of the crops that occur in the rotation tests from 1923 to 1929 are shown in figure 1.

From the above figure it will be seen that cotton is easily the most extensively grown crop in this area. In fact there seems to be a tendency for the cotton acreage to be on the increase. The lowest per cent of land occupied by cotton occurs in 1923 and the highest in 1929. On the average well over half of the total cultivated land on this project is planted to cotton.

Alfalfa ranks next to cotton in having the largest acreage in this valley. But the acreage of alfalfa has been on the decline while cotton has been on the increase. In 1923 there was 41.1 per cent of the land devoted to the growing of alfalfa. In 1929 this figure was only 19.6

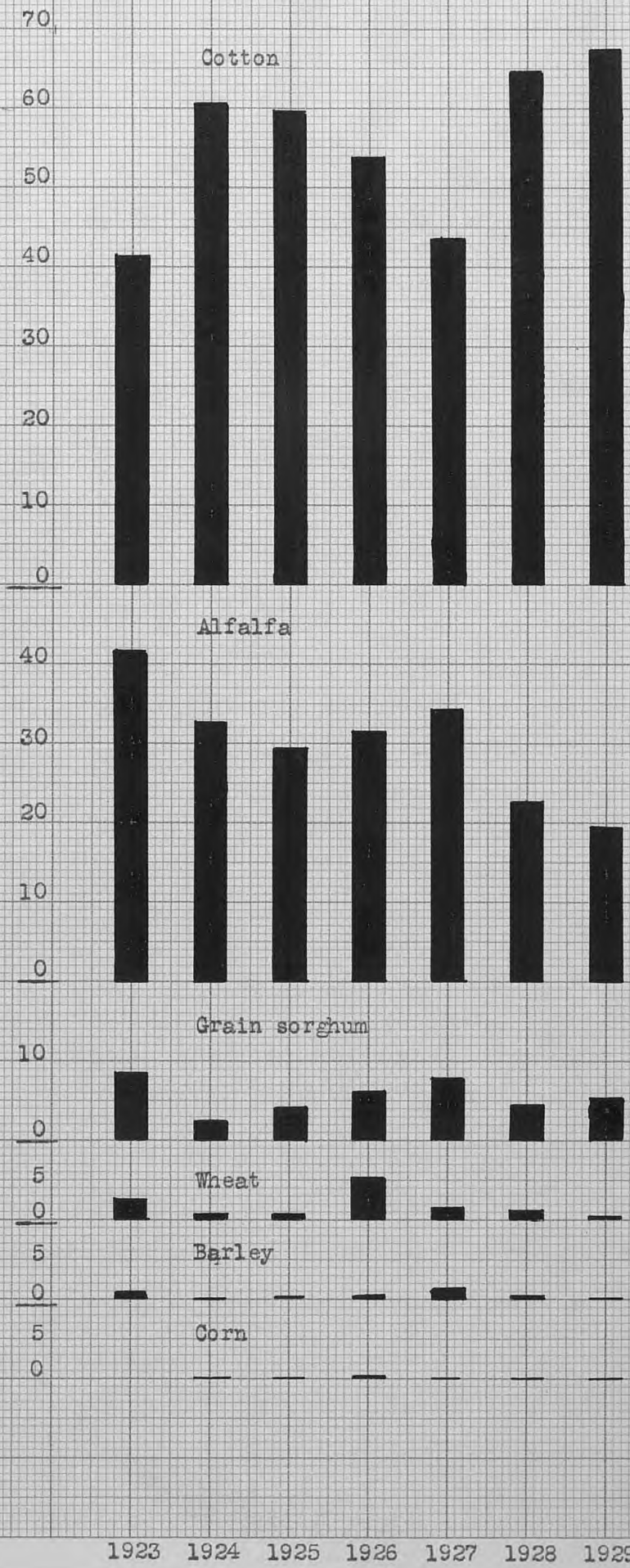


Fig. 1 The Per Cent of the Total Cropped Acreage of the Yuma Reclamation Project Grown in the Crops Used in the Rotation Experiments from 1923 to 1929

per cent. There seems to be quite a definite decline in the alfalfa acreage from 1923 to 1929. It will be seen from the figure that when the alfalfa acreage increases the cotton acreage decreases. The reverse is also true.

The acreage devoted to the production of cereals is small. As a rule the acreage of grain sorghum is greater than the combined acreage of the other three cereals, namely, wheat, barley, and corn. Grain sorghum has been holding its own as far as acreage is concerned. For the period, 1923 to 1929, an average of 5.6 per cent of the land has been devoted to the growing of grain sorghum.

The remaining three cereals, namely, wheat, barley, and corn are of but little importance in this region. On the average of 1.7 per cent of the total cropped area in this area are grown to wheat; 0.6 per cent to barley; and 0.03 per cent to corn. None of these acreages seem to be on the decrease or increase from year to year.

In conclusion it seems that cotton is the most important crop in this region with over one-half of the land being used for its growth. Alfalfa is next in importance with a declining acreage. It is doubtful if this decrease in acreage will continue to decrease because this crop is one of the best sources of fertility in this area. Cereals are of slight importance, and almost 8 per cent of the total

cropped acreage is grown to grain sorghum, wheat, barley, and corn.

The remainder of the cultivated land in this project is used for the production of crops such as watermelons, canteloupes, lettuce, pecans, citrus, dates, and minor truck crops. Some land is also used for pasture every year.

MATERIAL AND METHODS

The rotations were all started in 1923 at the United States Yuma Field Station, Bard, California. A map of the rotations are shown in figure 2. The portion of the field and the number of plats each rotation covers are also shown.

The nature of the crops in the fields preceding the rotations is of importance. It would have been desirable to have had all the fields in the same crops for at least three years. In this way all the rotations would have been started on lands of approximately the same degree of fertility. This would put the rotation crop yields for the first year on the same comparative basis. But this was not the case. The crops grown on the lands from 1918 to 1922 are given in Table II. The plats previous to 1922 were one-half acre in size and plats C-1 in 1922 included C-1-1 and C-1-2 while C-2 included C-2-2 and C-1-2, and so on.

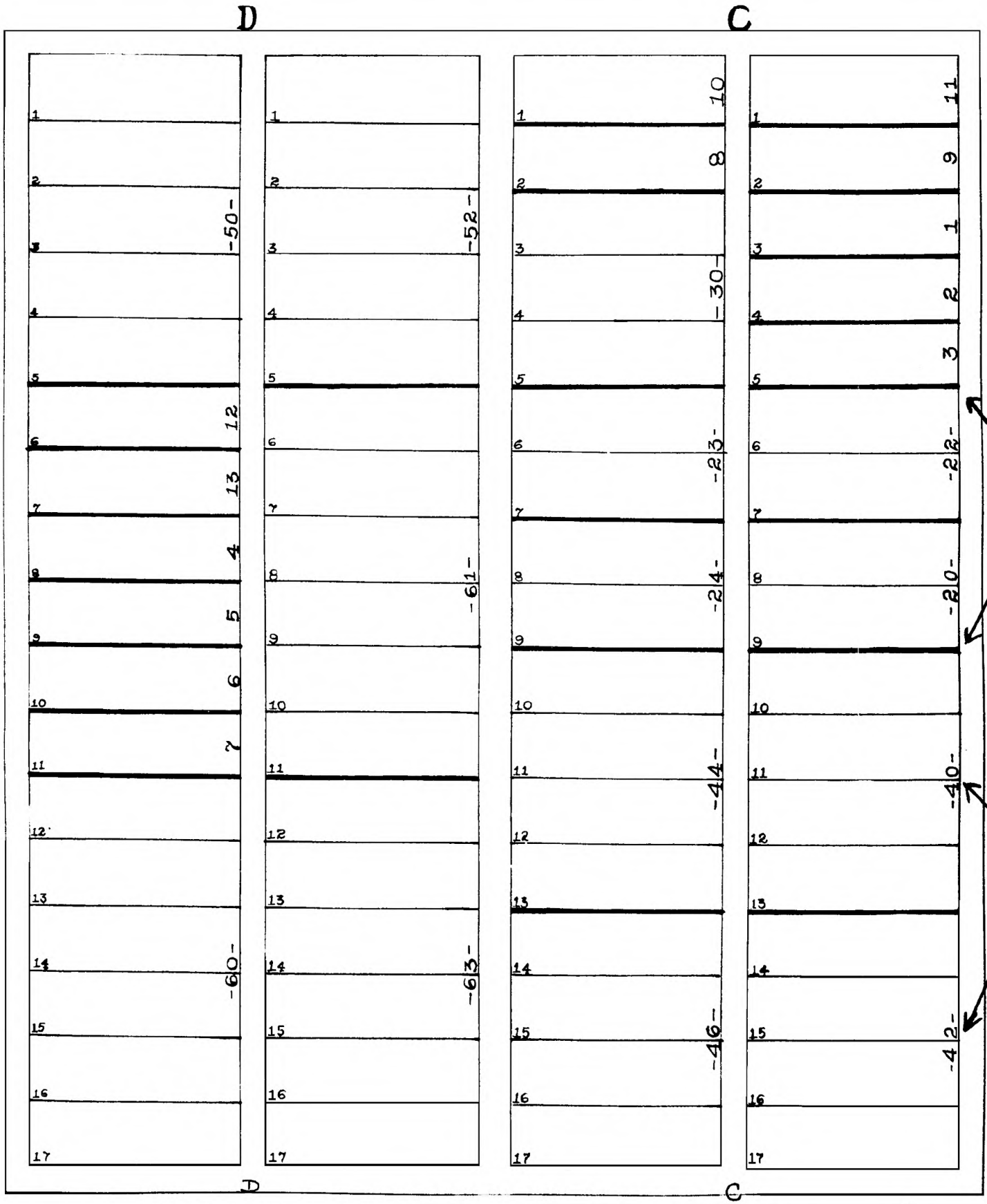


Fig.2 U.S.YUMA FIELD STATION

IRRIGATED CROP ROTATIONS

FIELDS C AND D.

Table II. Crops Grown on Each Plat in Fields C and D at the United States Yuma Field Station for Five Years Preceding the Rotations

Plat No.	1922	1921	1920	1919	1918
C-1	Cowpeas	Cowpeas	Barley, Grain Sorghum	Alfalfa	Alfalfa
C-2	Cowpeas	Cowpeas	Barley, Grain Sorghum	Alfalfa	Alfalfa
C-3	Cowpeas	Cowpeas	Barley, Grain Sorghum	Alfalfa	Alfalfa
C-4	Cowpeas	Cowpeas	Barley, Grain Sorghum	Alfalfa	Alfalfa
C-5	Cowpeas	Legumes	Barley, Grain Sorghum	Alfalfa	Alfalfa
C-6	Cowpeas	Legumes	Oats, Peas, Grain Sorghum	Grain Sorghum	Corn
C-7	Cowpeas	Legumes	Oats, Peas, Grain Sorghum	Millet	Grain Sorghum
C-8	Cowpeas	Figs	Figs	Figs	Figs
C-9	Cowpeas	Figs	Figs	Figs	Figs

C-10	Cowpeas	Figs, Alfalfa	Figs, Alfalfa	Figs, Alfalfa	Figs
C-11	Cowpeas	Figs, Alfalfa	Figs, Alfalfa	Figs, Alfalfa	Figs
C-12	Cowpeas	Figs, Alfalfa	Figs, Alfalfa	Figs, Alfalfa	Figs
C-13	Cowpeas	Figs, Alfalfa	Figs, Alfalfa	Figs, Alfalfa	Figs
C-14	Cowpeas	Figs, Alfalfa	Figs, Alfalfa	Figs, Alfalfa	Figs
C-15	Cowpeas	Figs, Alfalfa	Figs, Alfalfa	Figs, Alfalfa	Figs
C-16	Cowpeas	Figs, Alfalfa	Figs, Alfalfa	Figs, Alfalfa	Figs
C-17	Cowpeas	Figs, Alfalfa	Figs, Alfalfa	Figs, Alfalfa	Figs
D- 1	Cowpeas	Legumes, Grain Sorghum	Barley Grain Sorghum	Alfalfa	Alfalfa
D- 2	Cowpeas	Legumes, Grain Sorghum	Barley Grain Sorghum	Alfalfa	Alfalfa
D- 3	Cowpeas	Legumes, Grain Sorghum	Barley Grain Sorghum	Alfalfa	Alfalfa
D- 4	Cowpeas	Legumes, Grain Sorghum	Barley Grain Sorghum	Alfalfa	Alfalfa
D- 5	Cowpeas	Legumes, Grain Sorghum	Barley Grain Sorghum	Alfalfa	Alfalfa

D- 6	:Cowpeas	:Legumes, :Grain : Sorghum	:Barley, :Grain : Sorghum	:Alfalfa	:Alfalfa
D- 7	:Cowpeas	:Legumes, :Grain : Sorghum	:Barley, :Grain : Sorghum	:Alfalfa	:Alfalfa
D- 8	:Cowpeas	:Legumes, :Grain : Sorghum	:Barley, :Grain : Sorghum	:Alfalfa	:Alfalfa
D- 9	:Cowpeas	:Legumes, :Grain : Sorghum	:Barley, :Grain : Sorghum	:Alfalfa	:Alfalfa
D-10	:Cowpeas	:Legumes, :Grain : Sorghum	:Barley, :Grain : Sorghum	:Alfalfa :Flax	:Legumes
D-11	:Cowpeas	:Bur :Clover, :Grain : Sorghum	:Barley, :Grain : Sorghum	:Alfalfa :Flax	:Alfalfa
D-12	:Cowpeas	:Sour : Clover, :Grain : Sorghum	:Barley, :Grain : Sorghum	:Alfalfa :Flax	:Alfalfa
D-13	:Cowpeas	:Barley, :Grain : Sorghum	:Alfalfa	:Alfalfa	:Cotton
D-14	:Cowpeas	:Barley, :Grain : Sorghum	:Alfalfa	:Alfalfa	:Cotton
D-15	:Cowpeas	:Barley, :Grain : Sorghum	:Alfalfa	:Alfalfa	:Cotton
D-16	:Cowpeas	:Barley, :Grain : Sorghum	:Alfalfa	:Alfalfa	:Cotton
D-17	:Cowpeas	:Barley, :Grain : Sorghum	:Alfalfa	:Alfalfa	:Cotton

It will be noticed that the entire area was growing cowpeas in 1922. All the lands were plowed in the fall of 1921 and leveled. In the spring of 1922 the cowpeas were sown. Fourteen rows about 42 inches apart were planted in each plat. On September 13 and 14, one representative row from each plat was harvested and green weights taken. From the yield of this one row the acre yield was computed. These yields were to be used to secure some information on soil variation. After the row of cowpeas was removed the remainder of the crop was plowed under. The yields of the plats as based on the one row that was harvested in each plat are given in Table III.

The importance of the cowpea yields given in Table III may be questioned. Do they actually indicate the fertility of the soil? It seems that this is doubtful. If cowpeas were grown on the rotation lands from 1918 to 1922 and the yields taken as above the results would then be much more significant. But since the cowpeas were grown only for one year and the yields taken only from one row in each plat, it seems that it would be unjust to take these yields and correlate them with soil fertility. For example, plats C-10 to C-17 were treated exactly the same from 1919 to 1922 and the yields of cowpeas vary from 1.96 to 7.28 tons per

Table III. Yields of Cowpeas in 1922 on the Fields to be Used for the Rotation Experiments

Plat No.	Rotation No. Represented	Forage Yields: Pounds Row	Forage Yields: Pounds Plat	Forage Yields: Tons per Acre	Plat No.	Rotation No. Represented	Forage Yields: Pounds Row	Forage Yields: Pounds Plat	Forage Yields: Tons per Acre
C-I- 1	11	65	910	1.820	C-II- 1	10	105	1,470	2.940
- 2	9	145	2,030	4.060	-2	8	155	2,170	4.340
- 3	1	145	2,030	4.060	- 3	30	125	1,750	3.500
- 4	2	120	1,680	3.360	- 4	30	100	1,400	2.800
- 5	3	35	490	0.980	- 5	30	60	840	1.680
- 6	22	115	1,610	3.320	- 6	23	75	1,050	2.100
- 7	22	75	1,050	2.100	- 7	23	130	1,820	3.640
- 8	20	125	1,750	3.500	- 8	24	45	630	1.260
- 9	20	75	1,050	2.100	- 9	24	50	700	1.400
-10	40	85	1,190	2.380	-10	44	70	980	1.960
-11	40	210	2,940	5.880	-11	44	205	2,870	5.740
-12	40	125	1,750	3.500	-12	44	80	1,120	2.240
-13	40	260	3,640	7.280	-13	44	150	2,100	4.200
-14	42	160	2,240	4.480	-14	46	125	1,750	3.500
-15	42	140	1,960	3.920	-15	46	195	2,730	5.460
-16	42	90	1,260	2.520	-16	46	75	1,050	2.100
-17	42	95	1,330	2.660	-17	46	105	1,470	2.940
D-I- 1	52	180	2,520	5.040	D-II- 1	50	190	2,660	5.320
- 2	52	260	3,640	7.280	- 2	50	170	2,380	4.760
- 3	52	115	1,610	3.220	- 3	50	130	1,820	3.640
- 4	52	100	1,400	2.800	- 4	50	55	770	1.540
- 5	52	95	1,300	2.660	- 5	50	65	910	1.820
- 6	61	140	1,960	3.920	- 6	12	120	1,680	3.360
- 7	61	100	1,400	2.800	- 7	13	110	1,540	3.080
- 8	61	180	2,520	5.040	- 8	4	195	2,730	5.460
- 9	61	130	1,820	3.640	- 9	5	160	2,240	4.480
-10	61	255	3,570	7.140	-10	6	190	2,660	5.320
-11	61	170	2,380	4.760	-11	7	125	1,680	3.360
-12	63	110	1,540	3.080	-12	60	90	1,260	2.520
-13	63	120	1,680	3.360	-13	60	105	1,470	2.940
-14	63	155	2,170	4.340	-14	60	145	2,030	4.060
-15	63	70	980	1.960	-15	60	110	1,540	3.080
-16	63	160	2,240	4.480	-16	60	130	1,820	3.640
-17	63	185	2,590	5.180	-17	60	120	1,680	3.360

acre. Observations would indicate that the soil is not so variable as to cause such a difference in yields. It will also be noticed that the barley yields in 1923 do not have a tendency to be correlated with the cowpea yields as they should if the cowpea yields are to be taken as an index of the fertility of the original plats. It seems unquestionable that if there were several more years results the fertility conditions of the rotations when they were started in 1923 would be much better understood.

The rotations were originally planned to meet the immediate needs of the Yuma valley farmers. Due to the limit of available space all possible crop sequences or comparisons could not be included. Each rotation, however, was planned with the idea that it would contribute something toward securing an ideal crop sequence.

The 27 rotations cover an area of 68 different plats. Each plat is one-quarter of an acre in size. The plats are not duplicated, thus each crop in every rotation is grown only once every season. The rotations as outlined in 1923 are as follows:

Rotations

Rotation No.	Crop Sequence	Remarks
	Continuously Cropped Plats	
1	Alfalfa	12 tons of manure are applied alternate odd years.
2	Alfalfa	No treatment.
3	Alfalfa	300 pounds of superphosphate are applied alternate odd years.
4	Cotton	500 pounds of 4-9-4 commercial fertilizer are applied alternate odd years.
5	Cotton	12 tons of manure are applied alternate odd years.
6	Cotton	No treatment.
	One-Year Rotations	
7	Vetch Cotton	The vetch is planted in the fall in the cotton stalks and used as a green manure crop.
8	Barley Grain Sorghum	The barley is planted in the fall and harvested in early May. The land is left idle until the latter part of June when grain sorghum is planted.
9	Barley Sweet Clover Grain Sorghum	Barley is planted in the fall and used as a nurse crop for sweet clover. After the barley has been harvested the sweet clover is allowed to grow until the middle of June when it is used as a green manure for grain sorghum.

10	Vetch Grain Sorghum	The vetch is planted in the fall and plowed under the latter part of May. The land is then left idle until the latter part of June when grain sorghum is planted.
11	Barley Grain Sorghum	The barley is planted in the fall and 12 tons of manure are applied every year to the soil after the barley has been harvested. The grain sorghum is planted the latter part of June.
12	Barley Cowpeas Grain Sorghum	The barley is planted in the fall and after it has been harvested cowpeas are planted. The cowpeas are plowed under the last part of June and grain sorghum planted.
13	Wheat Corn	Wheat is planted in the fall and is harvested about the middle of May. The corn is planted the latter part of June.

Two-Year Rotations

20	Vetch Cotton Sweet Clover Grain Sorghum	The vetch is planted in the fall immediately after the grain sorghum has been harvested. It is then plowed up as a green manure crop early in March and cotton is planted. When the cotton has been picked sweet clover is planted and used as a green manure crop for grain sorghum.

22	Cotton Cowpeas Grain Sorghum	Cotton is planted in March of the first year. After the fall picking the land is left idle until the last of April when cowpeas are sown. These are used as a green manure for grain sorghum.
23	Cotton Grain Sorghum	The cotton is planted in the spring of the first year. After the cotton has been picked the land is plowed and left idle until the next June when grain sorghum is planted. 12 tons of manure are added each year after the grain sorghum has been harvested.
24	Barley Sweet Clover Corn Vetch Grain Sorghum	The barley is planted in the fall and used as a nurse crop for sweet clover. The sweet clover is plowed under the latter part of June and corn is planted. After the corn has been harvested the vetch is sown. The vetch is used as a green manure crop for grain sorghum. The vetch is usually plowed in May.

Three-Year Rotations

30	Cotton Sweet Clover Grain Sorghum Barley Cowpeas Corn	The cotton is planted the middle of March and after it is picked in the fall the sweet clover is sown. The following June the sweet clover is plowed under as a green manure crop and grain sorghum is planted. That same fall the barley is planted. The cowpeas are planted after the barley has been harvested in May and used as a green manure crop for corn.

Four-Year Rotations

40	Alfalfa Alfalfa Corn Cotton Cotton	Alfalfa is planted in the fall as soon as the second year of cotton is picked and the ground prepared. The second year of alfalfa is plowed up late in June and planted to corn. The corn is harvested in the fall and the first year of cotton planted the following March. This is followed by another year of cotton.
42	Alfalfa Alfalfa Wheat Corn Barley Grain Sorghum	The first year of alfalfa is planted in the fall after the grain sorghum has been removed from the land. The second year of alfalfa is fall plowed and wheat is planted. This is harvested the middle of May. In late June the corn is planted. After this is harvested in October the crop of barley is sown. The grain sorghum follows the barley the next June.
44	Alfalfa Alfalfa Cotton Cotton	The first year of alfalfa is planted after the second year of cotton has been picked and the soil prepared. The second year of alfalfa is plowed up early in spring and cotton planted in March. This crop of cotton is followed by another year of cotton after which alfalfa is again planted.
46	Alfalfa Alfalfa Barley Grain Sorghum Cotton	The second year of alfalfa is plowed up in the fall and barley planted. This is harvested the following May. Late that June grain sorghum is planted. This is followed by one year of cotton which is planted the following March.

Five-Year Rotations

50	Alfalfa Alfalfa Alfalfa Barley Grain Sorghum Cotton	The alfalfa is planted in the late fall after the cotton has been picked and the land prepared. The third year of alfalfa is fall plowed and planted to barley. In June of the fourth year the grain sorghum is planted. After this matures in October the land is plowed and left idle until cotton is planted the following March.
52	Alfalfa Alfalfa Alfalfa Alfalfa Grain Sorghum Cotton	The fourth year of alfalfa is plowed up in late June and the grain sorghum planted. After this matures in October the land is plowed and left idle until the following March when cotton is planted.

Six-Year Rotations

60	Alfalfa Alfalfa Alfalfa Barley Grain Sorghum Cotton Cotton	The alfalfa is planted after the second year of cotton has been picked and the land plowed. The third year of alfalfa is fall plowed and barley is planted. In June of the fourth year the grain sorghum is planted. This is followed by two successive years of cotton.
61	Alfalfa Alfalfa Alfalfa Cotton Cotton Grain Sorghum	The third year of alfalfa is hogged off. The hogs are removed in the fall and the land plowed. The next March the first year of cotton is planted followed by another year of cotton. The land is left idle from fall to the following June then grain sorghum is planted.

63	Barley Alfalfa Alfalfa Alfalfa Alfalfa Corn Cotton Cotton	Barley is fall planted and used as a nurse crop for the alfalfa. The fourth year of alfalfa is hogged off for one-half a year, or until the middle of June when it is plowed and corn planted. The corn matures late in October after which the ground is plowed. The corn is followed by two successive years of cotton.

PROBLEMS ENCOUNTERED

Rotations are by no means without their problems. At the head of the numerous list is one concerning the favoring of certain rotations at the expense of others. For illustration, barley in rotation 30 and in rotation 63 may be cited. In rotation 30, the barley is preceded by grain sorghum while in rotation 63 the barley is preceded by cotton. Barley shows its highest yields when it is planted during the middle November. Planting at this time can be easily accomplished in rotation 30. In rotation 63, however, the final picking of cotton and the preparation of the land cannot be completed until December is well along. Thus the question comes up, should the planting of barley in rotation 30 be held up until the land in rotation 63 is ready to be planted, thus putting the two plats on the same comparative yield basis? Or should rotation 30 be allowed to take

advantage of its earlier seeding allowance and let rotation 63 do the best it can under its handicap? Or perhaps the last picking of cotton could be discarded in order to give rotation 63 the same planting advantage as rotation 30? The same question comes up in connection with alfalfa. Alfalfa is at its best when planted in late October or as soon afterward as possible. Where alfalfa follows cotton it cannot be planted until the latter part of December. It will be noticed that rotation 63 has a double handicap in that the barley is after cotton and that the barley is also used as a nurse crop for alfalfa. Numerous other questions of this nature arose and were all answered together. The ultimate aim in rotations seems to be in securing the greatest total yield of all crops for a unit of time. With this in mind each rotation is kept as a separate unit, and one rotation is not influenced by another. Thus barley after grain sorghum is planted early while barley after cotton is planted later. This makes any rotation independent of all others.

CULTURAL PRACTICES

The cultural practices performed in these rotations are practically the same as those performed for the different crops throughout this region. They do not vary a great deal from one year to another. In the following pages each field practice will be discussed separately.

Land Preparation

Plowing.-- An attempt is made to plow as many plats as is possible. Whenever the plat is cropped to a legume it is plowed before another crop is planted. Plats that are to be planted to alfalfa are plowed and leveled very thoroughly before planting takes place. Barley plats that are to be planted to grain sorghum or corn, or grain sorghum plats that are to be planted to cotton are always plowed. Where vetch or sweet clover follow cotton or grain sorghum the plat is not plowed but double disked, and the seed broadcast. Cotton land is generally plowed before another crop is planted. Exceptions to this rule are in rotations 7, 20, 22, and 30 where a green manure follows the cotton. With the exception of rotation 1 all the manure applied to the plats is plowed under. In all plowing operations the two-way plow is used. The soil is plowed to a depth of about eight inches.

Disking.--The practice of disking the land is followed where green manure crops follow a cultivated crop. The only exception to this rule is in rotation 7 where the vetch is broadcast in the cotton plants. Plowed alfalfa plats are often disked before the following crop is planted. This loosens the ground and also kills much of the Bermuda grass that may have started growing again. Other plowed plats are seldom disked unless the soil is very cloddy, contains many weeds, or is very hard. Grain sorghum or corn plats that are to be planted to barley or wheat are thoroughly double disked before the latter is planted.

Harrowing.-- Plowed alfalfa plats are harrowed very thoroughly with a spike-tooth harrow as well as are the other plowed plats. No harrowing is given disked ground to which green manures are to be planted, but all other disked ground is harrowed before planting. When young alfalfa is planted the ground is harrowed dry, the seed planted, the ground rolled and then irrigated. In all other cases, however, an irrigation precedes the harrowing operations.

Renovating.--Renovating is essential to all second, third, and fourth year alfalfa plats in order to control Bermuda grass, water grass, sandburs, and other weeds. Renovating is accomplished by a spring-tooth harrow either in the winter or summer months and often both.

Leveling.--All plowed plats are leveled before planting and often disked plats if the land is left very uneven. Additional leveling is given all plats that are to be planted to alfalfa.

Rolling or Packing.-- An effort is made to roll every plat of young alfalfa after the seed has been planted and before the first irrigation. Oftentimes the barley and wheat is rolled, especially when it is used as a nurse crop for alfalfa or sweet clover.

Manuring.-- Barnyard manure is applied to rotations 1, 5, 11, and 23. In rotations 1 and 5 it is applied at the rate of 12 tons per acre on alternate odd years while in rotations 11 and 23 it is applied at the same rate every year. In all cases the manure is applied with a manure spreader. Rotation 1 receives manure in the winter months. It is desirable to apply a portion of the manure in early winter and the remainder after the first cutting of hay. This lessens the amount of manure raked up with the hay. In rotation 5 the manure is applied in the winter after the cotton stalks have been cut. The manure is thus plowed up with the stalks. In rotations 11 and 23 the manure is applied after the grain sorghum or barley have been removed from the land. This manure is plowed under as in rotation 5.

Applying Fertilizers.-- Most all the fertilizers are applied to the soil with a fertilizer drill. Old alfalfa plats that receive the superphosphate are fertilized after the first cutting of hay. Young alfalfa plats are not fertilized until they have been clipped. This is usually about the time the older alfalfa plats are being cut for hay the second time. Rotation 4 receives an application of 500 pounds of 4-9-4 fertilizer every other year. In 1923 and 1925 this was disked on the land just prior to the time the cotton was planted. In 1927 one-half of the amount was applied in this way and the other half as a side dressing after the cotton plants were well along. In 1929 fourteen furrows were made and the fertilizer scattered in these furrows. These furrows were then covered and the rows of cotton planted on top of them.

Seeding

Selection.-- With the exception of grain sorghum, the same varieties of crops have been grown in the rotation experiments since 1923. This makes it possible to select seed from the best plats and plants. Certain plats are set apart each year from which seed is to be obtained for the following year. These plats are very thoroughly rogued and are kept separate at harvest time. By selecting and

propagating the crops in this manner the problem in introducing new weeds and diseases with new varieties is reduced to a minimum.

Treatment for Diseases.-- Covered smut of wheat and barley and common smut of corn are the only prevalent grain diseases. The wheat is treated with copper carbonate at the rate of 3 to 4 ounces per bushel. Barley smut is controlled by the use of formaldehyde.

Time.-- The average dates at which the different crops are usually planted are as follows:

Alfalfa, middle of November to the latter part of December.

Cotton, March 15.

Grain sorghum, June 28 to July 8.

Corn, June 28 to July 8.

Barley, middle of November to the latter part of December.

Wheat, middle of November.

Sweet clover, November 15 to December 10.

Vetch, November 15.

Cowpeas, following grain sorghum, middle of March. following barley, middle of May.

Rate.-- The rates of planting are as follows: Cotton, 20 pounds; alfalfa, 20 pounds; grain sorghum, 6 pounds; barley, 70 pounds; wheat, 75 pounds; corn, 10 pounds; sweet clover, 15 pounds; cowpeas, 30 pounds; and vetch, 40 pounds per acre.

Method.--Corn, cotton, and grain sorghum are planted with a two-row planter. The rows are spaced 42 inches apart in each of these crops. Cowpeas were planted with a double disk drill but recently the above planter has been used. The rows here are spaced 21 inches apart. Barley, wheat, and vetch are planted with a double disk drill. Often the vetch is broadcast. Alfalfa and sweet clover are usually sown through the alfalfa hopper in the same drill although many times the seed is broadcast on the plat before the plat is irrigated.

Treatment After Seeding

Cultivation.--All crops that are planted in rows are cultivated as often as possible to control weeds and loosen the soil. Early cultivation is usually accomplished by using the diamond point shovels on the cultivator. When the plants are taller, a disk cultivator is used almost entirely. This ridges the rows high enough so they are not easily

flooded during irrigation. Before thinning cotton, corn, and grain sorghum the soil is first thrown away from the plants and after thinning it is again returned to the plants.

Thinning.-- When the corn, cotton, and grain sorghum are sufficiently tall they are thinned. Corn is thinned to an average distance of 18 inches and grain sorghum to 15 inches. In cotton, two different spacings are made, one-half of the plat being thinned to an average distance of 7 inches and the other half to an average distance of 14 inches. Cotton is allowed to make more growth than either corn or grain sorghum before it is thinned. By allowing the cotton plants to grow to a height of 8 to 10 inches before they are thinned there is a tendency for the cotton plants to produce less vegetative branches than if the cotton were thinned earlier.

Hoeing.-- Most of the hoeing is done early in the season before the plants get very tall. By keeping down the weeds until the crop plants shade the ground, there is little danger of finding many weeds later in the season. The principal weeds found in the crops are sandburs, water grass, and Bermuda grass.

Irrigation.--None of the crops are allowed to become too dry so as to lower the yield or watered too much as to injure their quality. As a rule, one crop receives the same number of irrigations in all the rotations. An irrigation is given to a plat in all cases before it is planted, except where alfalfa is to be planted, or sweet clover or vetch are to be broadcast. Here the crop is planted in dry soil and then irrigated.

After the first irrigation the crops are watered whenever they are in need of it. The first irrigation is quite important, especially with cotton. Here no irrigation is given until the plants show a definite need for water. In some years this is from 60 to 75 days after planting. Young alfalfa receives its first irrigation after planting as late as the plants are not harmed by the drought. During the summer months cotton and alfalfa are watered every week and often, even with such frequent watering, a wilted condition develops.

Grain sorghum and corn receive an irrigation about every two weeks during the summer months. During the flowering time, grain sorghum often requires watering every week. The crops are irrigated until the grain starts to ripen.

In the winter months barley and wheat require an irrigation about every three weeks, but in the spring an irrigation every two weeks is usually necessary.

Vetch is usually watered only once or twice during its period of growth. Winter irrigation seems to be harmful. Sweet clover requires more water and is treated about like alfalfa after the second irrigation. Cowpeas are watered from 2 to 4 times during their growth.

Harvesting

Time.--The harvesting of different crops in the rotations is scattered through the entire year. First to be harvested in the spring is alfalfa hay. The first crop of hay is often cut as early as the middle of March. A cutting of hay is obtained about every 5 to 6 weeks during the haying season. Barley and wheat reach maturity the early part of May. By the latter part of September many of the cotton bolls are open. Often picking is started at this time. Two pickings are always obtained from the cotton, the last picking often extending late into December. Corn and grain sorghum are mature the last part of October or the first part of November and are harvested as soon after this as possible.

Method.-- Alfalfa is mowed and raked soon afterward to reduce the loss of leaves. Shocking is done by hand. Wheat and barley are cut with a binder and shocked at once. The cotton is picked by hand. Each row is weighed separately at each picking. Grain sorghum is headed in the field and the heads piled on the end of the plat to dry. When dry they are weighed and threshed. The stalks are cut with a binder and shocked. Weights are taken after they have dried. Corn is harvested by snapping the ears in the field. Previous to 1926 the stalks were treated as they are with grain sorghum. Since 1926, however, they have been cut with a stalk cutter and no weights obtained.

DETAILED REPORT OF EACH ROTATED CROP

Introduction

It seems that after experimenting for seven years with crop rotations at this station numerous conclusions can be drawn. The rotation lands are cropped throughout the entire season thus rushing the experiments to a place where decreasing or increasing yields are not as apparent as they have been up to this time. The light soils in which the crops are grown decline in fertility very rapidly unless the right fertilizing constituents are supplied. For these reasons the seven years of results are probably more

conclusive here than they would be elsewhere.

In the following discussions the different determinations were obtained as follows:

1. Yield. All yields are expressed as acre yields unless otherwise stated. Barley, wheat, grain sorghum, and corn are given as bushels per acre. The weights used per bushel are barley, 48 pounds; wheat, 60 pounds; grain sorghum, 56 pounds; corn, 70 pounds (ear corn). Alfalfa is recorded as tons of hay per acre and cotton as pounds of seed cotton per acre.

2. Per cent Grain. The weight of grain divided by the total weight of the plat.

3. Probable Error of the Mean. By Merriman's formula 36 (1913) as follows:

$$rop = \frac{0.8453EV}{N\sqrt{n-1}}$$

The probable error is obtained by multiplying the sum of the departures from the mean by the quotient of $n\sqrt{n-1}$ into 0.8453 where n equals the number of yields involved.

When one crop is grown for more than one year the numeral one (1) follows the rotation number for the first year, and numeral two (2) follows the rotation number for the second year, etc., as follows: 40-1, 40-2, 40-3, etc.

In comparing yields a minus sign (-) signifies a decrease while a plus sign (+) signifies an increase in the yield.

All fertilizer applications are based on pounds or tons per acre as the case may be.

Alfalfa

It may be said that alfalfa is the foundation of most of our best organized rotations. The value derived from it on the following crop is on the average larger than that from any other crop. Oftentimes in these rotations there is a two-fold advantage of alfalfa. First, the crown and roots, and second, the foliage is often plowed under and acts as a green manure. The latter effect will be found in early spring with cotton following alfalfa and also in summer where corn or grain sorghum follow alfalfa. When the alfalfa is tall enough and in bloom it is cut before plowing and the weights taken. In the other cases it is plowed under and acts as a green manure crop. A comparison of the effect of these two methods has not been made.

The alfalfa situation has been rather mysterious since this valley was developed. The first few years the alfalfa yielded very heavily, but gradually a decline in the yields occurred. Experiments were conducted here in an effort to

find some fertilizer which would bring up the yields to their original standing. Superphosphate was found to meet the demands of alfalfa better than any other fertilizer and is now in general use by the farmers in this region.

When the rotation experiments were started in 1923 no fertilizers for alfalfa were used except those in rotations 1 and 3. The yields of alfalfa in the rotations were considered to be too low, so in 1924 the practice was started of fertilizing all the young alfalfa (except rotations 1, 2, and 3) with 300 pounds of superphosphate per acre. This caused an increase in the yield, especially in the first year of alfalfa. The second and third years, however, averaged much lower in yield than did the first year. The superphosphate would be used up by the first year of alfalfa and handicap the succeeding years, particularly those rotations where there are three and four years of alfalfa. A new system was agreed upon in 1928 whereby every plat of alfalfa in the rotations received an application of 300 pounds of superphosphate per acre in the spring of every year, (except rotations 1,2, and 3).

The effect of superphosphate on the yields of alfalfa is almost immediately noticeable, but after several cuttings the yields start to decline until more superphosphate is applied. It would seem from this that the crops that follow

alfalfa in the summer as grain sorghum and corn would be benefited more by the superphosphate in the soil than would crops sown in the fall or early spring as barley and cotton. Grain sorghum and corn, therefore, not only receive the effects of the alfalfa but also the superphosphate that has recently been applied to the alfalfa.

Alfalfa is planted in the fall as soon as the preceding crop can be removed from the land and the soil prepared for planting. It is always planted without a nurse crop except in rotation 63 where it is sown with barley.

The time of the first cutting of hay and the number of cuttings in a season often varies in the rotations from year to year. The first crop of alfalfa is often cut as early as the middle of March and often as late as the middle of April. The first year of alfalfa usually receives its first cutting about the time the older plats are being cut for the second time. In some years there are seven cuttings while during others there are only five.

In general the farmers follow the practice of allowing their alfalfa to lay dormant during the hot summer months. There are probably three main reasons why this is done. First, the irrigation water from the Colorado river carries an extraordinary large amount of silt at this time.

When this water is put on the soil the silt quickly settles and forms a layer so dense that the water is slow in penetrating into the soil. This tends to smother the alfalfa. Second, alfalfa naturally goes into a dormant stage here in the summer months. This is especially true with the Hairy Peruvian variety. Growth is very slow and the yields too low to pay for harvesting. Third, weeds as Bermuda grass, water grass, and sandburs are often plentiful in the alfalfa plats. During the summer they grow better than does the alfalfa. By allowing the alfalfa plats to dry out for four to six weeks during the hottest part of the summer these weeds are generally killed, especially the water grass and sandburs. This seems to be a very desirable means of keeping down weeds in the alfalfa.

The Hairy Peruvian variety of alfalfa has been used throughout all the rotation tests. It is one of the highest yielding varieties for this region. The winters are never severe enough to cause any winter killing. The Common Peruvian and Chilean varieties of alfalfa are also grown by some of the farmers in this region.

In Table IV are given the average yields of alfalfa hay in the rotations from 1923 to 1929. The yields given here are far below what they should be for this area. With an average of five or six cuttings every season the yields

Table IV. The Mean Yields of Alfalfa Hay in the Irrigated Rotations at the United States Yuma Field Station, 1923 to 1929

Rotation No.	Age in years	Yield per acre tons 1923	1924	1925	1926	1927	1928	1929	Mean		Rank
1	--	5.380	5.466	8.520	6.020	6.040	4.550	4.094	5.724	±0.34	1
2	--	2.610	2.388	2.610	1.324	1.400	1.110	1.148	1.789	±0.22	20
3	--	2.756	3.724	5.140	2.480	3.350	2.540	3.506	3.357	±0.21	4
40	1	5.500	3.860	3.210	3.350	3.120	2.770	2.940	3.536	±0.23	3
40	2	1.400	3.480	3.720	0.776	1.710	3.400	2.176	2.380	±0.34	15
42	1	3.800	1.934	3.430	3.140	1.790	1.290	2.009	2.485	±0.29	13
42	2	2.130	4.936	3.350	2.350	3.230	1.770	2.704	2.924	±0.27	7
44	1	3.040	2.826	3.850	5.030	1.510	2.160	2.970	3.055	±0.27	5
44	2	4.250	3.830	3.810	2.856	6.220	1.170	3.206	3.620	±0.36	2
44	3	- - -	1.060	0.250	0.028	0.500	- - -	- - -	0.263	- - -	27
46	1	3.244	3.142	3.650	2.560	1.940	2.270	2.780	2.798	±0.16	9
46	2	2.250	3.194	4.610	2.210	2.340	1.550	3.990	2.878	±0.31	8
50	1	1.826	1.256	2.760	2.620	1.710	1.660	1.050	1.840	±0.17	19
50	2	3.976	2.186	2.760	1.262	3.360	1.880	2.338	2.537	±0.24	11
50	3	2.720	3.780	2.030	1.354	1.750	2.770	3.042	2.492	±0.23	12
52	1	1.420	1.770	3.460	5.100	2.180	1.600	1.410	2.420	±0.37	14
52	2	2.504	1.682	3.840	1.856	4.810	1.340	3.506	2.791	±0.37	10
52	3	4.070	4.174	2.720	1.464	1.990	4.130	2.738	3.041	±0.32	6
52	4	1.350	1.922	2.110	0.856	1.000	1.180	2.316	1.533	±0.16	25
60	1	2.660	1.212	2.240	2.090	1.050	0.760	1.980	1.713	±0.21	21
60	2	1.066	1.702	2.880	0.998	1.890	1.110	2.094	1.677	±0.18	23
60	3	1.150	1.580	2.520	1.294	0.950	1.970	1.680	1.592	±0.20	24
61	1	1.534	1.750	2.430	2.470	1.130	0.430	2.040	1.684	±0.19	22
61	2	0.570	1.478	3.190	1.292	2.592	1.760	2.370	1.893	±0.24	18
61	3	-- - - - - - - - - - - - Hogged Off - - - - - - - - - - - - -									
63	1	1.150	1.024	1.140	1.420	1.100	0.470	1.620	1.132	±0.08	26
63	2	1.654	1.516	2.280	2.786	1.860	3.170	2.866	2.305	±0.19	16
63	3	2.100	1.536	3.590	0.918	1.400	2.120	3.440	2.158	±0.27	17
63	4	-- - - - - - - - - - - - Hogged Off - - - - - - - - - - - - -									
Maximum		5.500	5.466	8.520	6.020	6.220	4.550	4.094			
Minimum		0.570	1.024	1.140	0.776	0.950	0.430	1.050			
Average		2.543	2.530	3.190	2.220	2.293	1.959	2.539	2.467	±0.09	--

should easily be above 4 tons per acre instead of 2.4 tons per acre. The highest yielding plat is in rotation 1. In 1925 this rotation yielded 8.52 tons of hay per acre. The lowest yielding plat is the first year of alfalfa in rotation 63 where barley is used as a nurse crop. The average yield of hay from year to year seems to be slightly on the decline, the average yield in 1926, 1927, and 1928 being far below the average for the seven years. The average yield in 1929, however, is about the same as it was when the rotations were started.

The Effect of Superphosphate on the Yield of Alfalfa.--Superphosphate is the most widely used fertilizer for alfalfa in this region. Applications vary from 200 to 500 pounds per acre. The effect of this fertilizer on the yield of alfalfa can be demonstrated by comparing the yields of rotations 2 and 3. Rotation 2 has been continuously cropped to alfalfa since 1923 with no treatment or fertilizer of any sort. Rotation 3 has also been continuously cropped to alfalfa since 1923 but receives 300 pounds of superphosphate on alternate odd years. The comparison of the yields of these two rotations is given in Table V.

Table V. The Effect of Superphosphate on the Yield of Alfalfa

Rotation No.	Yields per acre tons							
	1923	1924	1925	1926	1927	1928	1929	Average
2	2.610	2.388	2.610	1.324	1.400	1.110	1.148	1.789 ±0.22
3	2.756	3.724	5.140	2.480	3.350	2.540	3.506	3.357 ±0.21
Increase in Yield	0.146	1.336	2.530	1.156	1.950	1.430	2.358	1.568 ±0.21
Per cent increase	5.5	55.8	96.9	87.3	139.3	128.8	205.3	87.7 - - -

Each year there is an increase in the yield of the phosphated plat over the check plat. The average increase in yield is 1.568 ± 0.21 tons per acre. More frequent or heavier applications would probably result in a still larger increase in yield. It seems from the above results that the practice of applying superphosphate to alfalfa is very profitable.

Since the superphosphate is applied on alternate odd years it would seem that the yields of alfalfa would be greater during the odd years than during the even years. These results are given in Table VI.

Table VI. The Yields of Alfalfa in Rotation 3 During Odd Years and During Even Years

Odd Years	Yield	Even Years	Yield
1923	2.756	1924	3.724
1925	5.140	1926	2.480
1927	3.350	1928	2.540
1929	3.506		
Average	3.688 ± 0.35	Average	2.915 ± 0.29

Increase in yield of odd years, 0.773 ± 0.32 tons.

The yields during odd years, or during those when the superphosphate is applied, are easily higher than those during even years. The average yield of the odd years is 0.773 ± 0.32 tons higher than the average yield of the even years. If the decrease in yield is 0.773 ± 0.32 tons every year it would be between two and three years before the yield in rotation 3 would be down to what it is in rotation 2.

The Effect of Manure on the Yield of Alfalfa.--

The practice of applying manure to the alfalfa is not followed to a great extent due to the difficulty encountered in obtaining the manure. However, tests here show that manure is a superior fertilizer. This is shown in Table VII.

Table VII. The Effect of Manure on the Yield of Alfalfa

Rotation No.	Yields per acre tons							
	1923	1924	1925	1926	1927	1928	1929	Average
1	5.380	5.466	8.520	6.020	6.040	4.550	5.094	5.724 ±0.34
2	2.610	2.388	2.610	1.324	1.400	1.110	1.148	1.789 ±0.22
Increase in Yield	2.770	3.078	5.910	4.696	4.640	3.440	3.946	3.935 ±0.29
Per cent Increase	106	129	239	355	331	309	344	219

The splendid effect of manure on the yield of alfalfa cannot be questioned. A comparison of Tables V and VII clearly shows that manure is of greater value to the alfalfa in these rotations than is superphosphate. The average increase in yield due to the manure is even greater than the average yield of rotation 3 from 1923 to 1929 where the superphosphate is applied. The highest increase of the manured plat over the check plat was in 1925 when rotation 1 yielded almost 5 tons more than did rotation 2.

The manured and phosphated plats not only show a higher yield than does the check plat but they also start growing earlier in the spring and more quickly after a cutting. There is also considerable difference in the height of alfalfa in the different plats. The main differences, however, are in the stand and in the yield.

The manure in rotation 1, like the superphosphate in rotation 3, is applied on alternate odd years. The yields of the plat during odd and during even years are shown in Table VIII.

Table VIII. The Yields of Alfalfa in Rotation 1 During Odd Years and During Even Years

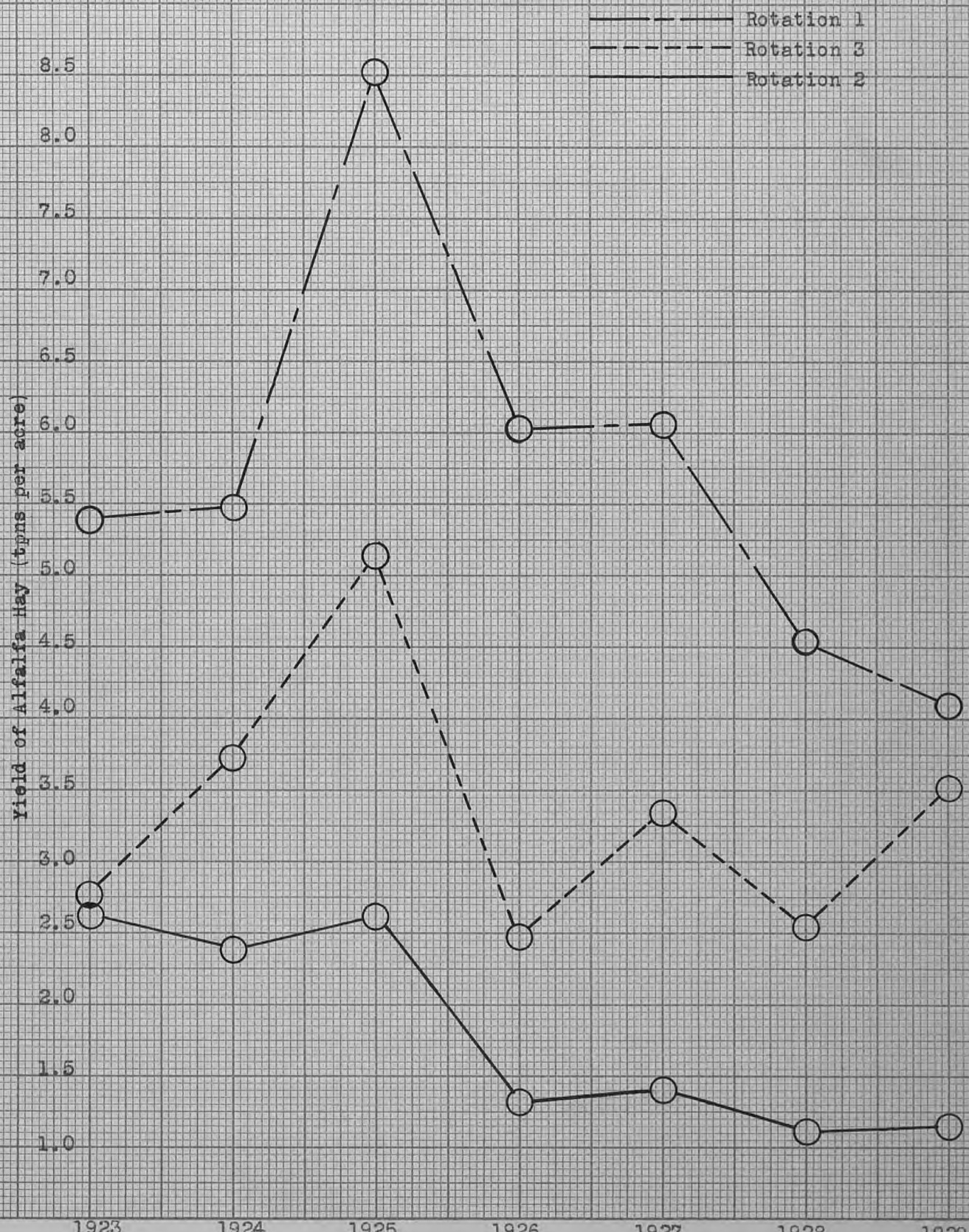
Odd Years	Yield	Even Years	Yield
1923	5.380	1924	5.466
1925	8.520	1926	6.020
1927	6.040	1928	4.550
1929	4.094	----	-----
Average	6.009 ±0.62	Average	5.345 ±0.29

Increase in yield of the odd years, 0.664 tons.

The decrease in yield of the even years, or the second year after the application of the manure, is smaller than the difference in yield between the odd and even years in rotation 3. It seems from this that an application of 12 tons of manure to alfalfa would increase the yield over a longer period of time than an application of 300 pounds of superphosphate. In other words, the superphosphate runs out more rapidly than does the manure.

A Comparison of the Yields of Alfalfa Hay in Rotations 1 and 3 at the Different Cuttings.-- A summary of the yields of the various cuttings was made to determine whether there was any difference in the cutting at which the maximum yields were obtained in rotations 1 and 3. Generally alfalfa responds more rapidly to an application of superphosphate

Fig. 3 A Comparison of the Yields of Alfalfa in Rotations 1, 2, and 3 at the United States Yuma Field Station, 1923 to 1929



than it does to an application of barnyard manure. The yields of alfalfa, however, do not seem to decline as rapidly after an application of manure as they do after an application of superphosphate. In Table IX the yields at the various cuttings are compared, as well as the yields of the cuttings during odd years, or the same year the fertilizers are applied, and during even years, or the second year after the fertilizer applications.

In both rotations 1 and 3 the highest average yield from 1923 to 1929 was obtained in the third cutting. The decline in the yield in the remainder of the cuttings is greater in rotation 3 than in rotation 1. The highest average yield of the odd years in rotation 1 was obtained in the fourth cutting. The highest average yield of the odd years in rotation 3 was obtained in the third cutting. Both the superphosphate and manure are applied to these two rotations after the first cutting of hay. The effect of the superphosphate is almost immediately noticeable in rotation 3 because the second cutting of hay averages almost as high as does the third cutting. The highest yield in rotation 1 was obtained in the third cutting. This seems to indicate that alfalfa responds more rapidly to applications of superphosphate than it does to applications of manure.

Table IX. A Comparison of the Yields of Alfalfa Hay in Rotations 1 and 3 at the Different Cuttings

Year	1	2	3	4	5	6	7
			Rotation No. 1				
1923	0.800	1.100	1.490	1.410	0.580	---	---
1924	0.880	1.300	1.300	1.200	0.500	0.256	---
1925	0.570	1.640	1.820	2.020	1.210	1.260	---
1926	0.460	1.600	1.360	1.040	0.820	0.460	0.280
1927	0.860	1.220	1.140	1.240	1.580	---	---
1928	0.950	0.860	0.960	0.740	1.040	---	---
1929	0.334	0.600	1.040	1.320	0.800	---	---
Average	0.694	1.188	1.302	1.282	0.932	0.668	0.280
Average Odd Years:	0.642	1.140	1.372	1.498	1.042	---	---
Average Even Years:	0.764	1.254	1.206	0.986	0.786	---	---
			Rotation No. 3				
1923	0.240	0.990	0.580	0.690	0.256	---	---
1924	0.350	0.556	0.500	0.580	0.290	0.112	---
1925	0.250	1.140	1.220	1.140	0.710	0.680	---
1926	0.020	0.680	0.560	0.480	0.290	0.370	0.080
1927	0.140	0.740	0.820	0.790	0.860	---	---
1928	0.550	0.580	0.680	0.370	0.360	---	---
1929	0.266	0.600	1.100	1.100	0.440	---	---
Average	0.260	0.756	0.780	0.736	0.458	0.388	0.080
Average Odd Years:	0.224	0.868	0.930	0.930	0.566	---	---
Average Even Years:	0.302	0.606	0.580	0.476	0.314	---	---

The highest average yield of alfalfa in the even years is found in the second cutting in both rotations 1 and 3. After this a gradual decline in yield is found until more fertilizer is applied. It is interesting to note that the average yield of the second cutting in rotation 1 is higher in the even years than it is in the odd years. In rotation 3 the opposite is found. This again shows that alfalfa responds more rapidly to superphosphate than it does to manure and that the effect of manure is more lasting than is the effect of superphosphate.

The Relationship Between the Average Yield of Alfalfa and the Length of the Rotation System.-- It is interesting to note that as the length of the rotation system increases the average yield of alfalfa decreases. Just what causes this is hard to say. Perhaps there are too many crops intervening between the alfalfa years, thus putting the soil on a lowered fertility basis. Or perhaps the lowering of the yield of alfalfa in the longer rotations is due to the addition of several third and fourth years of alfalfa which would naturally lower the yields. The results are given in Table X.

Table X. The Relationship of the Average Yield of Alfalfa and the Length of the Rotation System

Rotation No.	Number of years in Alfalfa	Average Yield of the Rotation	Average
	Four-Year Rotations		
40 (1)	2	2.958	
42	2	2.705	
44	2	3.338	
46	2	2.838	2.959
	Five-Year Rotations		
50	3	2.289	
52 (2)	4	2.446	2.368
	Six-Year Rotations		
60	3	1.661	
61	3	1.789	
63 (3)	4	1.865	1.772

(1) The second year of alfalfa is plowed late in June and corn planted.
(2) The fourth year of alfalfa is plowed late in June and grain sorghum planted.
(3) The fourth year of alfalfa is pastured to hogs.

A decrease in yield as the rotation system gets longer was obtained in every case. Other factors besides the number of years in alfalfa must enter in because the five- and six-year rotations have about the same number of years in alfalfa but still the average yield is lower in the six-year rotations than in the five-year rotations.

Since a longer rotation seems to lower the yield of alfalfa hay the question arises as to whether this was due to the intervening crops or the addition of the third and fourth years of alfalfa. Rotation 3 has the fourth highest yielding alfalfa plat and receives 300 pounds of superphosphate on alternate odd years. For 1928 and 1929 all the alfalfa plats in the rotations (except rotations 1, 2, and 3) received 300 pounds of superphosphate every year. Previous to 1928 it was applied to the first year of alfalfa only. But just considering the period of 1928 and 1929 it would seem that all the alfalfa plats that receive 300 pounds of superphosphate every year would be much higher in yield than rotation 3 where this fertilizer is applied every other year. But this is not the case. In 1928 there were only five plats that had a higher yield than did rotation 3 and in 1929 there was only one. This shows clearly that even though the other rotations receive their superphosphate every year they average much lower in yield than rotation 3 which receives it every other year. The most probable reason for this seems to be the intervening crops in the other rotations.

The Effect of the Age of Alfalfa on the Yield.-- The age of alfalfa has a great deal to do with the average yield. When superphosphate was applied only to the first year of alfalfa this year showed the highest yield. But now since each plat gets an application of 300 pounds of superphosphate every year, the average yield of the first year of alfalfa is lower than either the second or third years. The summary is given in Table XI.

The second year of alfalfa leads the list with an average of 2.556 ±0.13 tons of hay. The average of the third year is 2.321 ±0.22 tons. Both are higher than the first year which is 2.296 ±0.19 tons. The first year of alfalfa in rotation 63 is lower than any other. This is probably due to the fact that barley is here used as a nurse crop. This would cause one less cutting of hay to be harvested the first year.

The Effect of the Average Yield of Alfalfa Upon the Yield of the Following Crop.-- It would usually be expected that if the average yield of alfalfa in a rotation is high the yield of the following crop would also be high. There are three rotations in which barley follows alfalfa, two in which cotton follows alfalfa, and two in which corn follows

Table XI. The Effect of the Age of Alfalfa on the Yield

Rotation No.	Years of Alfalfa: First Year		Second Year		Third Year		Fourth Year		Average	
1	-	-	-	-	-	-	-	-	5.724	±0.34
2	-	-	-	-	-	-	-	-	1.789	±0.22
3	-	-	-	-	-	-	-	-	3.357	±0.21
40 (a)	3.536	±0.23	2.380	±0.34	-	-	-	-	-	-
42	2.485	±0.29	2.924	±0.27	-	-	-	-	-	-
44	3.055	±0.27	3.620	±0.36	-	-	-	-	-	-
46	2.798	±0.16	2.878	±0.31	-	-	-	-	-	-
50	1.840	±0.17	2.537	±0.24	2.493	±0.26	-	-	-	-
52 (b)	2.420	±0.37	2.791	±0.37	3.041	±0.32	1.533	±0.16	-	-
60	1.713	±0.21	1.677	±0.18	1.592	±0.20	-	-	-	-
61	1.684	±0.19	1.893	±0.24	-	-	-	-	-	-
63	1.132	±0.08	2.305	±0.19	2.158	±0.27	-	-	-	-
Average	2.296	±0.19	2.556	±0.13	2.321	±0.22	1.533	±0.16	-	-

(a) The second year of alfalfa is plowed late in June and corn planted.
(b) The fourth year of alfalfa is plowed late in June and grain sorghum planted.

alfalfa. The effect of the average yield of alfalfa on the yield of the following crop is shown in Table XII.

Table XII. The Effect of the Average Yield of Alfalfa on the Yield of the Following Crop

Rotation No.	Average Yield of Alfalfa	Average Yield of Following Crop
	Barley following Alfalfa	
	Tons	Bus.
60	1.661	21.6
50	2.289	22.9
46	2.838	31.4
	Cotton following Alfalfa	
	Tons	Lbs.
61	1.789	1,543
44	3.338	1,749
	Corn following Alfalfa	
	Tons	Bus.
63	1.865	24.2
42	2.958	23.8

In both the barley and cotton there is an increase in the yield as the average yield of alfalfa increases. This was found in every case with these two crops. In corn, however, a slightly lower yield was obtained in rotation 42 where the average yield of alfalfa is higher. Perhaps the fact that the corn in rotation 63 is planted on a hogged off alfalfa plat would tend to increase its yield. In the discussion of corn later in this paper it will be found that the highest yield of corn was not obtained in a plat that immediately follows alfalfa. This may help to explain the fact that a higher yield of corn was obtained where the average yield of alfalfa was lower. With barley and cotton, however, it may be said that as the average yield of alfalfa increases there is generally an accompanying increase in the yield of the following crop. This may in part be due to the larger root system and a large number of nodules found in the higher yielding plats of alfalfa.

Cotton

The cotton plats in the rotations have been of greater interest to the visitors at this station than any of the other crops. This is perhaps due to the large amount of cotton grown in this region and because the soil troubles encountered in the Yuma valley are very similar to those found on this station.

Since the rotations were started there has been only one variety of cotton grown on them, namely, Pima. Pima is an Egyptian cotton and has an average length of staple of about one and five-eighths inches. This cotton yields very well and makes an excellent showing in the plats due to its height and large number of bolls.

The planting of cotton often offers some difficulties. The ground is always plowed. At this time it is given one irrigation and as soon as the soil dries out it is harrowed and the cotton planted. A few of the plats are not very uniform as to soil. Portions of these plats are quite sandy while other portions of the same plat have much clay in them. It is with this latter type of soil that a good stand is often hard to obtain. The soil here remains wet for a long

period of time but planting must be accomplished before the sandier portions of the plat becomes too dry. After planting, the heavier soil dries out and cracks and thus leaves the cotton seed exposed to the sun. Under such conditions the seed will not germinate. Replanting is usually done by hand. If large portions of the plat has a poor stand the entire plat is replanted with a two-row planter. As a general rule, second plantings of cotton do not yield as well as do those planted earlier. Early planting is recommended in that it brings the cotton plant into the months of high maximum and minimum temperatures and high humidities with most of its squares forming into bolls, thus lessening the percentage of shedding. Later plantings would bring the plants into this period with its squares just forming. This usually causes a high per cent of shedding and a corresponding decrease in the yield.

The average date of planting of cotton is about March 15. Cotton is planted at the rate of 20 pounds per acre. As soon as the plants are above ground they are cultivated with a shovel cultivator. Later a disk cultivator is used, first throwing the soil away from the plants and then back toward the plants. Cultivation is continued until the plants are injured by the cultivator. At this time a

one-horse cultivator is used and one or two additional cultivations are given. In addition to these cultivations the cotton receives about five hoeings each season.

The time the first irrigation is applied is very important in the growing of cotton. The plants are allowed to remain dry as long as possible. A certain degree of wilting does not seem to harm the plants. After the first irrigation is applied water is given to the cotton plats whenever needed. During the hot summer months the cotton receives water every week. Even with such frequent irrigations some of the cotton begins to wilt before the end of the week.

The first picking of cotton is started as soon as a majority of the bolls are open. It is desirable to pick the cotton as soon as possible since the seed cotton of the Pima variety has the undesirable trait of stringing out of the boll. There is also the danger of a high wind blowing much of the cotton out of the boll and on the ground. Different experiments seem to indicate that the quality of the lint is lowered by leaving the cotton in the boll too long. It is, therefore, desirable to pick the cotton as soon as one can.

The yields of cotton in the different rotations from 1923 to 1929 are given in Table XIII. It will at once be

Table XIII. The Mean Yields of Seed Cotton in the Irrigated Rotations at the United States Yuma Field Station, 1923 to 1929

Rotation No.	Yields of Seed Cotton Per Acre (Pounds) 1923	1924	1925	1926	1927	1928	1929	Mean	Rank
4	764	784	1,272	1,674	1,038	1,272	1,058	1,123:±83.2	15
5	1,252	956	2,552	2,428	1,722	1,804	2,040	1,822:±153.2	1
6	728	800	996	1,470	734	1,188	918	976:± 71.6	18
7	744	600	1,016	1,440	778	1,124	1,180	983:± 81.6	17
20	644	824	1,964	1,278	1,586	720	1,642	1,237:±150.1	11
22	636	592	1,144	1,076	850	668	1,154	874:± 74.1	20
23	844	1,032	1,416	1,900	1,172	1,188	1,206	1,251:± 80.2	10
30	456	280	1,032	1,044	664	988	696	737:± 84.1	21
40	884	784	2,596	2,758	1,146	872	1,940	1,569:±255.2	4
40	772	520	852	2,359	1,504	944	1,038	1,141:±160.7	14
44	1,008	2,136	1,848	1,979	4,624	2,136	1,512	1,749:±108.8	2
44	980	984	2,268	1,624	1,056	1,044	1,830	1,398:±150.7	6
46	1,244	1,144	1,104	1,992	1,614	1,260	1,114	1,353:± 88.7	9
50	728	672	1,116	1,460	840	1,192	1,352	1,051:± 89.7	16
52	684	808	2,680	1,846	922	1,100	1,450	1,356:±188.2	8
60	688	904	1,100	1,717	1,466	1,164	1,144	1,169:± 83.3	13
60	420	600	948	1,554	842	1,424	1,042	976:±107.8	19
61	672	832	1,632	2,044	2,026	1,876	1,722	1,543:±156.1	5
61	792	708	984	1,462	1,160	1,940	1,602	1,235:±132.4	12
63	1,064	1,948	1,660	2,490	1,864	1,584	1,436	1,721:±112.4	3
63	732	1,072	1,620	1,790	1,280	1,620	1,632	1,392:±107.8	7
Maximum	1,252	2,136	2,680	2,758	2,026	2,136	2,040	--	--
Minimum	420	280	852	1,044	664	668	696	--	--
Average	797	904	1,514	1,780	1,233	1,291	1,364	1,269:± 86.1	--

noticed that the variation in yield is very large, the difference between the highest yielding and the lowest yielding rotation being 1,085 pounds of seed cotton. This is considerably higher than the average yield of some of the rotation plats. Rotation 5, a continuously cropped plat to which 12 tons of manure are applied alternate odd years, leads the list with a yearly average of 1,822 ±153.2 pounds of seed cotton. It is easily the highest yielding plat of cotton in the rotations.

The effect of alfalfa and the number of intervening crops between alfalfa and cotton on the yield of the first year of cotton is very noticeable. The results are given in Table XIV.

Table XIV. The Effect of Alfalfa and the Number of Intervening Crops Between the Alfalfa and Cotton on the Yield of the First Year of Cotton

Rotation No.	Crop Sequence	Ave. Yield 1923 to 1929		Ave.
	A. No Crops Intervening			
44-1	2 years alfalfa, cotton, cotton	1,749	±108.8	
61-1	3 years alfalfa, cotton, cotton, grain sorghum	1,543	±156.1	1,646
	B. One Crop Intervening			
40-1	2 years alfalfa, corn, cotton, cotton	1,569	±255.2	
52	3 years alfalfa, grain sorghum, cotton	1,356	±188.2	
63-1	4 years alfalfa, corn, cotton, cotton	1,721	±112.4	1,549
	C. Two Crops Intervening			
46	2 years alfalfa, barley, grain sorghum, cotton	1,353	± 88.7	
60-1	3 years alfalfa, barley, grain sorghum, cotton, cotton	1,169	± 83.3	
50	3 years alfalfa, barley, grain sorghum, cotton	1,051	± 89.7	1,191

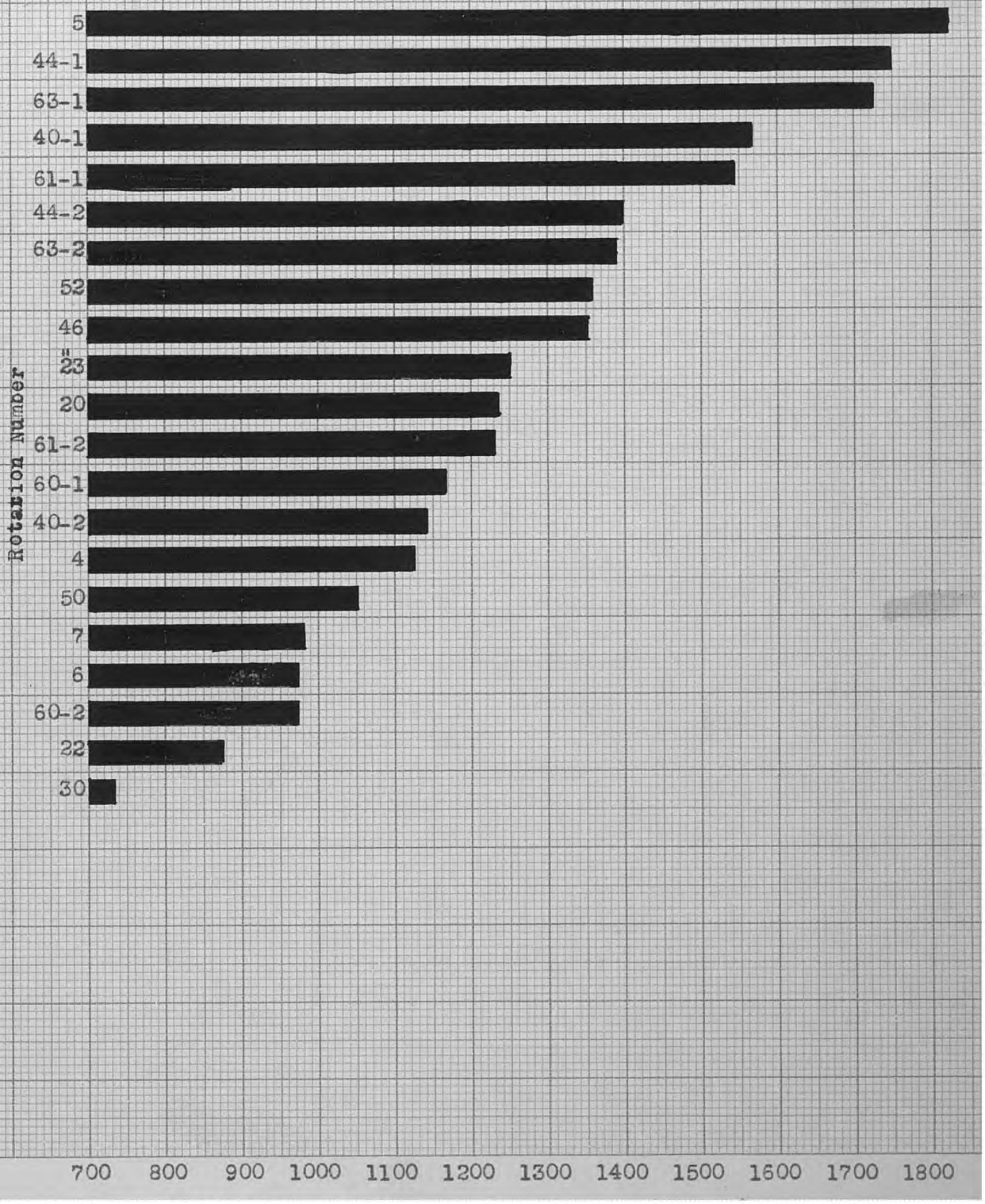
Division A represents those rotations in which cotton directly follows the alfalfa. This division includes rotations 44, and 61. The average yield of these two plats is 1,646 pounds. Division B shows the rotations that have one grain crop between the alfalfa and the cotton. In this division are rotations 40, 52, and 63, the average yield of which is 1,649 pounds of seed cotton per acre. The last division, C., represents the rotations with two crops intervening between the alfalfa and the cotton. The rotations in this division, namely, 46, 60, and 50, run much lower in yield and average only 1,191 pounds of seed cotton. The table shows a gradual decline in yield from where alfalfa is followed by cotton to where there are two crops intervening between the alfalfa and the cotton. From these data it seems that the highest yields of cotton are to be expected when it immediately follows the crop of alfalfa.

The reduction of yield in the second year of cotton varies in the different rotations where two successive years of cotton are grown. This is shown in Table XV.

Table XV. The Reduction of Yield in the Second Year of Cotton Where Two Successive Years of Cotton are Grown

Rotation No.	Crop Sequence	Ave. Yield 1923 to 1929		Reduction in Yield
44-1	2 years alfalfa, cotton, cotton	1,749	±108.8	
44-2	2 years alfalfa, cotton, cotton	1,398	±150.7	351
61-1	3 years alfalfa, cotton, cotton, grain sorghum	1,543	±156.1	
61-2	3 years alfalfa, cotton, cotton, grain sorghum	1,235	±132.4	308
40-1	2 years alfalfa, corn, cotton, cotton	1,569	±255.2	
40-2	2 years alfalfa, corn, cotton, cotton	1,141	±160.7	428
63-1	4 years alfalfa, corn, cotton, cotton, barley	1,721	±112.4	
	4 years alfalfa, corn, cotton, cotton, barley	1,392	±107.8	329
60-1	3 years alfalfa, barley, grain sorghum, cotton, cotton	1,169	± 83.3	
60-2	3 years alfalfa, barley, grain sorghum, cotton, cotton	976	±107.8	193

Fig. 4 The Average Yields of Cotton in the Irrigated Rotations at the United States Yuma Field Station, 1923 to 1929



The second year of cotton in rotation 44 is 351 pounds lower than in the first year. In rotation 61 this difference is only 308 pounds. It seems that this variation can be attributed to the third year of alfalfa in rotation 61. Rotation 44, which has only two years of alfalfa followed by two years of cotton, has not enough reserve food on hand after the first year of cotton is grown, thus a larger reeduction in yield is found than in rotation 61 where three years of alfalfa are grown and probably also a larger food supply results. Similar conditions are found in rotations 40 and 63. Rotation 40 shows a larger reduction than any of the other rotations. Probably the addition of corn between the alfalfa and the cotton would aid in decreasing the fertility of the soil and thus cause a greater reduction in the second year of cotton. The addition of two years of alfalfa to rotation 63 has decreased the reduction almost 100 pounds when compared to rotation 40.

In rotation 60 there are two crops intervening between the alfalfa and cotton and a low reduction in yield results. This may be due to the low yield of the first year of cotton. The yield of the second year of cotton is as low as that in rotation 6, a continuously cropped plat to which no fertilizer has been added. This seems to indicate that the barley, grain sorghum, and the first year of cotton in

rotation 60 use up all the fertility supplied by the alfalfa and leaves the second year of cotton to be grown on a non-fertile soil as in rotation 6. It thus seems that in order to get a small reduction in yield between the first and second years of cotton, three successive years of alfalfa followed directly by two years of cotton would be desirable.

The Effect of Barnyard Manure on the Yield of Cotton.--The practice of applying fertilizers to cotton is one quite generally followed. These fertilizers take the place of alfalfa and very often yields are obtained that are higher than those obtained by using alfalfa in the rotations. In using fertilizers care must be taken to select those that do not cause an excess of vegetative growth.

The effect of manure on the yield of cotton can be demonstrated by comparing the yields of rotations 5 and 6. Rotation 5 is continuously cropped to cotton and receives 12 tons of manure alternate odd years. Rotation 6 is also continuously cropped but receives no fertilizer or treatment of any sort. The comparative yields of these two rotations are given in Table XVI.

Table XVI. The Effect of Manure on the Yield of Cotton

Rotation No.	Yield of Seed Cotton Per Acre, Pounds								
	1923	1924	1925	1926	1927	1928	1929	Average	
5	1,252	956	2,552	2,428	1,722	1,804	2,040	1,822	±153.2
6	728	800	998	1,470	734	1,188	918	976	± 71.6
Increase in Yield . . .	524	156	1,554	959	988	616	1,122	846	±122.3
Per Cent Increase .	72	19	156	65	134	52	122	87	----

It will be seen that the average increase due to manure was 846 ±122.3 pounds of seed cotton per acre. The highest increase occurred in 1925 when the manured plats yielded 1,554 pounds above the check plat. The practice of applying manure to cotton thus seems to be very much worth while.

Since the manure on rotation is only applied on alternate odd years, it would be natural to expect the cotton on even years to yield less than that grown on odd years, or the same year the manure was applied. This is shown in Table XVII.

Table XVII. A Comparison of the Yields of Cotton in Rotation 5 on Odd Years, or Immediately Following the Application of Manure, and on Even Years, or the Second Year After the Manure

Odd Years	Yield	Even Years	Yield
1923	1,252	1924	956
1925	2,552	1926	2,428
1927	1,772	1928	1,804
1929	2,040		
Average	1,904 ±191.3	Average	1,729 ±278.5

Average decrease in the Yield of the even years, 175 pounds.

The decrease in yield of the even years is constant throughout the entire period except in 1928 when an increase occurred in the second year of cotton after the manure was applied. The average decrease in yield was 175 pounds of seed cotton per acre. It is doubtful whether a rotation with six tons of manure applied every year would keep up the record high yield that has been established in rotation 5.

The Effect of a Complete Fertilizer on the Yield of Cotton.-- When manure is difficult to obtain there is left another practice to increase the yield of cotton, namely, to apply a complete fertilizer. The use of complete fertilizers for cotton usually does not seem to bring the desired results. It has been hard, indeed, to obtain a complete fertilizer that will increase the yield of cotton as does manure. So many fertilizers are on the market that much experimentation is usually necessary to find one that fulfills the desire of the grower and also the buyer and the manufacturer.

The effect of a complete fertilizer on the yield of cotton can be shown by comparing the yields of rotations 4 and 6. Rotation 4 is a continuously cropped plat of cotton that receives 500 pounds of 4-9-4 complete fertilizer to the acre on alternate odd years. The results are shown in Table XVIII.

Table XVIII. The Effect of a 4-9-4 Complete Fertilizer on the Yield of Cotton

Rotation No.	Yield of Seed Cotton Per Acre, Pounds								
	1923	1924	1925	1926	1927	1928	1929	Average	
4	764	784	1,272	1,874	1,036	1,272	1,058	1,123	± 83.2
6	728	800	996	1,470	734	1,188	918	976	± 71.6
Difference in Yield	+ 36	- 16	+ 276	+ 204	+ 304	+ 184	+ 140	+147	± 32.3
Per Cent Difference	+ 5.0	- 2.0	+ 28	+ 14	+ 41	+ 7	15	+ 15.1	----

Fig. 5. An Excellent Result is Obtained by Applying 12 Tons of Manure During Alternate Odd Years to Rotation 5. (Nov.2,1929)

Fig. 6. Pima Cotton in Rotation 7,1929

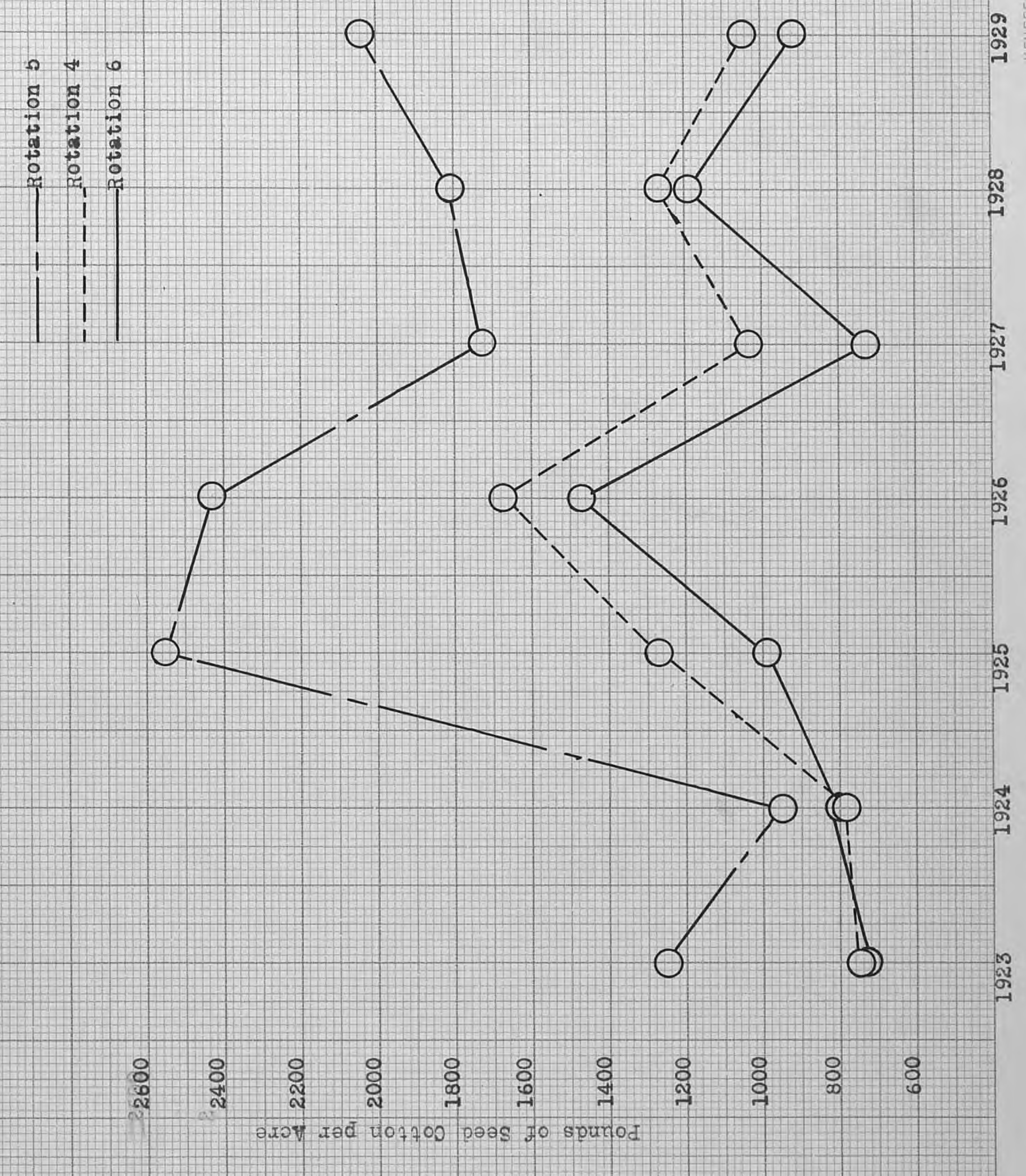


Fig. 7 A Comparison of the Yields of Cotton in Rotations 4, 5, and 6 at the United States Yuma Field Station, 1923 to 1929

During every year except 1924 there was an increase in the yield of the complete fertilizer over the check plat. The average increase in yield was 147 ±32.3 pounds, or 700 pounds less than the increase of rotation 5 over rotation 6. These results, however, seem to indicate that a complete fertilizer could be used with profitable results, although not as profitable as the practice of applying manure.

The fertilizer in rotation 4 is applied during alternate odd years the same as the manure in rotation 5. It would also be expected in this case that the cotton grown immediately after the fertilizer was applied would yield higher than the second year of cotton. This, however, is not the case as is shown in Table XIX.

Table XIX. A Comparison of the Yield of Cotton in Rotation 4 During Odd Years, or Immediately After the Application of the 4-9-4 Complete Fertilizer, and During Even Years, or the Second Year After the Fertilizer

Odd Years	Yield	Even Years	Yield
1923	764	1924	784
1925	1,272	1926	1,674
1927	1,038	1928	1,272
1929	1,058		
Average	1,033 ± 65.9	Average	1,243 ± 165.4

Increase in the yield of the even years, 210 pounds.

It is strange that results such as this should be obtained. Perhaps the complete fertilizer is toxic to cotton when applied in such large amounts. If this is the case the toxicity would be lessened after the first year of cotton is grown and a greater increase in yield would be noted with the second year of cotton after the fertilizer had been applied. This was found to be true from the above table. But the first year of cotton has a higher average yield than the check plat or rotation 6, so some fertilizing element must be obtained from the complete fertilizer for the first year of cotton. An increase in the yield of the even years, or the second year after the fertilizer was applied, was noted in every year from 1923 to 1929. The average increase was 210 pounds per acre. Just what would cause this increase is not known, but it would be interesting to fertilize cotton with smaller applications of 4-9-4 complete fertilizer and perhaps also have three or four years intervening between the applications.

The Effect of Green Manure on the Yield of Cotton.--In addition to using alfalfa and applying manure and complete fertilizers to increase the yield of cotton, green manures are often grown. Rotations 7, 20, 22, and 30, are of this nature. Vetch is very desirable for this purpose because it can be planted very early in the fall and thus

attain a good height before it is to be plowed for cotton in the spring.

Rotation 7 is continuously cropped to cotton with only vetch as a green manure and a source of plant food. This vetch is broadcast into the cotton plants before the cotton is picked and watered at short intervals to insure a good germination and stand. Even after the cotton is picked the stalks are not cut down but allowed to stand. The stalks aid in the growth of the vetch since the vetch stems twine around them. In the spring before the cotton is to be planted the stalks are cut and the entire plat plowed.

The actual value of the vetch can be demonstrated by comparing rotation 7 with rotation 6. This has been done in Table XX.

Table XX. The Effect of Vetch on the Yield of Cotton

Rotation No.	Yield of Seed Cotton Per Acre, Pounds							
	1923	1924	1925	1926	1927	1928	1929	Average
7	744	600	1,016	1,440	778	1,124	1,180	983 :+ 81.6
6	728	800	998	1,470	734	1,188	918	976 :+ 71.6
Increase (+) or Decrease (-)	+ 16	-200	+ 18	- 30	+ 44	- 64	+262	+ 7 : --

The benefits derived by using vetch as a green manure seem to be too slight to warrant much popularity. The average increase in yield due to the vetch is only 7 pounds per acre.

Green manure is also used in rotations 20, 22, and 30. Of these, rotation 20, a rotation of sweet clover, grain sorghum, vetch, and cotton, produces the highest yields of cotton. Vetch in this rotation is broadcast as soon as the grain sorghum is removed from the land. The average yield of cotton here is much higher than that in rotation 7 where vetch is also used. This difference seems to be due to the sweet clover in rotation 20, since other rotations here indicate that sweet clover is a superior crop when used as a green manure.

The value of cowpeas as green manure seems to be negligible. This crop is used in rotations 22 and 30. In rotation 30 the crop sequence is as follows: Sweet clover, grain sorghum, barley, cowpeas, corn, and cotton. The fertility furnished by the sweet clover is completely used up by the grain sorghum since the barley yield is lower. than in any other rotation. Hence, the cowpeas, corn, and cotton part of rotation 30 can be compared with rotation 22 where cowpeas, grain sorghum, and cotton are grown. The average yield of cotton in rotation 22 is 874 ±74.1 pounds and in

Fig.8. Rotation 30 Contains the Lowest Yielding Cotton Plat in the Rotations. (Nov.26,1929)

Fig.9. Plowing Vetch for Cotton in Rotation 20.(The Vetch does not make a very desirable growth during the winter months.)

rotation 30 it is 737 ±84.1 pounds. If the above assumption can be made then corn before cotton reduces the yield of cotton 137 pounds more than does grain sorghum before cotton.

Grain Sorghum

Grain sorghum is the most important grain crop in this area. It also seems to be the best adapted cereal for this warm climate. The seed is grown mostly for feed for live stock. As the live stock industry increases in importance it is probable that grain sorghum will replace most of the other cereals that are now being grown on this project.

The best results with grain sorghum are obtained when it is planted the first part of July. The seed is planted in rows 42 inches apart. When the plants are from 4 to 6 inches in height they are thinned to an average distance of 15 inches. Approximately five cultivations, six irrigations, and two hoeings are given the grain sorghum every season. Maturity of the plants is reached by the latter part of October. The grain sorghum heads are clipped from the plants and piled on one end of the plat. When

they are thoroughly dry they are threshed. The stalks are then cut with a stalk cutter, shocked, and weighed when dry. The yields of grain and stalks are thus obtained in all the grain sorghum plats.

Until 1929 the Dwarf variety of milo had been grown in the rotation experiments. In 1929, however, this variety was replaced by Double Dwarf. The chief difference between these two varieties is probably the height. Double Dwarf seems to be more desirable in that it can be cultivated for a longer period in the spring and thus aid in controlling weeds. It is short and therefore easier to head; less irrigation is required because of the less amount of foliage, and because it does not ledge easily. There does not seem to be much difference in the yield of Dwarf and Double Dwarf.

The average yields of grain sorghum from 1923 to 1929 are given in Table XXI. It will be seen from the table that the highest grain yields are in rotations that contain no alfalfa. Rotation 11, the highest yielding plat, consists of 12 tons of manure every year after the barley and then grain sorghum is planted. In rotation 20, which contains the second highest yield of grain sorghum, sweet clover is used as a green manure. Rotation 8, consisting only of

Table XXI. The Average Yields of Grain Sorghum in the Irrigated Rotations at the United States Yuma Field Station, 1923 to 1929

Rotation No.	Yields per Acre, Bushels 1923	1924	1925	1926	1927	1928	1929	Mean		Rank
8	42.3	56.4	58.4	48.4	49.9	39.9	38.3	47.7	± 2.2	3
9	21.1	40.7	49.8	44.5	40.6	40.1	40.5	39.6	± 1.8	7
10	9.0	32.9	37.1	27.5	31.4	25.4	21.8	26.4	± 2.3	13
11	14.5	44.8	69.2	52.2	59.7	75.3	49.0	52.1	± 4.7	1
20	14.4	65.8	47.3	75.6	50.4	50.4	41.0	49.3	± 4.4	2
22	12.5	42.1	24.9	32.9	25.2	26.7	33.0	28.2	± 2.3	12
23	18.2	23.9	36.8	26.3	39.9	29.1	30.0	29.2	± 1.9	11
24	6.1	27.6	21.8	27.3	28.6	26.2	27.0	23.5	± 1.9	15
30	11.1	25.4	24.8	29.7	28.6	20.9	32.5	24.7	± 1.7	14
42	20.6	52.9	36.8	49.8	54.3	42.7	38.8	42.3	± 3.0	4
46	11.9	43.3	47.7	55.2	51.1	33.9	35.1	39.7	± 3.8	6
50	20.4	51.3	50.0	31.4	37.2	46.4	37.3	39.1	± 3.0	8
52	6.1	60.2	45.5	26.5	39.9	46.5	59.5	40.6	± 4.9	5
60	20.4	41.7	35.4	44.0	40.1	38.1	39.5	37.0	± 1.8	9
61	17.4	36.8	25.6	28.6	25.2	33.7	37.3	29.2	± 1.6	10
Maximum	42.3	65.8	69.2	75.6	59.7	75.3	59.5	---	---	---
Minimum	6.1	23.9	21.8	27.3	25.2	20.9	21.8	---	---	---
Average	16.4	43.1	40.7	40.0	40.1	38.4	37.4	36.6	± 2.0	---

barley and grain sorghum, has the third highest yield of grain sorghum. It will be remembered that this combination with no fertilizer of any sort has the second highest yielding plat of barley. The maximum yield from 1923 to 1929 was obtained in rotation 20 in 1926. Here the sweet clover brought the yield up to 75.6 bushels per acre.

Among the rotations that include alfalfa, rotation 42 is the highest and ranks fourth in the entire list. The grain sorghum in this rotation is the second year after alfalfa but it still yields higher than rotation 52 where the grain sorghum follows alfalfa. Results such as these seem to indicate that grain sorghum following alfalfa is not the best combination to secure the highest yields of grain sorghum.

The average yields from one year to another shows much less variation in grain sorghum than in any other crop. Probably grain sorghum is less subject to seasonal variations and conditions than any other crop used in these experiments.

The average yields of grain sorghum stalks from 1923 to 1929 are shown in Table XXII. The highest average yield of sorghum stalks is obtained in rotation 8 which consists only of barley and grain sorghum. The reason why this

Table XXII. The Average Yields of Sorghum Stalks in the Irrigated Rotations at the United States Yuma Field Station, 1923 to 1929

Rotation No.	Yields Per Acre Tons 1923	1924	1925	1926	1927	1928	1929	Mean	Rank
8	1.000	4.832	5.960	6.120	5.70	4.32	2.710	4.377 ± 0.52	1
9	---	2.656	5.440	5.490	3.72	3.76	2.260	3.888 ± 0.31	4
10	0.800	2.000	3.210	3.390	3.52	2.50	2.980	2.354 ± 0.32	13
11	1.490	4.212	5.700	4.910	4.71	4.91	2.900	4.119 ± 0.38	3
20	1.450	3.362	5.030	8.240	4.54	5.78	1.980	4.340 ± 0.56	2
22	1.470	2.880	2.340	3.460	2.15	1.74	1.220	2.180 ± 0.21	14
23	1.380	1.682	3.340	3.290	3.800	1.940	1.770	2.457 ± 0.30	12
24	0.570	1.994	2.000	3.180	2.480	2.380	1.200	1.972 ± 0.21	15
30	2.600	1.790	2.300	4.300	2.500	2.120	1.600	2.459 ± 0.20	11
42	1.070	1.752	3.740	6.090	4.77	3.80	2.160	3.340 ± 0.50	7
46	0.370	2.146	4.810	7.430	4.98	3.32	1.670	3.532 ± 0.65	6
50	2.480	3.010	5.980	3.800	3.02	2.70	1.370	3.194 ± 0.33	9
52	2.000	6.230	3.710	3.240	4.710	3.480	3.030	3.771 ± 0.33	5
60	1.550	2.632	3.880	5.660	4.640	2.560	1.590	3.216 ± 0.45	8
61	1.410	2.124	2.900	2.900	2.900	3.300	1.990	2.503 ± 0.20	10
Maximum	2.600	6.230	5.980	8.240	5.70	5.78	3.030	--- ---	--
Minimum	0.370	1.682	2.000	2.900	2.15	1.74	0.980	--- ---	--
Average	1.403	2.892	4.023	4.767	3.876	3.241	1.895	3.143 ± 0.32	--

rotation should be so high in the yields of barley, grain sorghum, and sorghum stalks is not known. It seems that such a combination works out very well when only yield is considered. The second highest yield of grain sorghum stalks is in rotation 20 where the cereal follows sweet clover. In rotation 11 where the manure is applied a higher yield of stalks would be expected than what was obtained. Among the rotations that contain alfalfa, rotation 52 yields the most stalks. This rotation, however, ranks fifth in the total list. This again seems to indicate that alfalfa does not increase the yield of grain sorghum as much as does certain other treatments.

The Effect of Manure on the Yield of Grain Sorghum.--Rotations 8 and 11 are the same except for the 12 tons of manure that are applied to rotation 11 every year. A comparison of the yields of these two rotations would, therefore, show the effect of manure on the yields of grain sorghum. The results are shown in Table XXIII.

Table XXIII. The Effect of Manure on the Yields of Grain Sorghum

Rotation No.	1923	1924	1925	1926	1927	1928	1929	Average
				Yields of Grain Bus. per Acre				
8	42.3	56.4	58.4	48.4	49.9	39.9	38.3	47.7 ± 2.2
11	14.5	44.8	69.2	52.2	59.7	75.3	49.0	52.1 ± 4.7
Increase or Decrease	- 27.9	-11.6	±10.8	3.8	+ 9.8	+35.4	+10.7	4.4 ± 4.8
				Yields of Stalks Tons per Acre				
8	1.0	4.83	5.96	6.12	5.70	4.32	2.70	4.38 ± 0.52
11	1.49	4.21	5.70	4.91	4.71	4.91	2.90	4.12 ± 0.38
Increase or Decrease	+0.49	-0.62	- 0.26	-1.21	-0.99	+ 0.59	+0.20	0.26 ± 0.20

It seems that the yields of grain in rotation 8 are on the decline from 1923 to 1929 while the yields in rotation 11 are on the increase. In 1923 and 1924 rotation 8 yielded more than did rotation 11. It is not known why rotation 11 yielded so low in 1923 and 1924. An increase in the yield of the manured plat was found in the remainder of the years. The average increase of rotation 11 over rotation 8 was 4.4 ±4.8 bushels which is hardly significant. The stalk yields vary in the same manner as do the grain yields. Rotation 8 has the highest stalk yield. The average difference for the seven years was 0.26 ±0.20 tons per acre. From this experiment it seems that manure causes an increase in the grain yield and a decrease in the stalk yields of grain sorghum. The differences, however, are too small to draw any definite conclusion.

A Comparison of the Effect of Different Green Manures on the Yields of Grain Sorghum.-- In the rotation experiments three different kinds of green manures are used for grain sorghum. In rotations 9, 20, and 30 sweet clover is used. Cowpeas are used in rotation 22 and vetch in rotations 10 and 24. The yields of grain obtained by using these three different green manures are given in Table XXIV.

Table XXIV. A Comparison of the Effects of Different Green Manures on the Yields of Grain Sorghum

Rotation No.	1923	1924	1925	1926	1927	1928	1929	Average	
				Sweet Clover					
9	21.1	40.7	49.8	44.5	40.6	40.1	40.5	39.6 ± 1.8	
20	14.4	55.8	47.3	75.6	50.4	50.4	41.0	49.3 ± 4.4	
30	11.1	25.4	24.8	29.7	28.6	20.9	32.5	24.7 ± 1.7	37.9 ± 4.7
				Cowpeas					
22	12.5	42.1	24.9	32.9	25.2	26.7	33.0	28.2 ± 2.3	28.2 ± 2.3
				Vetch					
10	9.0	32.0	37.1	27.5	31.4	25.4	21.8	26.4 ± 2.3	
24	6.1	27.6	21.8	27.3	28.6	26.2	27.0	23.5 ± 1.9	25.0 ± 1.2

Fig. 10. In 1929 Double Dwarf Milo Made Its First Appearance in the Rotations

Table XXIV shows that sweet clover is easily the most desirable green manure crop for the production of grain sorghum. The average yields obtained by using sweet clover is 9.7 bushels higher than where cowpeas are used and 12.9 bushels higher than where vetch is used. The highest yielding plat of grain sorghum from 1923 to 1929 was found in rotation 20 where sweet clover was used as a green manure. Where vetch is used the yields are very low.

There is a great difference in the growth of sweet clover, cowpeas, and vetch. Sweet clover is always the rankest in growth and has more foliage than either of the other two crops. Cowpeas are planted early in the spring and make a moderate growth. The vetch is seeded or broadcast in the fall but the growth is usually unsatisfactory. During the winter months it is too cold for the vetch to make much progress, and when warmer weather occurs in the spring the vetch plants are past their growing stage and start to bloom and produce seed. This may be the reason why the grain sorghum yields are so low when preceded by vetch as a green manure crop.

A Comparison of the Effect of Different Green Manures on the Yields of Sorghum Stalks.-- The effect of sweet clover, cowpeas, and vetch on the yields of sorghum stalks is shown in Table XXV.

Table XXV. A Comparison of the Effect of Different Green Manures on the Yields of Sorghum Stalks

Rotation No.	1923	1924	1925	1926	1927	1928	1929	Average		
9				Sweet Clover						
9	--	2.66	5.44	5.49	3.72	3.76	2.26	3.89	±0.31	
20	1.45	3.36	5.03	8.24	4.54	5.78	1.98	4.34	±0.56	
30	2.60	1.79	2.30	4.30	2.50	2.12	1.60	2.46	±0.20	3.53 ± 0.40
				Cowpeas						
22	1.47	2.88	2.34	3.46	2.15	1.74	1.22	2.18	±0.21	2.18 ± 0.21
				Vetch						
10	0.80	2.08	3.21	3.39	3.52	2.50	0.98	2.35	±0.32	
24	0.57	1.99	2.00	3.18	2.48	2.38	1.20	1.97	±0.21	2.16 ± 0.16

It seems that the different green manures have the same effect on the yields of sorghum stalks as they do on the grain. Rotations with sweet clover produce the highest yields of both sorghum stalks and also grain. The stalks in this class yielded 1.38 tons more than where cowpeas were used and 1.40 tons per acre more than where vetch was used.

Alfalfa and sweet clover increase the yields of grain sorghum about the same amount. The average yield of grain sorghum in the rotations that contain alfalfa is 38.0 bushels, only 0.1 bushel more than what is obtained by the use of sweet clover. In the sorghum stalks the average yield of the rotations containing alfalfa is 3.26 tons while those that contain sweet clover have an average yield of 3.53 tons per acre. It can thus be said that alfalfa and sweet clover are about of equal value in increasing the yields of grain sorghum, and each is better than either cowpeas or vetch.

Barley

It cannot be said that barley is one of the major crops in this region. It is not grown a great deal for grain nor is it used much as a nurse crop for alfalfa. Barley fits very nicely into a rotation with corn or grain sorghum. In order to obtain maximum yields barley should be planted the first part of November. Planting at this time brings it to maturity between the first and the middle of May. Sowings are made at the rate of 70 pounds to the acre. After the barley has been removed from the field the plat is prepared for the next crop which is usually corn or grain sorghum.

The Coast variety of barley has been used in the rotations. This variety yields higher than most other varieties, stools very well, and as a rule lodges but rarely.

The yields of barley in the different rotations from 1923 to 1929 are given in Table XXVI.

The average yield of barley in all the rotations for the seven years is only 18.1 bushels per acre. This average yield is hardly high enough to create much excitement. From Table XXVI it will be noticed that there has been a

Table XXVI. A Summary of the Barley Yields in the Irrigated Rotations at the United States Yuma Field Station, Bard, California, 1923 to 1929

Rotation No.	Yields Per Acre Bushels 1923	1924	1925	1926	1927	1928	1929	Average		Rank
8	64.5	30.8	16.5	23.0	11.9	9.5	8.5	23.6	± 4.9	2
9	49.2	25.4	21.6	30.8	10.5	12.4	7.8	22.5	± 3.7	4
11	22.8	26.0	22.2	16.3	20.0	12.3	15.7	19.3	± 1.3	7
12	18.9	15.0	2.9	6.3	7.8	3.5	3.8	8.3	± 1.1	9
24	15.0	4.6	7.1	8.2	5.7	5.9	4.9	7.3	± 0.8	10
30	9.7	10.4	2.8	6.4	4.3	6.7	2.9	6.2	± 0.8	11
42	46.5	23.2	14.3	17.9	16.4	17.2	11.2	20.9	± 2.7	6
46	45.3	25.3	31.0	43.3	30.3	19.7	24.8	31.4	± 2.5	1
50	28.7	17.4	31.5	22.7	19.7	18.3	22.6	22.9	± 1.4	3
60	24.6	19.0	17.9	26.1	21.2	18.0	24.4	21.6	± 1.0	5
63	27.3	12.5	6.1	20.6	10.8	9.3	16.1	14.7	± 2.0	8
Maximum	64.8	30.8	31.5	43.3	30.3	19.7	24.8	---	---	--
Minimum	9.7	4.6	2.8	6.3	4.3	3.5	2.9	---	---	--
Average	32.1	19.1	15.8	20.1	14.4	12.1	12.9	18.1	± 1.7	--

gradual decline in the average yearly yield from 1923 to 1929. The cause of this is not definitely known. Perhaps all the rotations that include barley are not suited for its production. The highest average yield was obtained in 1923, the first year the rotations were started, but this cannot be attributed to alfalfa or increased fertility because no fertilizer had been applied immediately before the rotations were started and alfalfa had been growing on a very small portion of the land. It thus seems that the lowering of the fertility of the soil is not entirely the cause of this gradual decline in yield.

The abruptness of the decline in the yield of barley depends upon the nature of the rotation system. Rotations that are based on alfalfa show a very gradual decline in yield. The decline in the barley yields in rotations 8, 42, and 46 are shown in figure 12. Rotation 8 is not based on alfalfa and declined in yield from 64.8 bushels in 1923 to 8.5 bushels in 1929. In rotation 42 the barley is grown one year after the alfalfa, wheat, and corn being the intervening crops. From figure 12 it will be noticed that the decline in yield is not as abrupt as it is in rotation 8. A still smaller decline in the barley yields is found in rotation 46 where the barley follows alfalfa. Rotation 46

Fig. 11. Coast Barley in Rotation 50 Following Alfalfa, 1929

Fig. 12. In Rotation 12 the Barley Averages Only 8.3 Bushels Per Acre

is also the highest yielding plat of barley in the rotations.

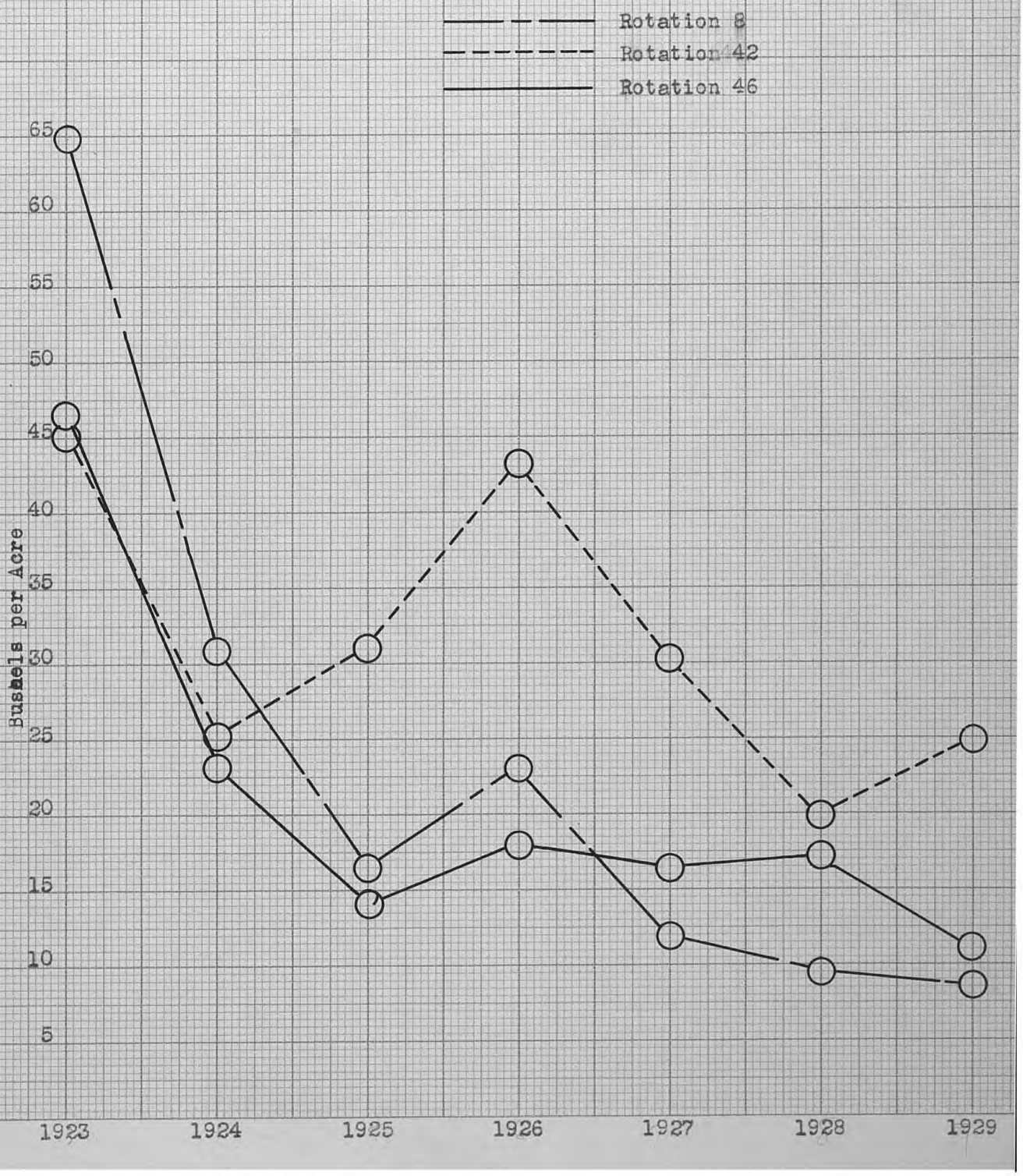
It does not seem possible that rotation 8, consisting only of barley and grain sorghum, should have the second highest yielding barley plat in the rotations. The yields in 1923 and 1924 do much to raise this yield. The average yield of barley in this rotation from 1925 to 1929 is 13.9 bushels per acre. The popular idea that grain sorghum hurts the crop which follows it does not seem to hold true in this case.

The Effect of Alfalfa on the Yield of Barley.-- It will at once be noticed from Table XXVI that rotations containing alfalfa, or rotations 42, 50, 60, and 63, rank higher in yield than those that do not contain alfalfa. These results are given in Table XXVII.

Table XXVII. A Comparison of the Average Yields of Barley from Rotations Containing Alfalfa and From Those That Do Not Contain Alfalfa

Treatment	Yield of Barley Per Acre, Bushels								
	1923	1924	1925	1926	1927	1928	1929	Average	
Alfalfa	34.5	19.5	20.2	26.1	19.7	16.5	19.8	22.3	± 1.7
No Alfalfa	30.1	18.7	12.2	15.2	10.0	8.4	7.3	14.5	± 2.0
Increase in Yield Due to Alfalfa . . .	4.4	0.8	8.0	10.9	9.7	8.1	12.5	7.8	± 1.0
Per Cent Increase	14.5	4.3	65.6	71.7	97.0	96.4	171.2	53.1	--

Fig. 13 Trends in the Barley Yields from 1923 to 1929 in Rotations 8, 42, and 46



The benefits derived by the use of alfalfa in a rotation are easily seen. During every year there was an increase in the average yield of the rotations that contained alfalfa over those that contained no alfalfa. In the non-alfalfa rotations it will be noticed that there is a gradual decline in yield from 1923 when it was 30.1 bushels, to 1929 when the decline in yield was only 7.3 bushels per acre.

A Comparison of the Yields of Barley Following Alfalfa and the Second and Third Years After Alfalfa.--It will be remembered that the best yields of cotton were obtained when grown immediately after alfalfa. Barley responds in the same manner as would be expected. In rotations 46, 50, and 60, the barley is planted right after the alfalfa is plowed. In rotation 42, it is planted the second year after alfalfa and in rotation 63 the third year after alfalfa. The average yields are given in Table XXVIII.

Table XXVIII. A Comparison of the Yields of Barley Following Alfalfa and the Second and Third Years After Alfalfa

Rotation No.	Crop Sequence	Yield of Rotation	Average Yield
	A. Barley Following Alfalfa		
46	2 years alfalfa, barley, grain sorghum, cotton	31.4	
50	3 years alfalfa, barley, grain sorghum, cotton	22.9	
60	3 years alfalfa, barley, grain sorghum, cotton, cotton	25.3	25.3
	B. Barley Second Year After Alfalfa		
42	2 years alfalfa, wheat, corn, barley † grain sorghum	20.9	20.9
	C. Barley Third Year After Alfalfa		
63	4 years alfalfa, corn, cotton, cotton barley	14.7	14.7

The highest average yield is obtained when the barley follows alfalfa and considerable reduction where barley comes the second and third years after alfalfa. It is interesting to note that in rotation 63 where the barley is planted after the third cultivated crop after alfalfa, the average yield of 14.7 bushels per acre is much higher

than those in rotations 12, 24, and 30 where green manures are relied upon. This difference may be partially due to the fact that green manures do not directly precede barley in any of the rotations. The barley in the green manure rotations are the lowest yielding plats of barley in the rotations. This again shows the unsatisfactory results obtained by the use of green manure on this station.

Corn

Corn is treated very much the same in the rotations as grain sorghum. It is planted the latter part of June or the first part of July in rows 42 inches apart. When the corn is well above ground it is cultivated twice with a disk cultivator, first throwing the soil toward the plants and then away from the plants. The corn is thinned to an average spacing of about 18 inches when the plants are about 10 inches in height. Approximately five cultivations are given it every season. Harvesting is usually completed by the latter part of October. The husked corn is piled up on one end of the border and allowed to dry out. It is then weighed and the yield calculated on the basis of 72 pounds to the bushel.

The Laguna or Mexican June variety of corn has been used in the rotation experiments. Good quality has been secured by continual selection every season. Although smut can be noticed there is seldom enough to reduce the yield. A great deal of corn earworm is noticed every year and often the damage is considerable.

In Table XXIX are given the average yields of corn in the rotations from 1923 to 1929. From the table it will be seen that the highest yielding plat of corn is not one directly following alfalfa. It also seems that by hogging off the last year of alfalfa and then planting corn that better yields of corn are secured than when corn follows alfalfa ordinarily. The highest yielding plat of corn is in rotation 42, a rotation of two years alfalfa, wheat, corn, barley, and grain sorghum. This crop sequence causes corn to yield 30.5 bushels over a period of seven years. Next highest in yield is rotation 63, or following hogged off alfalfa. Third in rank is rotation 40, or two years alfalfa, corn, cotton, cotton. Cowpeas seem to increase the yield of corn more than does sweet clover as seen by comparing rotations 30 and 12 which contain cowpeas, with rotation 24 which contains sweet clover. Rotation 24 has the lowest yielding plat of corn in the rotations, averaging

Table XXIX. The Average Yields of Corn in the Irrigated Rotations at the United States Yuma Field Station, 1923 to 1929

Rotation No.	Yields per Acre Bushels 1923	1924	1925	1926	1927	1928	1929	Average		Rank
12	10.8	14.5	18.9	11.1	11.1	14.2	16.4	13.9	± 0.8	4
13	6.9	15.0	18.9	8.9	12.5	17.5	12.5	13.2	± 1.2	6
24	11.1	8.3	17.2	7.2	16.1	13.1	11.9	12.1	± 1.0	7
30	11.3	16.1	17.8	10.0	10.0	13.9	13.6	13.2	± 0.8	5
40	20.2	17.2	38.3	16.1	19.7	33.3	21.9	23.8	± 2.4	3
42	19.1	22.2	43.3	22.8	38.1	34.2	33.6	30.5	± 2.7	1
63	20.1	17.8	24.4	18.9	20.0	42.8	25.3	24.2	± 2.0	2
Maximum	20.2	22.2	43.3	22.8	38.1	42.8	33.6	----	----	--
Minimum	6.9	8.3	17.2	7.2	10.0	13.1	11.9	----	----	--
Average	14.2	15.9	25.5	13.6	18.2	24.1	19.3	18.7	± 1.3	--

Fig.14. Rotation 42 Yielded 23.6 Bushels of Mexican June Corn in 1929

Fig.15. Corn in Rotation 13, a Rotation Consisting of Wheat and Corn in 1929

only 12.1 bushels per acre. This is even lower than in rotation 13 where only wheat and corn are found with no source of fertilizer. It may be that corn follows wheat very nicely because this same sequence was also found in rotation 42, the highest yielding corn plat in the rotations.

The Effect of Alfalfa on the Yield of Corn.--

Although the highest yield of corn was not immediately following alfalfa, yet the average yield of the rotations that contain alfalfa produce more corn than those that do not. This is shown in Table XXX.

The rotations containing alfalfa, namely, rotations 40, 42, and 63, yield exactly twice as much as those having no alfalfa. Each year there was an increase in yield. It appears as though the increase in yield due to alfalfa shows a gradual incline from 1923 to 1929.

From the corn experiments it seems that alfalfa is a detriment to the yield of corn when grown immediately following the alfalfa, and that a 100 per cent increase in the yield of corn was noted in the rotations containing alfalfa over those containing no alfalfa.

Table XXX. The Effect of Alfalfa on the Yield of Corn

Treatment	1923	1924	1925	1926	1927	1928	1929	Average	
Alfalfa	19.8	19.1	35.3	19.3	25.9	36.8	26.9	26.2	± 2.1
No Alfalfa . .	10.0	13.5	18.2	9.3	12.4	14.8	13.8	13.1	± 0.8
Increase in Yield due to alfalfa . .	9.8	5.6	17.1	10.0	13.5	22.0	13.1	13.1	± 1.3

Wheat

Because of the slight importance of wheat in this area it has not been used much in the rotations. Only two rotations contain this cereal, one in a four-year rotation following alfalfa, and the other in an annual rotation with corn. If, however, wheat should at some time be of greater importance it seems possible that the numerous results obtained from barley in these rotations could also be applicable to wheat.

The variety Early Baart has been consistently used in these tests. It is planted early in November and comes to maturity the first part of May, thus giving sufficient time to prepare the soil for the corn that is to follow. Baart wheat when sown at this time is very resistant to rust and smut and does not lodge.

The differences between the two plats of wheat in 1929 are shown in figures 16 and 17.

The average yield of the two wheat plats and the difference in yield from 1923 to 1929 are given in Table XXXI. Rotation 13 has decreased from 12.4 bushels per acre in 1923 to 3.4 bushels in 1929. This decrease has been

Fig. 16. Baart Wheat in Rotation 42,1929

Fig. 17. Wheat in Rotation 13 is Very Short, Has Small Heads, and Yields Very Low.

Table XXXI. The Average Yields of Wheat in the Irrigated Rotations at the United States Yuma Field Station, 1923 to 1929

Rotation No.	1923	1924	1925	1926	1927	1928	1929	Average
13	12.4	7.2	5.1	7.9	7.0	3.9	3.4	6.7 ± 0.8
42	23.3	22.3	25.9	27.7	26.1	20.0	15.2	22.9 ± 1.1
Average Difference in Yield	10.9	15.1	20.8	19.8	19.1	16.1	11.8	16.2 ± 1.1

fairly constant. No fertilizer is applied to this rotation and its yield is only 6.7 bushels per acre. Rotation 42 with two years alfalfa followed by wheat, corn, barley, and grain sorghum is consistently higher in yield and averages 22.9 bushels per acre. Since in one rotation the wheat follows alfalfa and the other rotation consists only of corn and wheat, the difference between the two yields would be the effect of alfalfa on the yield of wheat. Thus alfalfa increases the yield of wheat 16.2 bushels per acre.

The per cent of grain in the two rotations varies in the opposite manner as does the yield. This would be expected in that a high-yielding plat of wheat usually has more straw and culms and is also taller than one that yields much less. The per cents of grain are given in Table XXXII.

In every case except in 1927, the per cent of grain is higher in rotation 13 than it is in rotation 42. In rotation 13 the total weight of the plat consists of about one-half grain and one-half straw. In rotation 42 the total weight of the plat consists of about three-eighths grain and five-eighths straw. It thus seems from the table that if the yield decreases there is an increase in the per cent of grain in the plat.

Table XXXII. The Per Cent of Grain in the Wheat Plats in Rotations 13 and 42, 1923 to 1929

Rotation No.	1923	1924	1925	1926	1927	1928	1929	Average	
13	43.3	40.0	63.3	43.7	45.7	52.7	46.4	47.9	± 2.0
42	36.7	37.9	33.4	35.3	49.3	40.5	29.2	37.5	± 1.5
Average . .	40.0	39.0	48.4	39.5	47.5	46.6	37.8	42.7	± 1.4

PASTURING ALFALFA WITH HOGS

The practice of hogging off alfalfa in this section is one that seems to be very profitable during certain years Often, however, a lower net return per acre is obtained in this manner than if the alfalfa had been grown for its hay. There are not many farmers in this area that pasture their alfalfa with hogs. This may be due to the difficulty in obtaining young pigs in the early spring months when hog pasturing is usually started.

Two rotations are devoted to the experiment of hogging off alfalfa, namely, rotations 61 and 63. In rotation 61, the third year of alfalfa is hogged off. In this rotation, the experiment may continue through the summer months as no crop is grown on the hogged off alfalfa plat until the following spring. The fourth year of alfalfa is pastured to hogs in rotation 63. Here the experiment must be closed by the latter part of June as this plat is then plowed and planted to corn.

In comparing rotations 61 and 63 as to the length of time the alfalfa is pastured, it will be found that during many years the hogs are removed from both of these plats at about the same time. This is due to the fact that often-

times the third and fourth year of alfalfa has a poor stand. This allows an unusual amount of Bermuda grass to get started and also causes the alfalfa plants to be eaten very closely to the ground. A combination of these two factors tends to slow up the growth and often kill some of the alfalfa plants. For this reason hogs in rotation 61 are sometimes removed in early summer.

On the average there are about five hogs in each rotation each year. In addition to the alfalfa obtained the hogs receive a grain ration which consists of 2 per cent of their live weight. This grain consists of ground milo. Weighings of the hogs are made at two-week intervals and the amount of grain to be fed is calculated from the last weighing. Water is supplied at all times by driving a pipe to water and attaching a pump.

A summary of results obtained by hogging off the third year of alfalfa in rotation 61 is given in Table XXXIII. A loss in the net return per acre was noted in the first year, or 1923, and the last year, or 1929. During the entire seven years, however, an average net return per acre of $28.88 was obtained. In 1925 and 1926 the pasturing period has been divided into the spring period and the summer period. The spring period ends at the time the hogs are removed in rotation 63. In each case it will be noted

Table XXXIII. A Summary of the Results Obtained by Pasturing Hogs in Rotation 61

	1923	1924	1925 Spring Period	1925 Summer Period	1925 Average	1926 Spring Period	1926 Summer Period	1926 Average	1927	1928	1929	Average
Crop	Alfalfa	Alfalfa	Alfalfa	Alfalfa	Alfalfa	Alfalfa	Alfalfa	Alfalfa	Alfalfa	Alfalfa	Alfalfa	Alfalfa
Area of plat	¼ acre	¼ acre	¼ acre	¼ acre	¼ acre	¼ acre	¼ acre	¼ acre	¼ acre	¼ acre	¼ acre	¼ acre
Test began	July 13	March 13	March 3	June 27	- - - -	March 13	June 26	- - -	March 22	April 16	March 1	- - - -
Test closed	Sept.14	July 14	June 27	Oct.14	- - - -	June 12	August 28	- - -	June 30	August 15	June 8	- - - -
Number of days	63	123	116	109	112.5	91	31	77	101	121	100	100
Number of hogs	5	5	4	4	4	6	5	6	5	5	6	5
Ration	2 per cent grain	2 per cent grain	2 per cent grain	2 per cent grain	2 per cent grain	2 per cent grain	2 per cent grain	2 per cent grain	2 per cent grain	2 per cent grain	2 per cent grain	2percent grain
Total initial weight,Lbs.	345	250	245	473	359	461	345	403	169	230	430	312
Total final weight,Lbs.	460	806	786	940	863	835	473	654	464	475	608	619
Total gain, Lbs.	115	556	541	467	504	374	128	251	295	245	178	306
Ave.initial weight, Lbs.	69	50	61	118	89.5	77	69	73	33.8	46.0	71.7	62
Ave.final weight,Lbs.	92	161	196	235	215.5	139	95	117	92.8	95.0	101.3	125
Ave.gain per hog, Lbs.	23	111	135	117	126	62	26	44	59	49	29.3	63
Ave.daily gain, Lbs.	0.365	0.902	1.164	1.073	1.119	0.681	0.413	0.547	0.58	0.40	0.29	0.60
Grain consumed, Lbs.	504	1,298	1,195	1,540	1,368	1,308	506	907	578	960	948	938
Grain per 100 Lbs. gain	436.2	233.4	220.8	329.8	275.3	349.7	395.0	372.3	195.9	391.9	532.6	348.2
Pork produced per acre	460	2,224	2,164	1,868	2,016	1,496	512	1,004	1,180	980	712	1,225
Net return per acre	-$4.40	$92.60	$96.90	$32.80	$64.85	$ 18.80	$ 0.60	$ 9.70	$ 60.20	$ 2.00	-$23.60	$28.77

that the net returns are greater in the spring period than in the summer period. Even at this, hogging off alfalfa in the summer months seems to be profitable, especially in 1925 when $32.80 was obtained as the net returns per acre. If all hogging off experiments should be as profitable as they were in 1924 and 1925 a large portion of the alfalfa in this region would probably be treated in this manner.

In calculating the net returns per acre the grain fed was charged at the rate of 2.5 cents per pound. The pork produced was figured at $0.10 per pound.

The results obtained by hogging off the fourth year of alfalfa in rotation 63 are summarized in Table XXXIV. The average length of the experiment in this rotation is 93 days, or only seven days less than in rotation 61. Yet the average net return per acre is over $10 higher in rotation 63 than it is in rotation 61. A financial loss in rotation 63 was obtained in 1923 and 1927. The highest return per acre was in 1924 when a sum of $119.20 was netted by the hogs. The average daily gain in rotation 63 is 0.76 pounds while in rotation 61 it is 0.60 pounds. The average total initial weight of the hogs in rotation 63 is higher than it is in rotation 61. It does not seem, however, that this would cause the higher net return in rotation 63. The amount

Table XXXIV. A Summary of the Results Obtained by Pasturing Hogs in Rotation 63

	1923	1924	1925	1926	1927	1928	1929	Average
Crop	Alfalfa	Alfalfa	Alfalfa	Alfalfa	Alfalfa	Alfalfa	Alfalfa	Alfalfa
Area of plat	¼ acre	¼ acre	¼ acre	¼ acre	¼ acre	¼ acre	¼ acre	¼ acre
Test began	Apr.5	Mar.15	Mar. 3	Mar.13	Mar.22	Apr.16	Mar.1	- - - -
Test closed	July 11	June 14	June 27	June 12	June 30	June 13	June 8	- - - -
Number of days	97	91	116	91	101	57	100	93
Number of hogs	6	5	4	5	5	5	5	5
Ration	2 per cent grain	2 per cent grain	2 per cent grain	2 per cent grain	2 per cent grain	2 per cent grain	2 per cent grain	2 per cent grain
Total initial weight,Lbs.	615	290	245	441	432	270	165	351
Total final weight,Lbs.	908	845	786	806	691	470	386	699
Total gain, Lbs.	293	555	541	365	259	200	221	348
Ave.initial weight,Lbs.	103	58	61	88.2	86.4	54	33	70
Ave.final weight,Lbs.	152	169	196	161.2	138.2	94	77.2	141
Ave.gain per hog,Lbs.	49	111	135	73	51.8	40	44.2	72
Ave.daily gain,Lbs.	0.505	1.220	1.164	0.802	0.51	0.70	0.44	0.76
Grain consumed,Lbs.	1,177	1,028	1,195	1,148	1,116	570	751	998
Grain per 100 Lbs.gain	401.7	185.2	220.9	314.5	430.9	285	339.8	311.1
Pork produced per acre	1,172	2,220	2,164	1,460	1,036	800	881	1,390
Net return per acre	$ 0.12	$119.20	$ 96.90	$ 31.20	$ 8.00	$ 23.00	$ 13.00	$ 39.31

of grain fed per 100 pounds gain is 348.2 pounds in rotation 61 and 311.1 pounds in rotation 63.

In comparing these two hog pasturing experiments it seems that rotation 63 is more desirable. It produces a larger average net return per acre in one-half a year than rotation 61 does in the entire year. The results in rotation 61 seem to show that summer pasturing is not as profitable as spring pasturing. It thus seems that hog pasturing the fourth year of alfalfa in rotation 63 until the latter part of June and then plowing the land and planting corn that a still larger net return for that year would be received.

It has previously been mentioned that alfalfa enters into a somewhat dormant condition during the summer months. This fact alone should be enough to discourage hogging off alfalfa in the summer period. The problem of intense summer heat is often rather serious, but usually no damage results if abundant water and shade are provided.

Fig. 18. The Fourth Year of Alfalfa is Pastured to Hogs in Rotation 63

SUMMARY AND CONCLUSIONS

1. Alfalfa is the basis of most of the better organized rotations. As the average yield of alfalfa increases there is a tendency for the average yield of the following crop to increase.

2. Three-hundred pounds of superphosphate per acre on alternate odd years increased the yields of alfalfa by 87.8 per cent. Twelve tons of manure every other year caused this increase in yield to be 219 per cent. The superphosphate seems to be used up by the alfalfa much more rapidly than the manure.

3. The average yield of alfalfa decreases as the length of the rotation system increases.

4. Cotton yields on the average of 100 pounds per acre more following alfalfa than following one grain crop after alfalfa. When two grain crops intervene between the alfalfa and cotton a still greater decrease in the yield of cotton is found.

5. Twelve tons of manure every other year has increased the average yield of cotton by 87 per cent. Green manures increase the yields of cotton but slightly.

6. There is a common opinion that grain sorghum injures the succeeding crop. From the rotations discussed it has been noted that when barley followed grain sorghum the yield of barley did not seem to be affected. However, when cotton was grown after the grain sorghum the yield of cotton showed considerable decrease. It will be remembered that barley is planted immediately following grain sorghum while the cotton is planted from four to five months after the grain sorghum has been harvested. It thus seems that crops immediately following grain sorghum are not injured while crops planted for a longer period after the grain sorghum are injured.

7. Sweet clover, cowpeas, and vetch stand in this order in increasing the yields of grain sorghum. Sweet clover as a green manure was equal to alfalfa for grain sorghum.

8. The yields of barley have been on the decline with the highest yields and least declines found where the barley immediately follows the alfalfa.

9. The practice of hogging off the third and fourth years of alfalfa is often more profitable than if the alfalfa had been allowed to produce hay.

ACKNOWLEDGMENT

The author wishes to express his sincere appreciation and thanks to Dr. F. L. Duley, Professor of Soils at the Kansas State Agricultural College, Manhattan, for his most helpful suggestions and criticisms concerning the thesis.

To Mr. E. G. Noble, Superintendent of the United States Yuma Field Station, Bard, California, is due much praise for permitting me to use the results of the rotation experiments which he has supervised during the period, 1923 to 1929.

LITERATURE CITED

Aune, Beyer
1927. Work of the Belle Fourche Field Station in 1923, 1924, and 1925. U.S.D.A. Dept. Circ. 417.

Breazeale, J. F.
1926. A Study of the Colorado River Silt. Univ. of Ariz. Tech.Bul.No.8.

Creighton, D. E.
1930. Rotate it Right -- If You Don't, Milo Hurts Its Successor. Los Angeles Times (Farm and Orchard),Jan.19,1930

Forbes, R. H.
1902. River Irrigating Waters of Arizona, Their Character and Effects. Univ. of Ariz. Agr.Expt.Sta.Bul. 44.

Hansen, Dan
1926. Growing Corn on Irrigated Land. Univ. of Mont. Agr.Expt.Sta.Bul.193.

Hastings, Stephen H. and Hansen, Dan
1929. Irrigated Crop Rotations in Southern Montana. U.S.D.A. Tech.Bul. 144.

Holden, James A.
1923. Crop Rotation Under Irrigation. Univ. of Nebr. Agr.Expt.Sta. Bul.190.

Knight, E. W.
1929. Work of the Newlands Field Station, Nevada, 1924 to 1927. U.S.D.A. Circ. 69.

Merriman, Mansfield
1913. Method of Least Squares. Edition 8, New York, p.223.

Pittman, D. W.
1924. Maintaining the Productivity of Irrigated Land.
Utah Agr.Expt.Sta. Bul.188.

Savage, D. A. and Powers, LeRoy
1928. Experiments with Sugar Beets.
Univ. of Mont. Agr,Expt.Sta. Bul.215.

Scofield, C. S.
1918. Effect of Farm Manure in Stimulating the Yields of Irrigated Crops.
Jour. Agr. Res., 15: 493-504.

Scofield, C. S.
1920. The Effect of Alfalfa on the Subsequent Yields of Irrigated Field Crops.
U.S.D.A. Bul. 881.

Westover, H. L. and Noble, Edward G.
1926. Fertilizer Experiments with Alfalfa Conducted at the United States Yuma Field Station, Bard, California, 1919 to 1925.
U.S.D.A. Dept.Bul.1418.