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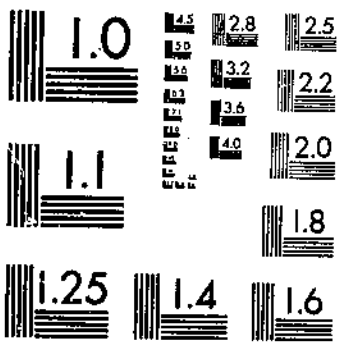

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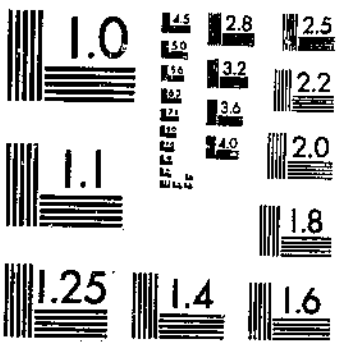

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IRRIGATED CROP ROTATIONS IN WESTERN NEBRASKA, 1912–34

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INTRODUCTION

Crop production under irrigation is not subjected to the losses incurred as a result of periodical droughts often encountered even in the eastern United States. However, in eliminating this hazard by developing an assured water supply, the irrigation farmer assumes increased responsibilities. Not only are costly structures required for impounding water, or approximately equivalent investments necessary for otherwise developing a water supply, but other expenses are involved, including the operation and maintenance of the system as well as preparation of the land and application of the water—all of which are substantial items in the cost of crop production. Hence it is evident that while the possibilities of insuring returns are greater where the hazards of drought are eliminated, the financial risks are somewhat increased. Furthermore, it must be recognized that in a large measure the crops produced under irrigation come into direct competition with those generally grown throughout the country. It is evident, then, that if a successful irrigated agriculture is to continue, the yields harvested from these lands must be larger than those of ordinary farming in order to absorb these increased fixed costs of irrigation.

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It is becoming increasingly apparent that maintaining crop yields under irrigated conditions is dependent chiefly upon the following four factors: (1) The relation of the quality of the water supplies and the character of the soil solution as influenced by the irrigation water applied; (2) injuries sustained due to plant diseases and insect pests; (3) knowledge as to adaptable crops and varieties which will best meet the existing economic, soil, and climatic conditions of the region; and (4) recognition of the importance of various crop sequences on the yields of subsequent crop yields, as well as the extent to which yields are stimulated by such soil-improvement crops as sweetclover and alfalfa as compared with fertilizers or farm manure. Factors 3 and 4 are essentially agronomic, and the work of the field stations operated by this Division has been centered on these problems.

Like previous publications (*4*, *8*) [1] on the same subject, this bulletin is devoted to a presentation of the results of a comprehensive series of rotation experiments conducted at the Scotts Bluff (Nebr.) Field Station. In view of the fact that the results cover a 23-year period extending from 1912 to 1934, they make a substantial contribution to the knowledge of the crops and rotational practices best adapted to maintain or increase crop yields, so that even when relatively low prices exist, as in the past few years, the better farm practices have given profitable returns.

LOCATION AND SOIL CONDITIONS

The irrigated area here considered is located in western Nebraska and eastern Wyoming and includes some 375,000 acres in the North Platte reclamation project and adjacent areas lying along the North Platte River, extending some 20 miles into Wyoming and some 60 miles eastward from the Wyoming-Nebraska State line. The water supply is obtained from the natural flow of the North Platte River, supplemented by storage in the Pathfinder and Guernsey Reservoirs. As the water comes from the high mountains of Colorado, the result of rains and melting snow, its salt content is low.

The irrigated area has an elevation of approximately 4,000 feet above sea level and is located on the western edge of the region where farming without irrigation is practicable. The local precipitation is slightly more than 14 inches, most of which falls during the summer months, April to September. The rainfall is decidedly variable and much of it occurs in the form of light local showers; in such instances it is of little agricultural significance and irrigation is required if good crop yields are to be harvested. Hailstorms occur occasionally. The average frost-free period at the field station for the past 24 years has been 133 days.

The more important crops of the area are forage crops, alfalfa predominating, sugar beets, potatoes, small grains, and corn. Dairying is also an important farm enterprise. As the North Platte project is surrounded by extensive ranges, most of the surplus forage and grain crops produced on the project are utilized by dairy herds and in the fattening of lambs and to a lesser extent beef cattle. However, the most important cash crops grown in the area are sugar beets and potatoes. As this condition has existed for many years, the problem of maintaining the yields of these crops has continually

[1] Italic numbers in parentheses refer to Literature Cited, p. 36.

confronted growers. While farm manure has been available on many farms, the amount has been far short of the requirements needed to maintain the productivity of the soil. Therefore, farmers have had to resort to such rotational practices as are conducive to maintaining the yields of sugar beets and potatoes.

The chief soils of the project range from a sandy loam to loamy fine sand, with the Mitchell, a very fine sandy loam, predominating (*9*). The project is notably free from heavier soil types characteristic of many irrigated areas throughout the West. The land is relatively productive and responds readily and favorably to good cultural practices, such as well planned rotations and applications of farm manure. Aside from the lowlands bordering the North Platte River, the agricultural lands mostly have natural and effective drainage. The soil where these investigations were conducted has been classed as Tripp very fine sandy loam, typical of the extensive areas of terraces lying north of the North Platte River. Soils of this type are among the more productive found on the project.

The Scotts Bluff Field Station was established in 1910 on a tract of land which had not previously been cultivated. The native veg-

FIGURE 1.—A view of some of the plots in the irrigated rotations at the Scotts Bluff Field Station.

etation consisted of herbaceous plants, chiefly grasses. The land devoted to these irrigated rotations was broken up in the fall of 1910 and seeded to oats in the spring of 1911. In the fall of that year the field was laid out in 5 series of plots, each comprising one-fourth acre. In each series there are 18 plots, or a total of 90 in the 5 series. The plots are separated by 5-foot alleys, except that a 20-foot crossroad occurs between plots 5 and 6 and a 30-foot crossroad between plots 11 and 12 across the 5 series. The series are numbered I to V from west to east, and the plots are numbered 1 to 18 from north to south. Prior to 1920 plots 2 to 11 in series V were not used for rotation experiments, but in that year a new 4-year rotation, no. 45, was started on plots 2 to 5 of that series, and a new 6-year rotation was started on plots 6 to 11. In 1920 a 7-year rotation also was begun on 7 plots at the south end of a series adjoining series I on the west. These plots were designated series O, and the plots in the new rotation, no. 71, are numbered 12 to 18, inclusive. A partial view of several of the plots is shown in figure 1, looking to the southeast with series I in the foreground.

The rotation experiments conducted at the station are similar in scope and character to those included at this same time as a part of the investigational program in effect at the Belle Fourche Field Station near Newell, S. Dak., and at the Huntley Field Station near Huntley, Mont.,[2] which have been the subject of former publications (*1*, *2*, *3*, *5*, *6*, *7*).

PLAN OF THE ROTATIONS

The rotation experiments were planned to ascertain the effect on crop yields of: (1) Growing crops in 2-year and 3-year rotations as compared with growing the same crops continuously on the same land; (2) applying farm manure once during the cycle of these 2- and 3-year rotations, comparison being made with similar rotations in which manure is not used; and (3) incorporating alfalfa as a crop in the rotation, comparison being made with similar 2- and 3-year rotations not including alfalfa.

In addition to these major questions, which constituted the chief aim of the rotation experiments, information was sought on the following points: (1) The yields of winter wheat as compared with spring wheat, both of which may be grown in the area; (2) the effect on the yields of spring wheat grown continuously, and returning to the land each year the straw produced with a view to maintaining the supply of organic matter in the soil; (3) the effect of rye plowed under for green manure on the yields of potatoes and oats grown as a 2-year rotation in comparison with the yields from a similar rotation without this treatment; (4) the influence on subsequent crop yields of applying farm manure to rotations including alfalfa, as well as the comparative merits of alfalfa and sweetclover, the latter crop being harvested by livestock; and (5) in 6-year alfalfa rotation no. 65 the third year of alfalfa is harvested with hogs as well as the following crop of corn.

The following crops were included in the original series of rotations started in 1912: No. 1, oats; no. 2, sugar beets; no. 3, spring wheat; no. 4, potatoes; no. 5, winter wheat; no. 6, corn; no. 7, spring wheat (straw returned); no. 8, alfalfa; no. 9, flax. Each of these crops has been grown continuously on the same plot every year since 1912.

The following is a list of the 2-year and 3-year rotations in which the crops were grown in various combinations: No. 16, corn, oats; no. 18, spring wheat, sugar beets; no. 20, sugar beets, potatoes; no. 22, oats, sugar beets; no. 24, oats, potatoes; no. 26, potatoes, corn; no. 28, spring wheat, oats; no. 30, potatoes, oats, sugar beets; no. 32, corn, oats, sugar beets.

The following 2-year and 3-year rotations had farm manure applied in the sequence here indicated at the rate of 12 tons per acre: No. 21, sugar beets, manure, potatoes; no. 23, oats, manure, sugar beets; no. 25, oats, manure, potatoes; no. 31, potatoes, oats, manure, sugar beets.

In the following rotations alfalfa was grown for the period and in the sequence indicated: No. 40, alfalfa (2 years), potatoes, sugar

[2] These rotation experiments were planned and put into effect by C. S. Scofield, agriculturist in charge of the Division of Western Irrigation Agriculture, in collaboration with F. D. Farrell. The supervision of the field work and the preparation of the detailed reports, upon which this bulletin is based, were under the direction of Fritz Knorr from 1912 to 1917. The late James A. Holden succeeded as superintendent of the station and acted in that capacity until his death in December 1934.

beets; no. 42, alfalfa (2 years), oats, sugar beets; no. 44, alfalfa (2 years), potatoes, oats; no. 48, alfalfa (2 years), spring wheat, oats; no. 60, alfalfa (3 years), potatoes, oats, sugar beets; no. 62, alfalfa (3 years), corn, oats, sugar beets. In addition to the foregoing, one rotation included both manure and alfalfa, no. 61, alfalfa (3 years), potatoes, oats (manure), sugar beets.

The following include the subordinate rotations: No. 7, spring wheat grown continuously on the same land, with the straw returned, to compare with rotation no. 3; no. 27, oats, rye plowed under, potatoes, to compare with no. 24; no. 65, alfalfa (3 years, pastured with hogs the third year), corn (harvested by hogs), flax, oats.

The preceding list of rotations include those that were started in 1912. In 1920 three additional rotations were begun, as follows: No. 45, oats, sweetclover, sugar beets, sugar beets (the sweetclover seeded with the oats and pastured with sheep); no. 64, oats, alfalfa (3 years), potatoes, sugar beets; no. 71, oats, alfalfa (3 years), potatoes, sugar beets, manure, sugar beets. The purpose of rotation no. 45 is to determine the possibility of keeping up the yields of sugar beets in a short rotation through the use of sweetclover which is pastured. This rotation is not directly comparable to any other in the series; it is rather to be grouped with the subordinate rotations nos. 27 and 65. Rotation no. 64 may be compared with rotation no. 30, though it differs from the latter in two respects, namely, it includes 3 years of alfalfa and the sequence of other crops is not the same. In rotation no. 30, the sequence is potatoes, oats, sugar beets; whereas in rotation no. 64 it is potatoes, sugar beets, oats. This rotation may be compared also with rotation no. 60, from which it differs in one respect, namely, in the sequence of crops other than alfalfa. Rotation no. 71 is comparable with rotation no. 64, from which it differs in having two consecutive crops of sugar beets between the potatoes and oats, with manure applied to the second-year sugar beets.

In these rotation experiments each crop involved in each rotation is grown every year. This requires that as many plots shall be devoted to each rotation as there are years in the cycle of each rotation. By this procedure it becomes possible to compare the yields each year from the same crops grown in the different rotations.

LIST OF THE ROTATIONS

The following is a list of the rotations arranged in numerical order for convenience of reference:

Crops grown continuously on the same plots

1. Oats.
2. Sugar beets.
3. Spring wheat.
4. Potatoes.
5. Winter wheat.
6. Corn.
7. Spring wheat (straw returned).
8. Alfalfa.
9. Flax.

2-year rotations

16. Corn, oats.
18. Spring wheat, sugar beets.
20. Sugar beets, potatoes.
21. Sugar beets (manure), potatoes.
22. Oats, sugar beets.
23. Oats (manure), sugar beets.
24. Oats, potatoes.
25. Oats (manure), potatoes.
26. Potatoes, corn.
27. Oats (followed by rye plowed under), potatoes.
28. Spring wheat, oats.

3-year rotations

30. Potatoes, oats, sugar beets.
31. Potatoes, oats (manure), sugar beets.
32. Corn, oats, sugar beets.

4-year rotations

40. Alfalfa (2 years), potatoes, sugar beets.
42. Alfalfa (2 years), oats, sugar beets.
44. Alfalfa (2 years), potatoes, oats.
45. Oats seeded with sweetclover (sweetclover being pastured with sheep), sugar beets (2 years).
48. Alfalfa (2 years), spring wheat, oats.

6-year rotations

60. Alfalfa (3 years), potatoes, oats, sugar beets.
61. Alfalfa (3 years), potatoes, oats (manure), sugar beets.
62. Alfalfa (3 years), corn, oats, sugar beets.
64. Alfalfa (3 years), potatoes, sugar beets, oats.
65. Alfalfa (3 years, pastured with hogs the third year),* corn (harvested by hogs), flax, oats.

7-year rotation

71. Alfalfa (3 years), potatoes, sugar beets (manure), sugar beets, oats.

The location of these rotations with reference to one another in the field is shown in figure 2.

CULTURAL PRACTICES

In conducting these investigations the methods adopted in performing the various cultural operations were in keeping with the better practices used in the locality. In order that the yields from the same crop in different rotations would be directly comparable, all were planted as nearly as possible at the same time and of the same variety each year. The treatment the plots received was as nearly identical as conditions permitted; all crops were harvested at the same time and otherwise received the same treatment insofar as conditions permitted.

Irrigation water was applied so as to meet adequately the varying demands of different crops, the aim being to maintain the supply of soil moisture at the optimum for plant growth. Alfalfa, grain, flax, and other drilled or broadcast crops were irrigated by the flooding method, while row crops were furrow irrigated.

In the rotations where alfalfa followed sugar beets the seed was sown in the spring without a nurse crop, after the land had been disked and harrowed. In the rotations where the alfalfa followed oats the seed was sown with a disk drill in the oat stubble immediately after harvest. Except in years when grasshoppers were numerous or excessive weed growth interfered, this method of seeding has given good results. When grasshopper or other injuries have been severe it has been necessary to plow the oat stubble in the early fall or the following spring and to reseed the alfalfa. At times these unfavorable conditions have occurred throughout the period, which accounts for no first-year alfalfa yields being given in certain instances. In the new rotations, nos. 64 and 71, alfalfa was seeded in the spring with oats as a nurse crop. During the first years of this experiment alfalfa sod was broken by a shallow plowing in the fall, followed by disking and deeper plowing the following spring. In recent years it has been broken by plowing to a depth of about 8 inches after growth starts in the spring.

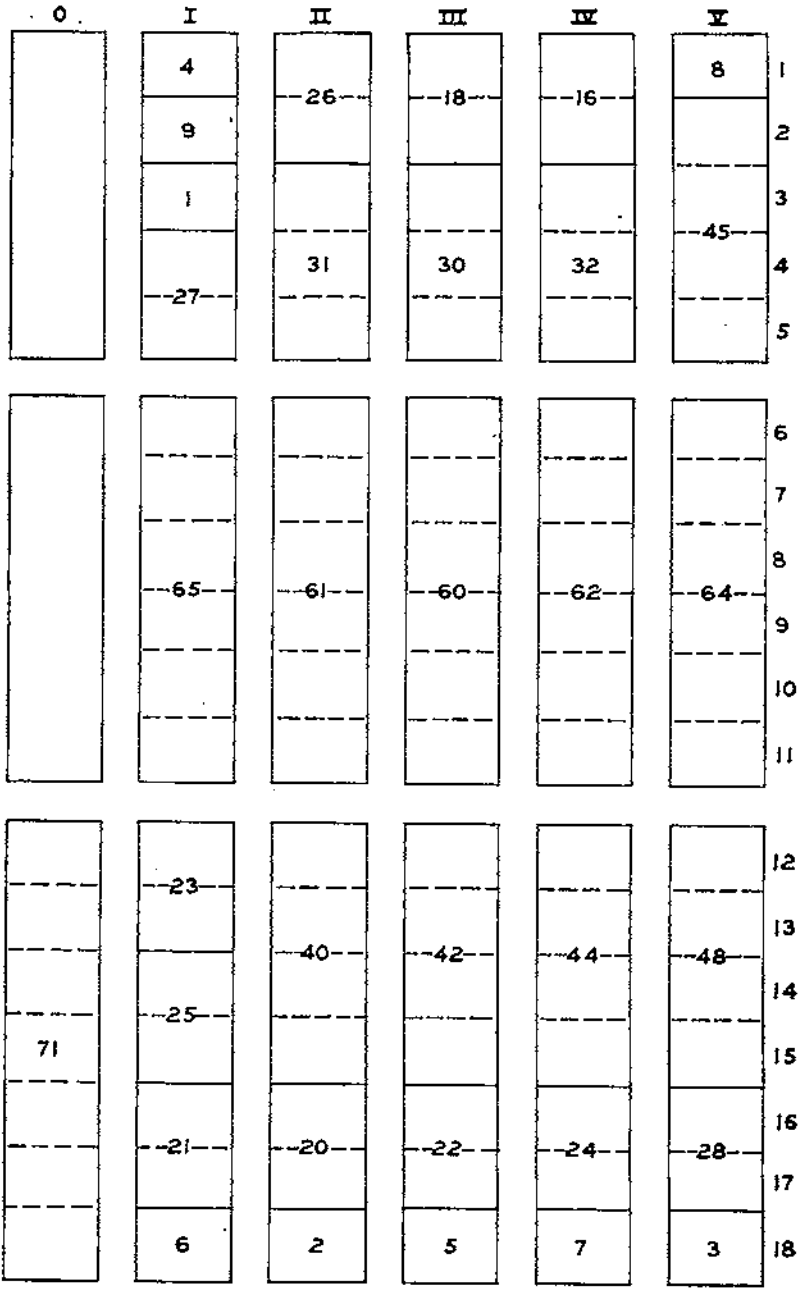

FIGURE 2.—Diagram showing the field location of the irrigated rotations at the Scotts Bluff Field Station.

Sugar beets were seeded on fall-plowed land where the crop followed small grain and on spring-disked land where this crop followed potatoes or beets. Seed of the Kleinwansleben variety was used and was obtained from the local sugar company. The crop was cultivated, thinned, and harvested according to local farm practice.

Where oats followed sugar beets, corn, or potatoes, the land was disked in the spring before seeding. When the preceding crop was small grain or flax, the land was plowed the previous autumn and disked in the spring. When oats followed alfalfa the land was plowed in the spring, just before seeding. A variety of oats known as Colorado No. 13 (Newmarket) was used from 1912 to 1927, and the Kherson (Nebraska No. 21) variety has since been grown.

Spring wheat was sown on fall-plowed land except in rotations nos. 18 and 48. In rotation no. 18 the preceding crop was sugar beets. In this rotation the plot to be sown to wheat was disked in the spring just before seeding. In rotation no. 48, the preceding crop being alfalfa, the land was plowed in the spring. The College Defiance variety was used from 1912 to 1919; the Galgalos variety from 1920 to 1922, and the Marquis variety from 1923 to 1934. The plot used for winter wheat was plowed and harrowed about a week before seeding time. The Turkey variety has been used continuously.

The plots to be used for potatoes were fall-plowed for rotations nos. 24 and 25 and spring-plowed for the others. In rotation no. 27, where the preceding crop was oats followed by rye, the rye was seeded in the oat stubble soon after harvest and plowed under the following spring. The White Pearl variety of potatoes was used from 1912 to 1918, the Downing in 1919, and the Bliss Triumph since. The plots devoted to corn were all spring-plowed. A local variety of Calico corn was used from 1912 to 1921 and a local yellow variety from 1922 to 1934.

CROP YIELDS IN DETAIL

The results from these rotation experiments from 1912 to 1925 were the subject of a publication in which the yields were given in detail for the 14 years (*8*). In the following tables only the mean yields are given for the period from 1912 to 1925, and the annual yields of sugar beets, oats, potatoes, corn, wheat, and alfalfa are included in detail from 1926 to 1934. Hence the annual yields for the entire 23 years are made available for comparison in this and the former publication, affording an opportunity to compare in a number of ways the effects of the different crop sequences and treatments to which the crops under consideration have been subjected. It also permits the reader to observe the annual fluctuations in yields and yield trends as influenced by the different treatments.

Substantial fluctuations in yields are to be expected in crop experiments of this nature, involving several crops and covering a long period of years. These fluctuations occur not only from year to year, chiefly because of the vicissitudes of the climate, but also within the same year due to accidental crop injuries. The extent to which climatic conditions have influenced crop growth is well shown by observing the yearly mean yields for the different crops. In a large measure the influence of the climate on the yields has been minimized by ascertaining the yield departures of each rotation and computing these mean departures by 7-year periods in the

tables giving the summarized results. Where accidental injuries have occurred they have been absorbed largely by averaging several units, so that the results recorded in the summary tables are believed to reflect the normal differences which should be expected under average irrigated farm conditions in the Scotts Bluff area.

OATS

The yields of oats are given in detail in table 1, also the mean from 1926 to 1934, together with the mean for the period from 1912 to 1925. The annual means have also been computed, and of the 21 rotations those returning the highest and lowest yields are indicated. For the last 9 years no complete crop failures have occurred, although extremely low yields were harvested in 1934. This was due chiefly to a shortage of irrigation water which existed throughout the growing season of that year. Also, relatively low yields were harvested in 1926 and again in 1931, largely due to unfavorable climatic conditions while the oat crop was maturing.

TABLE 1.—*Yields of oats from the irrigated rotations at the Scotts Bluff Field Station, 1912–34*

Rotation no.	Acre yields (bushels)										
	Mean, 1912–25	1926	1927	1928	1929	1930	1931	1932	1933	1934	Mean, 1926–34
1	46.0	15.5	37.7	37.1	26.3	22.0	16.4	34.5	27.1	4.8	24.7
16	48.1	9.0	23.9	36.0	23.4	20.5	22.5	43.6	27.6	14.1	24.5
22	54.1	14.3	30.6	46.2	29.0	20.1	21.6	35.5	22.5	17.4	27.4
23	65.1	38.4	09.6	86.2	78.4	44.0	40.8	73.9	57.5	5.6	54.0
24	55.3	8.5	23.4	42.6	38.0	17.0	17.5	27.1	26.9	15.5	24.2
25	62.7	20.0	70.9	84.5	74.0	35.5	36.0	59.8	48.6	14.4	50.3
27	62.3	14.3	30.8	66.2	37.8	22.7	14.5	40.4	34.3	7.3	30.8
28	44.3	8.3	22.1	34.5	23.8	12.1	14.3	24.8	18.3	4.4	18.7
30	59.0	13.4	28.9	47.4	31.0	19.9	18.1	45.3	24.9	17.1	27.3
31	73.4	30.6	56.4	84.4	60.5	49.6	42.5	78.3	51.0	18.1	52.4
32	46.9	11.4	31.5	25.2	19.0	20.9	21.5	40.8	23.6	22.5	24.0
42	69.7	68.1	77.0	79.2	92.0	70.5	24.9	63.3	57.1	13.0	60.6
44	72.2	48.9	82.1	91.9	77.0	74.9	39.1	70.9	55.0	32.9	63.0
45	[1] 56.3	41.0	61.2	72.2	64.6	51.1	35.8	53.4	42.4	16.4	48.7
48	67.5	38.4	68.2	87.4	72.6	51.1	25.8	74.3	60.1	17.0	55.0
60	71.5	51.0	79.6	104.8	87.0	65.8	35.0	75.3	53.4	18.6	63.4
61	75.9	69.5	99.0	108.0	89.4	70.1	34.1	87.3	60.0	20.0	70.9
62	63.7	50.5	82.6	86.8	87.5	63.6	36.0	69.3	51.6	18.3	60.7
64	[1] 67.9	65.3	89.5	78.8	63.2	63.3	20.9	61.1	49.5	16.9	57.5
65	72.7	35.1	89.0	95.0	80.0	53.9	24.0	81.0	58.0	6.4	58.0
71	[1] 64.3	64.5	107.1	90.5	90.0	51.1	40.6	75.4	73.0	16.1	69.3
Annual mean	61.9	34.5	60.5	70.8	60.8	42.9	28.6	58.3	44.0	15.0	46.0
Rotations returning highest yield	31	61	71	61	71	44	71	61	71	44	61
Rotations returning lowest yield	28	28	28	32	32	28	28	28	28	28	28

[1] Mean, 1920–25.

For the 9 years for which detailed yields are given, rotation no. 44 has returned the highest yields twice, no. 61 three times, and no. 71 four times out of the nine seasons. Of those rotations returning the lowest yields, rotation no. 32 appeared twice and no. 28 the other seven times. This latter is a 2-year spring wheat-oats cropping system, which is a highly undesirable practice, due in a large measure to excessive weed growth. These results indicate that for the first 14-year period as well as for the last 9-year period the most consistent high yields have been harvested from manured rotation no. 61.

There is afforded a direct comparison of the effect on the yields of oats of applications of farm manure as compared with alfalfa in rotations nos. 23 manured and 42, which has 2 years of alfalfa. For the last 9 years no. 42 has outyielded no. 23 by 5.6 bushels per acre. The same comparison may be made with rotation no. 31 as compared with no. 60, the latter outyielding the former for the same 9-year period by 11 bushels of oats per acre. It is apparent from these results that applications of farm manure have not stimulated the yields of oats to the extent that alfalfa has.

When the annual mean yields for the first 14-year period, 1912–25, are compared with the subsequent 9-year period it will be found that there is a difference in yield in favor of the former of 15.9 bushels per acre. Hence it appears there has been a general decline of productivity of the plots as a whole. Reference to the yields recorded in a former publication (*8*) indicates that the land was in a favorable condition for producing uniformly high yields during the early years. For the first 3 years, 1912 to 1914, the mean annual yield was 85.5 bushels per acre—a mean annual production not since equaled. In view of this relatively high productivity of the land when these experiments were initiated, it is to be expected that the mean annual yields would tend to decline, as a substantial number of the practices have proved to have an adverse effect on the yields of oats.

SUGAR BEETS

The acre yields of sugar beets are given in table 2, as this crop appears in 17 rotations. As has occurred with oats, the mean annual sugar-beet yields of 1934 were the lowest recorded for 23 years, chiefly due to a shortage of irrigation water.

TABLE 2.—*Yields of sugar beets from the irrigated rotations at the Scotts Bluff Field Station, 1912–34*

Rotation no	Acre yields (tons)										
	Mean, 1912–25	1926	1927	1928	1929	1930	1931	1932	1933	1934	Mean, 1926–34
2	9.3	6.4	5.9	8.8	6.7	6.8	4.5	6.4	4.1	2.7	5.8
18	11.6	7.8	8.6	9.0	9.3	9.2	7.1	7.8	8.0	4.3	7.9
20	11.9	8.6	8.4	10.5	9.7	8.9	7.2	9.0	6.4	4.1	7.9
21	16.4	16.0	14.3	20.6	19.3	18.3	14.8	15.0	15.8	11.1	16.2
22	11.3	7.9	9.8	9.0	9.3	11.0	5.0	7.1	8.3	4.1	8.1
23	18.2	17.0	17.9	21.5	19.9	21.4	17.5	15.6	17.7	13.0	18.0
30	11.7	9.6	9.1	10.1	7.8	9.5	5.5	8.4	7.2	5.1	8.0
31	17.9	17.6	15.9	21.5	18.1	18.4	16.1	19.5	17.7	12.1	17.4
32	11.3	10.2	8.4	10.2	9.1	10.6	6.8	8.5	6.2	5.0	8.4
40	18.0	16.8	13.9	13.0	11.7	19.1	15.8	14.2	12.4	10.4	14.1
42	15.0	15.0	16.4	15.3	14.3	18.1	16.1	15.3	10.2	10.8	14.3
45–1 [1]	[2] 20.0	16.4	16.5	18.3	19.3	20.1	17.0	17.5	10.8	12.1	17.1
45–2 [1]	[2] 16.6	13.3	16.0	16.7	14.1	16.2	14.1	14.1	14.7	8.7	14.3
60	15.1	13.0	11.1	15.7	13.0	14.2	14.0	10.9	10.0	10.2	12.6
61	19.5	19.5	16.6	21.6	17.2	18.8	17.9	17.4	13.9	13.7	17.4
62	14.7	11.8	12.6	16.1	10.5	14.3	11.9	14.0	13.1	10.6	12.8
64	[2] 18.7	16.7	16.2	20.3	12.4	15.9	15.8	15.7	15.3	10.7	15.2
71–1 [1]	[2] 19.1	13.6	12.6	20.0	12.0	12.8	14.4	21.0	11.4	10.0	14.1
71–2 [1]	[2] 19.3	18.2	16.3	21.0	18.0	20.2	13.7	20.2	17.5	14.2	17.7
Annual mean	15.0	13.5	12.9	15.7	13.1	14.9	12.3	13.6	11.9	9.1	13.0
Rotations returning highest yield	45–1	61	23	61	23	23	61	71–1	23, 31	71–2	23
Rotations returning lowest yield	2	2	2	2	2	2	2	2	2	2	2

[1] There are 2 crops of sugar beets grown during the completion of the cycle of rotation nos. 45 and 71; 45–1 implies the first crop and 45–2 the second. The same procedure is followed in rotation no. 71.
[2] Mean, 1920–25.

The mean yield for the period 1912 to 1925 is 15.6 tons per acre, with sweetclover pastured rotation no. 45–1 returning the highest yield, although this rotation was not included in the series until 1920. On the other hand, manured 2-year rotation no. 23 returned the highest yield for the 9-year period 1926 to 1934, with 0.9 ton more than the yield from no. 45–1. When the highest annual mean yields for the 9 years are compared, no. 61 had 3 years, no. 23 had 4 years, and rotations nos. 71–1 and 71–2 had 1 year each when the yields were equal to or the highest of the 17 cropping systems. It is particularly

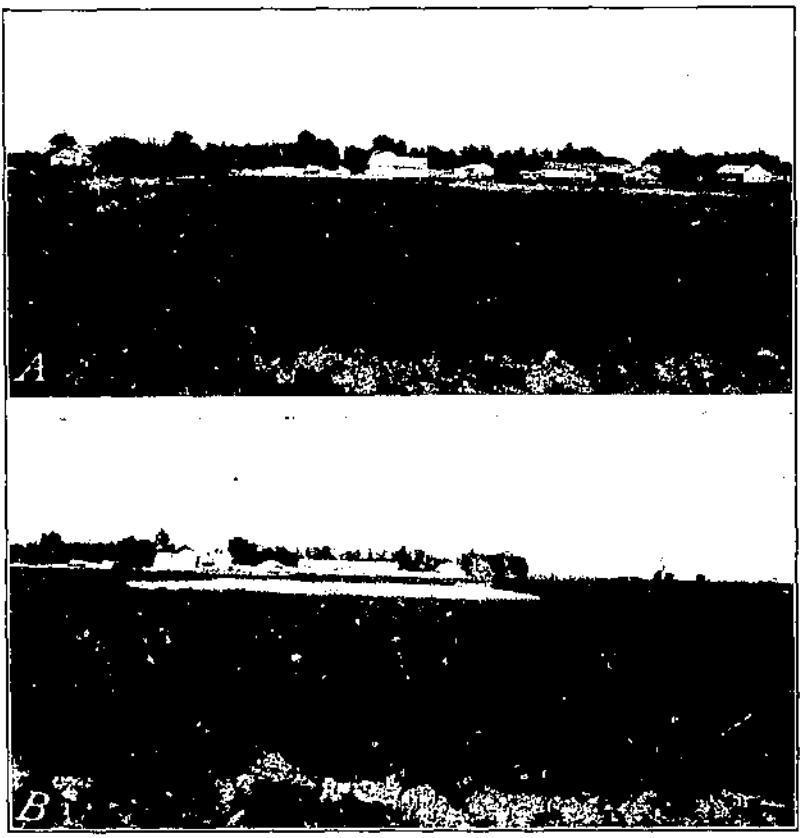

FIGURE 3.—*A*, Sugar beets in rotation 32, which had neither alfalfa nor manure. Mean yield of beets, 1926–34, 8.4 tons per acre. Compare with *B*. (Photographed July 22, 1930.) *B*, Sugar beets in rotation 45–1, which had sweetclover pastured 1 year. Mean yield of beets, 1926–34, 17.1 tons per acre. Compare with *A*. (Photographed July 22, 1930.)

significant that all of these rotations returning the highest yields had applications of farm manure or pasturing was practiced. In every instance rotation no. 2, which is constantly cropped to sugar beets, is the lowest. Of the untreated rotations, no. 32 has returned the highest mean yield of 8.4 tons per acre. This is 8.7 tons per acre less than has been harvested from no. 45–1 for the same period. This latter rotation has only 1 year of sweetclover which is pastured, and is otherwise intensively cropped, as one oat and two beet crops are grown during each cycle (fig. 3).

POTATOES

The mean acre yields of potatoes are recorded in table 3. In contrast to the yields of oats and sugar beets, the mean annual potato yields for the first 14 years were less than those harvested during the last 9-year period. A review of the yields for the first few years subsequent to 1912 indicated that the virgin soil conditions existing at that time were not favorable for the production of as high potato yields as has developed subsequently. As has occurred with the previous crops, low yields were harvested in 1934 because of a shortage of irrigation water.

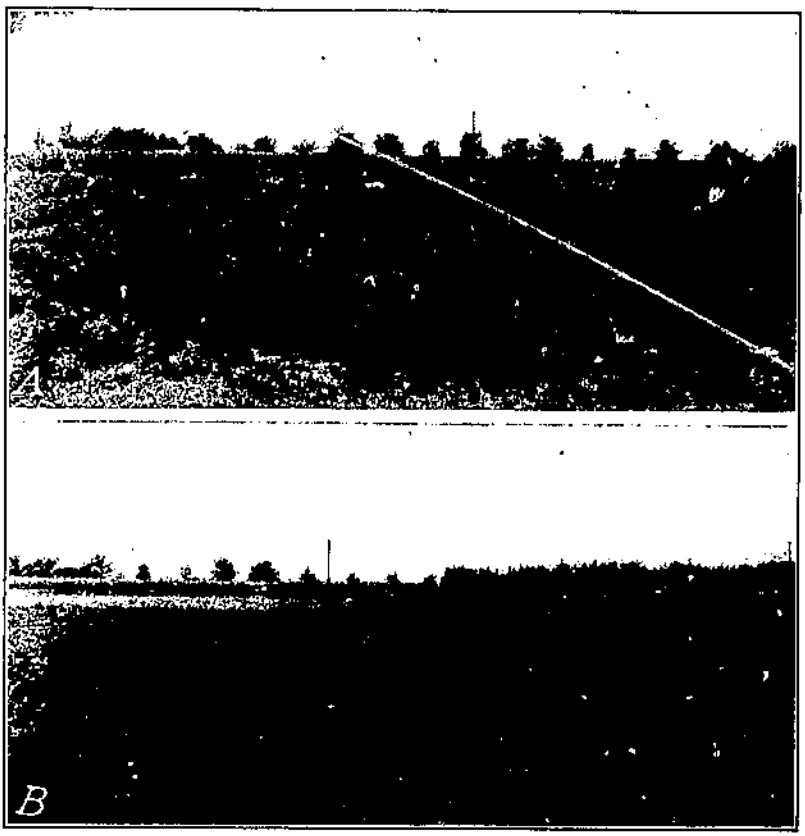

FIGURE 4.—*A*, Potatoes in simple 2-year rotation no. 20. Mean yield of potatoes, 1926–34, 144.6 bushels per acre. Compare with *B*. (Photographed August 16, 1931.) *B*, Potatoes in 4-year rotation no. 40, which is similar to rotation no. 20 except that it had 2 years of alfalfa. Mean yield of potatoes, 1926–34, 284.5 bushels per acre. Compare with *A*. (Photographed August 16, 1931.)

For the two summarized periods, 1912–25, and 1926–34, the highest mean annual yields of potatoes were harvested from 6-year alfalfa rotation no. 64, with 6-year manured alfalfa rotation a close second in both instances. When the mean individual annual yields are considered, rotation no. 71 was the highest once, nos. 60 and 64 twice each, and no. 61 returned the highest yields three out of the nine instances. In all 11 instances the lowest yield was harvested from continuously cropped rotation no. 4. Comparable with the results obtained with oats, including alfalfa in the cropping program, partic-

ularly for 3 years, has been distinctly more beneficial in its effect on potato yields than have applications of farm manure. The favorable influence which alfalfa has had on the yields of potatoes is apparent when the yields from this crop are compared in rotation nos. 40 and 20. These two rotations are similar except that no. 40 has 2 years of alfalfa, whereas no. 20 is an untreated rotation. For the last 9 years the mean yield from no. 40 was 139.9 bushels in excess of the yield from no. 20 (fig. 4).

TABLE 3.—*Yields of potatoes from the irrigated rotations at the Scotts Bluff Field Station, 1912–34*

Rotation no.	Acre yields (bushels)										
	Mean, 1912–25	1926	1927	1928	1929	1930	1931	1932	1933	1934	Mean, 1920–34
4	100.2	115.3	85.4	96.0	81.7	94.5	46.0	77.2	83.7	29.3	78.3
20	150.6	162.0	138.6	193.3	176.4	130.4	113.3	131.3	177.3	79.3	144.6
21	209.7	340.7	232.0	384.0	310.7	226.5	202.0	258.7	391.1	99.3	271.7
24	160.4	160.0	156.7	185.3	179.5	116.9	112.0	100.6	183.1	48.7	138.1
25	228.7	331.3	282.7	359.3	312.5	231.1	247.3	242.7	347.4	37.3	295.7
26	145.8	126.0	120.7	165.3	95.5	120.9	58.7	110.0	160.8	71.3	114.4
27	186.2	207.3	200.0	340.0	276.1	162.0	170.0	172.0	291.3	72.0	216.7
30	183.9	204.7	215.4	232.1	227.8	141.1	186.7	160.3	233.5	119.3	190.4
31	233.2	277.3	286.0	414.7	383.5	240.5	277.3	298.0	362.1	132.7	297.9
40	270.4	389.3	262.0	341.3	276.2	270.9	337.3	188.0	384.1	102.7	284.5
44	275.0	312.7	230.7	347.3	305.5	281.3	260.0	155.3	383.7	30.0	256.3
60	283.8	404.0	335.4	422.5	324.5	274.3	252.7	288.7	423.9	143.3	318.8
61	304.6	385.3	369.4	443.3	353.5	304.9	254.0	323.3	396.9	148.7	331.0
64	[1]309.8	374.7	329.4	442.7	330.3	335.9	345.3	254.7	415.2	165.3	332.6
71	[1]286.1	348.0	296.7	420.7	303.0	368.9	217.3	300.6	383.7	110.7	305.9
Annual mean	222.3	275.9	240.0	319.2	262.5	221.2	204.9	203.7	307.9	92.7	236.4
Rotations returning highest yield	64	60	61	61	31	71	64	61	60	64	64
Rotations returning lowest yield	4	4	4	4	4	4	4	4	4	4	4

[1] Mean, 1920–25.

WHEAT

The acre yields of wheat as this crop has appeared in the various cropping systems are given in table 4. The yields which have been harvested throughout the 23 years indicate that wheat is not a good crop under irrigation in the Scotts Bluff area. The results further justify the belief that wheat is less profitable than either oats or corn.

TABLE 4.—*Yields of wheat from the irrigated rotations at the Scotts Bluff Field Station, 1912–34*

Rotation no.	Acre yields (bushels)										
	Mean, 1912–25	1926	1927	1928	1929	1930	1931	1932	1933	1934	Mean, 1920–34
3	17.2	6.7	11.3	15.9	11.7	6.9	8.8	12.6	9.6	4.9	9.7
5	20.1	.0	18.0	20.0	13.2	11.0	9.3	6.1	9.7	1.3	9.8
7	16.8	9.0	12.3	15.9	9.0	8.1	8.9	12.5	8.0	6.0	9.8
18	23.1	5.8	17.3	20.1	12.5	7.3	9.7	16.7	10.5	3.9	11.5
28	18.6	5.7	12.7	13.0	10.4	9.4	8.7	14.1	9.4	4.5	9.8
48	27.9	13.0	23.7	25.3	22.4	26.7	11.9	28.2	31.1	.4	20.3
Annual mean	20.6	6.7	15.9	18.3	13.3	11.1	9.6	15.0	13.1	3.5	11.8
Rotations returning highest yield	48	48	48	48	48	48	48	48	48	7	48
Rotations returning lowest yield	7		3	28	7	3	28	5	7	48	3

However, it should be noted that in any of these rotations which include wheat crops are not included that would contribute to the production of large wheat yields. From 4-year alfalfa rotation no. 48 the highest yields have been harvested in all instances with the exception of the abnormal year 1934. Because of the water-shortage conditions that year such minor yield differences as did occur are valueless. Disregarding the year 1934, the lowest yields came twice each from rotations nos. 3, 5, 7, and 28.

CORN

Corn appears in 5 different cropping systems in these experiments, and the results are given in table 5 for the 23-year period. In the unfavorable year 1934 the yields from this crop were distinctly more satisfactory than were those from either oats or wheat, the mean being 25 bushels per acre. The highest mean annual yields of corn were harvested from 6-year alfalfa rotation no. 62. For the two summary periods, 1912–25, and 1926–34, the lowest mean annual yield was from continuously cropped plot 6. In 5 out of the 9 individual years plot 6 also returned the lowest yield and no. 16 in 3 of them. For the last 9-year period it is worthy of note that when the mean yield from plot 6 is compared with the 2-year corn-oats rotation no. 16 there is a difference of only 0.4 bushel per acre in favor of the latter cropping system. Thus it appears that in the case of a 2-year rotation including corn and oats but little better results may be expected with corn than would be the case were corn grown continuously on the same land.

TABLE 5.—*Yields of corn from the irrigated rotations at the Scotts Bluff Field Station, 1912–34*

Rotation no.	Acre yields (bushels)										
	Mean, 1912–25	1926	1927	1928	1929	1930	1931	1932	1933	1934	Mean, 1926–34
6	32.6	25.7	10.3	14.9	19.4	22.4	14.3	21.7	15.5	22.3	18.5
16	40.0	17.1	16.6	18.1	28.3	28.6	19.4	14.5	14.3	19.4	18.9
28	39.7	20.0	24.0	17.7	25.5	27.3	24.0	20.5	30.9	18.3	23.1
32	40.6	28.0	25.1	20.1	35.6	38.1	25.1	15.1	20.3	20.9	27.6
62	59.2	29.4	63.4	68.8	40.0	66.7	40.1	50.0	50.3	38.3	60.7
Annual mean	42.2	24.0	26.7	29.7	29.8	36.6	26.4	24.4	27.5	25.0	27.8
Rotations returning highest yield	62	62	62	62	62	62	62	62	62	62	62
Rotations returning lowest yield	6	16	6	6	6	6	6	16	16	28	6

FLAX

While flax has been included in two cropping programs in these experiments, continuously cropped plot 9 and rotation no. 65, the results obtained have been very unsatisfactory. In 7 out of the 14 years, 1912–25, no measurable yields were harvested from this crop (*8*). The yields obtained from 1926 to 1934 have been even less satisfactory. Consequently, a table giving the yields of flax is not included in this bulletin. Throughout the 23-year period it has been apparent that in the Scotts Bluff area the conditions, believed to be chiefly climatic, are not favorable to profitable yields of this crop.

ALFALFA

Alfalfa was incorporated in these experiments primarily for the purpose of observing its residual effect on succeeding crop yields when grown 2 or 3 successive years in a number of rotations as compared with similar rotations not including alfalfa. Also, there is afforded an opportunity of observing the influence alfalfa has exerted on the yields of the different crops under consideration as compared with applications of farm manure. While alfalfa is grown for 3 successive years in rotation no. 65, the yields from only 2 years have been harvested; the third year the crop was pastured with hogs. The alfalfa yields recorded in table 6 have been assembled in such a manner that it is possible to observe the yields the first, second, and, where they occur, the third year from seeding. The alfalfa yields given for no. 60–1 signify the first year from seeding, no. 60–2 the second year, and no. 60–3 the third-year crop. No yield is recorded for continuously cropped plot 8 in 1934. Because of excessive weed growth, which materially reduced the stand of alfalfa, this plot was plowed in the fall of 1933 and remained fallow throughout the following season. Further, it will be noted that in a number of instances no first-year yields were harvested. Because of unfavorable weather or other conditions at the time of spring seeding an unsatisfactory stand resulted. When this has occurred the land has been fallowed throughout the summer and reseeded in the late summer or early fall.

TABLE 6.—*Yields of alfalfa from the irrigated rotations, Scotts Bluff Field Station, 1912–34*

Rotation no.	Acre yields (tons)										
	Mean, 1912–25	1926	1927	1928	1929	1930	1931	1932	1933	1934	Mean, 1926–34
8	4.98	4.28	3.18	6.26	5.18	4.84	4.07	3.54	3.50	0.00	3.87
40–1	.97	.96	.74	.00	1.92	1.22	1.50	.00	1.52	.00	.87
40–2	4.83	5.66	3.16	5.40	5.48	4.88	3.60	5.02	5.34	4.38	4.77
42–1	.99	.92	.74	.00	2.36	1.08	1.64	.00	1.00	.00	.86
42–2	4.34	4.85	2.44	5.80	4.80	3.80	2.96	4.60	1.46	4.38	3.90
44–1	2.07	.86	.60	.00	3.00	2.68	1.90	.00	1.36	.00	1.16
44–2	4.43	4.74	2.70	6.44	5.44	4.16	4.10	4.34	1.32	4.26	4.17
48–1	2.20	.00	.54	.00	3.64	2.94	2.20	.00	1.06	.00	1.15
48–2	3.88	5.63	2.82	4.48	4.64	5.46	4.28	4.18	1.10	5.56	4.24
60–1	.94	1.30	.78	.00	1.70	2.80	1.34	.00	1.26	.00	1.02
60–2	4.47	5.07	3.28	4.82	4.46	3.62	5.16	4.50	4.60	4.88	4.43
60–3	5.25	6.00	4.12	5.58	6.10	4.08	4.62	4.62	5.12	5.00	5.03
61–1	1.00	1.14	1.04	.00	2.96	2.04	1.78	.00	1.40	.00	1.15
61–2	4.62	6.26	3.78	6.34	4.96	4.94	5.28	4.66	5.59	5.12	5.21
61–3	5.47	6.73	4.38	6.66	6.06	4.08	5.38	5.64	5.18	6.06	5.63
62–1	.96	.82	.70	.00	2.04	2.54	1.66	.00	1.42	.00	1.02
62–2	4.50	5.64	2.88	4.54	4.96	3.74	4.02	5.04	4.30	4.24	4.37
62–3	5.23	5.97	4.14	5.80	6.14	4.74	4.82	5.10	5.88	5.20	5.31
64–1 [1]	3.71	5.18	3.38	4.88	5.50	3.60	1.28	5.34	4.49	4.84	4.36
64–2	5.00	5.73	4.18	6.84	6.14	5.14	3.50	4.98	5.64	6.00	5.38
64–3	5.11	5.84	3.58	7.16	6.22	4.92	5.00	4.24	5.32	4.60	5.21
65–1	1.86	1.06	1.84	.00	4.50	4.97	.40	3.10	1.56	.00	1.84
65–2	4.58	6.27	4.02	6.94	6.00	5.50	5.88	2.92	6.35	6.22	5.57
71–1 [1]	4.64	5.12	3.06	4.78	5.30	4.71	2.52	4.20	4.97	4.24	4.32
71–2	4.14	5.58	3.80	6.02	6.14	3.64	4.30	4.10	5.64	3.52	4.75
71–3	5.58	5.98	4.12	5.76	5.08	5.08	4.42	4.58	5.78	2.70	4.83
Annual mean:											
First year	1.03	1.74	1.34	.97	3.30	2.77	1.69	1.26	2.00	.91	1.78
Second year	4.45	5.54	3.31	5.76	5.30	4.49	4.34	4.43	4.14	4.86	4.69
Third year	5.33	6.10	4.07	6.10	5.92	4.58	4.95	4.84	5.46	4.71	5.20

[1] In rotations nos. 64 and 71 alfalfa seed was drilled in with the oats; hence 64–1 and 71–1 imply the yields the second year from seeding. In all other rotations seeding is practiced the fall before or in the spring of the first year.

The lowest mean annual yields for each year and from both periods have resulted from the first season, as is to be expected. Satisfactory yields have been harvested the second season, but as a rule the third-year yields are somewhat greater. For the 9-year period, 1926–34, the highest mean yield for the third year, 5.63 tons per acre, is from manured rotation no. 61–3. The second highest yield of 5.57 tons for the same period is from rotation no. 65–2, the second year from planting and in a rotation which includes harvesting the third-year alfalfa and the following corn crop with hogs. These annual mean yields of alfalfa afford an opportunity to observe the variation in yields from one season to another and the yields which ordinarily may be expected. From 1926 to 1934 the third-year mean annual yields have ranged from a minimum of 4.07 tons to a maximum of 6.19 tons per acre, with a mean for the 9-year period of 5.2 tons per acre.

ANNUAL FLUCTUATION IN YIELDS

There have been given in the foregoing tables the crop yields of oats, sugar beets, potatoes, wheat, corn, and alfalfa summarized for the years 1912 to 1925 and in detail for the years 1926 to 1934. This method of presenting the data affords an opportunity to observe the trend of the yields throughout the 9-year period as compared with the previous 14-year mean for the different crop sequences as well as the annual fluctuations. It is apparent that for the 9 years where it is possible to observe the yields in detail there have been seasons highly favorable for large crop yields, such as occurred in 1928, and other seasons when the conditions were highly unfavorable, such as was experienced in 1934. For the 9-year period the growth or other conditions have so operated that the crop yields were correspondingly favorably influenced, as in 1928, and depressed, as in 1934. However, other seasons have occurred when the yields of a certain crop have been high, such as those from potatoes in 1933; whereas for the same year sugar beets returned the second lowest mean yield harvested during the 9-year period.

In order to afford an opportunity of observing the annual fluctuation of yields from 1926 to 1934, table 7 is presented. The yields are expressed as percentages for each crop listed, based upon the mean annual yields for each crop and its departure from the mean for the 9 years. Also, following these figures, there are included the mean yields similarly expressed for the entire 23 years but divided into three 6-year periods and one 5-year period computed from the 23-year mean yields.

TABLE 7.—*Mean annual acre yields of oats, sugar beets, potatoes, corn, and wheat, expressed as percentages of the mean yields of all plots in detail from 1926 to 1934 and by periods for the entire 23 years*

Crop	1926	1927	1928	1929	1930	1931	1932	1933	1934	Mean			
										1912–17	1918–23	1924–29	1930–34
Oats	75	132	154	130	93	62	127	96	33	119	104	104	68
Sugar beets	104	99	121	101	115	95	105	92	70	105	100	106	88
Potatoes	117	102	135	111	94	87	80	136	39	100	78	128	92
Corn	86	96	107	107	132	95	88	99	90	136	97	87	77
Wheat	68	135	155	113	94	81	127	111	30	148	94	91	61
Mean	90	113	134	112	106	84	107	106	52	122	95	103	77

In considering individual years, with the exception of corn, the highest percentages occurred in 1928 with an annual mean for that year of 134, definitely the highest for the 9 years. The lowest for all crops except corn occurred in 1934, when the mean percentage for the year was only 52 percent, 32 points less than for 1931, the next lowest year. These figures emphasize the fact that the 4 years, 1926–29, with a mean percentage of 112 were distinctly more favorable than the following 5 years, which have a mean percentage of 91. This is further reflected in the summary percentages given in the last four columns. The highest mean of 122 percent occurred the first-year period, and the lowest of 77 percent was recorded during the last 5 years. The next lowest was for the 1918–23 period.

YIELDS FROM THE VARIOUS CROPS IN THE DIFFERENT ROTATIONS SUMMARIZED

In compiling the results from these rotation experiments (tables 8–10, 12, and 13) it appeared that rotational effects could be most satisfactorily observed and compared if the yields were summarized as nearly as possible in four equal periods. By determining the mean yields for a period of years the fluctuations not attributed to treatments to which the different crops have been subjected are minimized, with the result that these assembled yields more accurately portray the differences which may be expected under average farm conditions in the North Platte Valley. The results are summarized for the 23 years by three 6-year periods covering 1912 to 1929 and a 5-year period, 1930–34. In addition to comparing one rotation with another, the rotations are grouped in such a manner that the yields from the 2- and 3-year rotations, both untreated and treated, as well as those having 2 and 3 years of alfalfa, may be compared with the continuously cropped rotations. Pasturing is incorporated as a treatment with sweetclover in rotation no. 45 and with alfalfa in rotation no. 65. It is possible to observe the influence this treatment has had on the yields of sugar beets, oats, and corn. Following these yield figures are the standard errors for each period in each rotation for the five crops under consideration. As far as possible to eliminate seasonal variations, these standard errors have been computed from the departures from the mean annual yields of all the rotations. These standard errors afford a measure of the significance of the yield differences which have occurred.

In columns 7 to 10 (tables 8–10, 12, and 13) are given the departures of these mean yields from the various rotations for the five crops from the mean yields of all rotations for each of the four periods. The mean departures for the four periods or for the past 23 years are given in the last column. This method of presentation affords means of observing the departures of the yields from each rotation referenced to the mean of all the different rotations for the different periods as well as indicating the yield trends. These yield differences have a practical application, particularly when sugar beets are considered. It has been found that the mean yield of beets from all of these rotations has not varied greatly from the project yields as reported by the Bureau of Reclamation. Hence it may be assumed that the rotations which have returned a minus difference are below the North Platte

Valley average, whereas those with a plus difference are above, the extent of course depending upon the magnitude of the plus or minus differences. In a measure, comparable comparisons may be made with the other crops involved.

Among other features these results emphasize the need of a constructive system of crop rotation or special treatment of the soil if the productivity of the soils on the North Platte project are to be maintained. In addition they contribute further evidence that while satisfactory yields may be obtained for some years if only crop rotation is practiced and no special treatment is included in the cropping program, yet eventually yields will decline without an occasional application of farm manure or unless such soil-improvement crops as alfalfa and sweetclover are included in the cropping program. It has been apparent that most immediate results in connection with the improvement in yields may be expected from applications of farm manure. However, the livestock population on the North Platte project has been able to supply only a small part of what would be required were maintaining the productivity of the soil dependent wholly upon such treatment. This condition was recognized at the time these experiments were begun, and alfalfa was included largely for the purpose of determining how effectively it could be utilized in the cropping system as a substitute for manure. Later sweetclover was added, partly because of its more rapid growth the first season and also because when it is pastured the danger of bloat is less than with alfalfa. In certain rotations observations have been made to ascertain how profitable the procedure may prove to be when corn, alfalfa, and sweetclover are harvested with livestock as compared with the more common practices of harvesting these crops for grain or hay. It was believed that determining the effect on succeeding crop yields when this practice was followed might result in assembling further information on how crop yields could be even more economically stimulated aside from the applications of farm manure.

In tables 8 to 13 the benefits in the form of increased yields due to improved cropping systems are clearly apparent. However, there are other important advantages not always reflected in crop yields. Growing the same crop on the same land even for a few years not infrequently results in excessive weed growth, intensifies the damage by plant diseases and insect pests, or increases the expense of their control. There are still further advantages resulting from crop rotation. When such a practice is followed, two or more crops are necessarily included in the cropping program, thus diversifying the farmer's activities. It is generally accepted as a fact in areas devoted to the production of the more common farm crops that farmers who diversify are able to utilize their time and equipment more effectively than if they are largely or wholly confining their operations to one crop. When farmers are not dependent solely upon an income from a single crop, as a rule their business is on a more stable basis, and a financial loss resulting from low yields or depressed prices on a particular crop does not necessarily indicate that they will sustain losses on their combined operations for the season. It is obvious that all the advantages of a well-planned rotation are not reflected in the foregoing and following tables, but such factors should be taken into

consideration when the comparative merits of the different cropping systems are being considered.

In making comparisons of the differences in yields obtained from the various crop sequences and treatments applied in these rotations, which are summarized in tables 8 to 13, it is recognized that but little emphasis should be placed upon the results for the first 6-year period, 1912–17. The land where these experiments were conducted was quite productive when first broken, with the result that in almost all instances good yields were harvested during the first few years, as is apparent from the detailed results previously recorded (8). Hence the differences in yields which have occurred during the latter years may be attributed to the rotational practices and treatments to which the different crops have been subjected.

By combining the yields from the different crops and treatments into 5- and 6-year periods extreme seasonal variations and accidental injuries have been minimized, yet there have been cycles of several years when the mean yields were relatively high as compared with other periods. Such conditions obtained throughout the first 6-year period, 1912–17, for all crops, as is apparent from the percentage figures given in table 7. Lower yields were harvested for the second 6-year period, seasonal conditions being distinctly unfavorable for the potato crop in 1918, for sugar beets in 1920, and somewhat unfavorable for oats in 1919 and again in 1921. On the other hand, for the three major crops, oats, sugar beets, and potatoes, the yields were above the average for the third 6-year period, 1924–29. The lowest yields for all five crops were for the 5-year period, 1930–34. There were 2 unfavorable seasons during these 5 years. In 1931 the climatic conditions were unfavorable for satisfactory yields for all crops listed. Again in 1934, chiefly due to a shortage of irrigation water, very low yields were harvested from the five crops. During none of the years 1930 to 1934 were conditions notably favorable for the production of large yields, as the highest mean percentage for all crops given in table 7 is 107 with a 5-year mean of 77 percent. In a large measure these facts afford an explanation as to why the yields of sugar beets, oats, and potatoes, particularly for the last period, are materially less than for the previous period, 1924–29, even with the better cropping programs. Consequently, in comparing the results given in the tables consideration must be given to the varying seasonal conditions in order that erroneous conclusions may not be drawn.

OATS

The average annual yields of oats with the standard error and departures are given in table 8 for the 4 periods. In addition to affording an opportunity of comparing the summary yields from the different rotations, one with another, the rotations are grouped and the yields averaged as follows: Continuous cropping, 2-year untreated rotations, 2-year manured rotations, 3-year rotations untreated and 1 having an application of manure, 4-year rotations having 2 years of alfalfa, 6-year rotations including 3 years of alfalfa, 2 rotations having 3 years of alfalfa and also an application of farm manure once during the completion of its cycle, and 2 rotations, nos. 45 and 65, which include harvesting crops with livestock.

TABLE 8.—*Mean annual yields of oats compared with the annual means of all rotations, showing the effect of continuous cropping, simple rotations, manure, alfalfa, alfalfa and manure, and pasturing at the Scotts Bluff Field Station, 1912–34*

Rotation	Crops in the rotation	Mean acre yields of oats (bushels), 6- and 5-year periods								
		Periodic yields and standard error				Increase (+) or decrease (−) as compared with the periodic means of all rotations				Mean departures for the 4 periods
		1912–17	1918–23	1924–29	1930–34	1912–17	1918–23	1924–29	1930–34	
Continuous cropping:										
No. 1	Oats	58.0±1.78	36.8±2.51	33.4±2.84	21.1±2.51	−8.4	−20.8	−24.8	−16.7	−17.7
2-year rotations, untreated:										
No. 16	Corn, oats	56.3±4.74	43.4±4.18	28.0±3.40	25.7±3.83	−10.0	−14.3	−30.2	−12.1	−16.7
No. 22	Oats, sugar beets	67.3±1.64	49.1±4.96	31.4±2.88	23.4±5.14	+1.0	−18.2	−26.8	−14.3	−14.6
No. 24	Oats, potatoes	68.9±3.57	45.7±4.27	33.1±2.92	21.0±5.51	+2.7	−12.0	−25.1	−16.8	−12.8
No. 27	Oats (followed by rye plowed under), potatoes.	75.2±4.07	53.8±2.56	41.2±4.29	25.6±2.29	+9.0	−3.9	−17.0	−12.1	−6.0
No. 28	Spring wheat, oats	57.3±5.39	35.1±2.69	26.6±2.11	14.8±4.52	−9.0	−22.6	−31.6	−23.0	−21.6
Mean		65.0	45.4	32.1	22.1	−1.3	−14.2	−26.1	−15.7	−14.3
2-year rotations, manured:										
No. 23	Oats (manure), sugar beets	69.5±2.45	63.1±3.08	64.8±3.67	44.4±4.72	+3.2	+5.4	+6.6	+6.6	+5.5
No. 25	Oats (manure), potatoes	63.7±4.76	60.9±1.85	64.8±3.37	38.9±2.52	−2.6	+3.2	+6.6	+1.1	+2.1
Mean		66.6	62.0	64.8	41.7	+.3	+4.3	+6.6	+3.9	+3.8
3-year rotations, untreated:										
No. 30	Potatoes, oats, sugar beets	65.4±3.54	56.1±3.57	36.4±3.56	25.1±4.31	−.9	−1.6	−21.8	−12.7	−9.3
No. 32	Corn, oats, sugar beets	54.9±6.24	43.6±4.03	25.5±4.14	25.9±5.50	−11.4	−14.1	−32.5	−11.9	−17.5
Mean		60.2	49.9	31.0	25.5	−6.2	−7.9	−27.2	−12.3	−13.4
3-year rotations, manured:										
No. 31	Potatoes, oats (manure), sugar beets	76.6±2.49	72.3±2.45	61.0±2.78	47.9±3.02	+10.4	+14.6	+2.8	+10.1	+9.5
4-year alfalfa rotations:										
No. 42	Alfalfa (2 years), oats, sugar beets	73.5±3.75	63.6±3.12	78.2±4.57	45.8±5.73	+7.2	+6.0	+20.0	+8.0	+10.3
No. 44	Alfalfa (2 years), potatoes, oats	75.4±3.59	66.2±2.81	76.9±1.21	54.6±4.02	+9.2	+8.6	+18.8	+16.8	+13.4
No. 48	Alfalfa (2 years), spring wheat, oats	67.1±5.41	63.5±2.61	71.4±2.62	45.7±3.82	+.8	+5.9	+13.2	+7.9	+7.0
Mean		72.0	64.4	75.5	48.7	+5.7	+6.8	+17.3	+10.9	+10.2

6-year alfalfa rotations, untreated:									
No. 60	Alfalfa (3 years), potatoes, oats, sugar beets	68.3±2.09	68.7±1.25	83.6±2.90	49.6±3.55	+2.0	+11.1	+25.5	+11.9	+12.6
No. 62	Alfalfa (3 years), corn, oats, sugar beets	55.4±4.01	65.4±1.81	70.0±2.57	47.8±2.94	−10.8	+7.8	+20.8	+10.0	+7.0
No. 64	Alfalfa (3 years), potatoes, sugar beets, oats (started 1920)		65.0±3.22	74.2±4.22	44.1±3.58		+7.0	+16.0	+6.4	+9.8
Mean		61.9	66.4	78.9	47.2	−4.4	+8.6	+20.8	+9.4	+9.8
6- and 7-year alfalfa rotations, manured:									
No. 61	Alfalfa (3 years), potatoes, oats (manure), sugar beets	69.7± .58	73.1±3.37	95.5±2.17	54.3±5.12	+3.4	+15.4	+37.3	+16.5	+18.2
No. 71	Alfalfa (3 years), potatoes, sugar beets (manure), sugar beets, oats (started 1920)		61.2±3.26	82.7±6.61	53.0±4.88		+2.9	+24.5	+15.3	+14.2
Mean		69.7	67.2	89.1	53.7	+3.4	+9.2	+30.9	+15.9	+16.2
Pastured rotations:									
No. 45	Oats with sweetclover, sweetclover pastured with sheep, sugar beets (2 years) (started 1920)		56.7±3.04	57.6±2.99	39.8±2.52		−1.3	−.6	+2.1	+.1
No. 65	Alfalfa (3 years, pastured with hogs third year), corn (harvested by hogs), flax, oats	70.4±4.06	72.8±4.90	76.4±4.52	44.6±6.04	−.3	+15.2	+18.2	+6.8	+10.0
Mean		70.4	64.8	67.0	42.2	−.3	+7.0	+8.8	+4.5	+5.1

In considering the mean yields of the different rotation groups, the lowest yields have been harvested from the continuously cropped oat plot, with those from the untreated 2-year rotations second. With one exception the highest yields have been harvested from the 6-year alfalfa rotations, which received applications of farm manure. Of the 21 rotations the most favorable results with oats have occurred in rotation no. 61, which has a plus departure of 18.2 bushels per acre. The second most favorable results have been obtained from the comparable rotation, no. 71, with a mean departure of +14.2 for the three periods. Pasturing has not stimulated the yields of oats as compared with 2- or 3-year alfalfa rotations, as rotation no. 45 has a mean departure of only +0.1 and no. 65 +10.0, with a mean for the two of +5.1. However, it should be noted that no. 45 has 2 years of sugar beets following the pastured sweetclover, and the oat crop is preceded by a crop of flax in no. 65. In this latter rotation the weed problem in the oat crop has been a yield-depressing factor.

In the mean departures for the 4-year period plot no. 1 has a mean of −17.7, the lowest of any of the treatments, with the 2- and 3-year untreated rotations next in order. Applications of farm manure have proved distinctly beneficial in stimulating the yield of oats as compared with those rotations not so treated, as plus departures have occurred in the mean for the two 2-year rotations and the one 3-year rotation. The highest mean departure of 16.2 bushels is from rotations nos. 61 and 71, both having 3 years of alfalfa and an application of manure during each cycle. In analyzing the results from the individual rotations the lowest oat yields have been harvested from rotation no. 28, oats and wheat. This has not proved to be a desirable combination for obtaining satisfactory yields of either oats or wheat, the yields being materially depressed due to the difficulty of controlling weed growth. Weed growth also has been an important factor in depressing the yields of oats in the next lowest plot no. 1, with a departure of −17.7 bushels.

SUGAR BEETS

Table 9 summarizes the mean acre yields of sugar beets, presenting the results statistically, as were those obtained with oats in table 8. In all there are 17 rotations and 19 yield comparisons, as the sugar-beet crop appears twice during the completion of the cycle of nos. 45 and 71.

Consistently the lowest yields have been harvested from plot 2, with the three 2-year and the two 3-year untreated rotations giving the second lowest yields. The next poorest results have been obtained from the three 6-year alfalfa rotations, nos. 60, 62, and 64, which have a mean plus departure of only +0.6 ton per acre. Of the remaining groups the two manured-alfalfa rotations, nos. 61 and 71, have the mean highest departure, with the two 2-year manured rotations 0.1 ton less for the 23-year period. Of the remaining groups the most satisfactory yields have resulted from rotation no. 45, and the two 4-year alfalfa rotations, nos. 40 and 42, of +2.3 and +1.9 tons, respectively.

TABLE 9.—*Mean annual yields of sugar beets compared with the annual means of all rotations, showing the effect of continuous cropping, simple rotations, manure, alfalfa and manure, and pasturing at the Scotts Bluff Field Station, 1912–34*

Rotation	Crops in the rotation	Mean acre yields of sugar beets (tons), 6- and 5-year periods								
		Periodic yields and standard error				Increase (+) or decrease (−) as compared with the periodic means of all rotations				Mean departures for the 4 periods
		1912–17	1918–23	1924–29	1930–34	1912–17	1918–23	1924–29	1930–34	
Continuous cropping:										
No. 2	Sugar beets	10.8±0.30	7.8±1.03	7.6±0.42	4.9±0.35	−3.9	−6.3	−7.4	−7.5	−6.3
2-year rotations, untreated:										
No. 18	Wheat, sugar beets	14.6± .76	8.5± .59	9.7± .43	7.3± .31	−.1	−5.6	−5.3	−5.0	−4.0
No. 20	Sugar beets, potatoes	13.1± .50	10.3± .99	10.2± .42	7.1± .24	−1.6	−3.8	−4.8	−5.2	−3.9
No. 22	Oats, sugar beets	12.8± .43	9.8± .71	9.9± .52	7.2 .78	−1.9	−4.3	−5.1	−5.1	−4.1
Mean		13.5	9.5	9.9	7.2	−1.2	−4.6	−5.1	−5.1	−4.0
2-year rotations, manured:										
No. 21	Sugar beets (manure), potatoes	14.7±1.00	16.7± .37	18.5± .68	15.3± .79	−.1	+2.6	+3.5	+3.4	+2.4
No. 23	Oats (manure), sugar beets	17.4± .51	18.1± .61	19.8± .55	17.0± .79	+2.7	+4.0	+4.8	+4.7	+4.1
Mean		16.1	17.4	19.2	16.2	+1.3	+3.3	+4.2	+4.1	+3.3
3-year rotations, untreated:										
No. 30	Potatoes, oats, sugar beets	12.9± .94	9.9± .52	10.4± .31	7.1± .46	−1.8	−4.2	−4.6	−5.2	−4.0
No. 32	Corn, oats, sugar beets	12.9± .50	9.7± .68	10.2± .41	7.0± .50	−1.9	−4.5	−4.8	−4.8	−4.0
Mean		12.9	9.8	10.3	7.4	−1.9	−4.4	−4.7	−5.0	−4.0
3-year rotation, manured:										
No. 31	Potatoes, oats (manure), sugar beets	18.2±.84	16.9± .42	18.8± .70	16.8± .57	+3.5	+2.8	+3.8	+4.4	+3.6
4-year alfalfa rotations:										
No. 40	Alfalfa (2 years), potatoes, sugar beets	17.6±. 50	18.0±1.27	15.7± .98	14.4± .77	+2.8	+3.8	+.7	+2.0	+2.3
No. 42	Alfalfa (2 years), oats, sugar beets	14.8±1.32	17.1± .99	15.1± .89	13.9± .86	+0.0	+2.9	+1.1	+1.5	+1.4
Mean		16.2	17.6	15.4	14.2	+1.4	+3.4	+.9	+1.8	+1.9

TABLE 9.—*Mean annual yields of sugar beets compared with the annual means of all rotations, showing the effect of continuous cropping, simple rotations, manure, alfalfa and manure, and pasturing at the Scotts Bluff Field Station, 1912–34*—Continued.

Rotation	Crops in the rotation	Mean acre yields of sugar beets (tons), 6- and 5-year periods								
		Periodic yields and standard error				Increase (+) or decrease (−) as compared with the periodic means of all rotations				Mean departures for the 4 periods
		1912–17	1918–23	1924–29	1930–34	1912–17	1918–23	1924–29	1930–34	
4-year sweet clover (pastured) rotations:										
No. 45–1	Oats with sweetclover, sweetclover pastured with sheep, sugar beets (2 years) (started 1920).	----------	16.2± .93	19.4± .64	16.7± .40	-------	+2.3	+4.4	+4.3	+3.7
No. 45–2		----------	14.0±1.78	16.2± .54	13.6± .55	-------	+.1	+1.2	+1.2	+.8
Mean		----------	15.1	17.8	15.2	-------	+1.2	+2.8	+2.8	+2.3
6-year alfalfa rotations:										
No. 60	Alfalfa (3 years), potatoes, oats, sugar beets.	14.1± .47	14.7± .72	15.4± .58	11.9± .84	−.7	+.6	+.4	−.5	−.1
No. 62	Alfalfa (3 years), corn, oats, sugar beets.	14.1± .66	14.4± .33	14.3± .47	12.8± .42	−.6	+.3	−.7	+.4	−.2
No. 64	Alfalfa (3 years), potatoes, sugar beets, oats (started 1920).	----------	14.8±1.20	18.0± .81	14.3± .82	-------	+1.0	+3.1	+1.9	+2.0
Mean		14.1	14.6	15.9	13.0	−.7	+.6	+.9	+.6	+.6
6- and 7-year alfalfa rotations, manured:										
No. 61	Alfalfa (3 years), potatoes, oats (manure), sugar beets.	18.5± .60	19.0± .86	20.5± .58	16.3± .59	+3.8	+4.9	+5.5	+4.0	+4.6
No. 71–1	Alfalfa (3 years), potatoes, sugar beets (manure), sugar beets, oats (started 1920)	----------	17.0± .62	16.3± .90	13.9±1.62	-------	+3.1	+1.3	+1.6	+2.0
No. 71–2		----------	17.7±1.08	19.0± .45	17.2±2.18	-------	+3.9	+4.0	+2.7	+3.5
Mean		18.5	17.9	18.6	15.8	+3.8	+4.0	+3.6	+2.8	+3.4

When the results from the individual rotations are reviewed it is found that the highest yields have been harvested from the 6-year alfalfa rotation no. 61, which has an application of manure preceding the beet crop. This cropping system shows an indicated increase of 10.9 tons per acre over the continuously cropped no. 2. The next best results have been obtained from the 2-year oats-beets rotation no. 23, which gets an application of manure every other year preceding the beet crop. As compared with the continuously cropped plot, there is an indicated superiority of 10.4 tons per acre throughout the 23 years. The other 2-year manured rotation, no. 21, is superior to the continuously cropped plot by 8.7 tons of beets. However, in this instance, manure did not immediately precede the beets as in rotation no. 23, but was applied to the preceding crop, potatoes. The yield differences of beets resulting from rotations nos. 45–1, 31, and 71–2 closely follow those obtained from rotation no. 23. From these results it appears that harvesting one or more crops by the pasturing method is nearly as effective in stimulating the yields of beets as are applications of farm manure.

Alfalfa alone, whether growing for 2 or 3 years and regardless of the crops and sequences, has not resulted in stimulating the yields of beets as have applications of farm manure or the practice of pasturing. The largest increase over continuous cropping is 8.6 tons per acre from rotation no. 40; no. 64 is second with 8.3 tons. In both of these rotations the beets are preceded by potatoes. In other instances oats are the preceding crop, a sequence which has not resulted in as satisfactory yields as have occurred where the beet crop has followed potatoes. The exceptions have been with nos. 23 and 21, but in these cases the oat crop is followed by an application of manure in no. 23, whereas in no. 21 the manure is applied to the potatoes.

A comparison of the beet yields from rotation no. 40 with those from rotation no. 42 shows an increase of 0.9 ton per acre in favor of no. 40. Rotations nos. 60 and 62 have minus departures of 0.1 and 0.2 ton of beets, respectively. This may be attributed chiefly to the fact that not only do oats precede beets in both instances, but also that two crops intervene between the alfalfa and the beets, as compared with only one crop in the case of rotation no. 64, which has a plus departure of 2.0 tons of beets. These results further indicate that as favorable results may be expected with 2 years of alfalfa as with 3 years; this is apparent when the beet yields from rotation no. 40 are compared with those from no. 64.

POTATOES

The yields of potatoes are given in table 10 as this crop appears in 15 different cropping systems. There is one continuously cropped plot, four 2-year rotations untreated and two which receive applications of farm manure, one 3-year untreated rotation, and a similar rotation to which manure is applied. There are six alfalfa rotations, two having 2 years of alfalfa, two having 3 years of alfalfa, and two having 3 years of alfalfa together with an application of farm manure during each cycle.

TABLE 10.—*Mean annual yields of potatoes compared with the annual means of all rotations, showing the effect of continuous cropping, simple rotations, manure, alfalfa, and alfalfa and manure, at the Scotts Bluff Field Station, 1912–34*

Rotation	Crops in the rotation	Mean acre yields of potatoes (bushels), 6- and 5-year periods								
		Periodic yields and standard error				Increase (+) or decrease (−) as compared with the periodic means of all rotations				Mean departures for the 4 periods
		1912–17	1918–23	1924–29	1930–34	1912–17	1918–23	1924–29	1930–34	
Continuous cropping:										
No. 4	Potatoes	126.5±18.02	59.1±11.50	111.4±10.79	65.2±26.05	−80.7	−114.3	−175.0	−140.8	−127.7
2-year rotations, untreated:										
No. 20	Potatoes, sugar beets	183.4±82.21	108.0±15.53	170.1± 8.37	126.3±19.11	−40.5	−65.3	−116.2	−79.8	−75.5
No. 24	Potatoes, oats	182.3±16.43	121.0±18.74	184.7± 8.84	112.3±13.49	−41.6	−52.4	−101.6	−93.8	−72.4
No. 26	Potatoes, corn	175.7±13.94	101.6±11.62	147.5± 8.45	104.3±22.97	−48.1	−71.8	−138.8	−101.7	−90.1
No. 27	Potatoes, oats (followed by rye plowed under)	188.9±27.32	152.2± 9.84	274.1±14.86	173.5± 7.45	−35.0	−21.2	−12.3	−32.6	−25.3
Mean		182.6	120.7	194.1	129.1	−41.3	−52.7	−92.2	−77.0	−65.8
2-year rotations, manured:										
No. 21	Potatoes, sugar beets (manure)	212.1±13.97	154.5±17.18	334.1±12.08	235.5±16.87	−11.8	−18.8	+47.8	+29.4	+11.7
No. 25	Potatoes, oats (manure)	229.7±10.01	191.4± 9.57	326.9±16.21	221.2±18.59	+5.8	+18.0	+40.5	+15.1	+19.9
Mean		220.9	173.0	330.5	228.4	−3.0	−.4	+44.2	+22.3	+15.8
3-year rotation, untreated:										
No. 30	Potatoes, oats, sugar beets	225.4± 9.42	131.8± 7.03	218.5±13.15	166.8±19.36	+1.5	−41.5	−67.8	−39.3	−36.8
3-year rotation, manured:										
No. 31	Potatoes, oats (manure), sugar beets	246.1± 4.21	185.5±15.25	339.5±18.67	263.9±12.04	+22.3	+12.1	+53.2	+57.8	+36.4
4-year alfalfa rotations:										
No. 40	Alfalfa (2 years), potatoes, sugar beets	269.9±20.95	242.0± 9.31	344.5±19.30	258.4±25.92	+46.1	+68.6	+58.2	+52.3	+56.3
No. 44	Alfalfa (2 years), potatoes, oats	295.5±15.09	215.2±20.86	330.5±16.92	222.1±29.49	+71.6	+41.8	+44.2	+16.0	+43.4
Mean		282.7	228.6	337.5	240.3	+58.9	+55.2	+51.2	+34.2	+49.9

6-year alfalfa rotations, untreated:									
No. 60	Alfalfa (3 years), potatoes, oats, sugar beets	278.4±13.96	258.7±16.13	372.7±12.21	276.6±12.44	+54.6	+85.4	+86.4	+70.5	+74.2
No. 64	Alfalfa (3 years), potatoes, sugar beets, oats (started 1920)		241.9± 5.39	383.4± 7.68	303.3±15.83		+71.0	+97.1	+97.2	+88.4
Mean		278.4	250.3	378.1	290.0	+54.6	+78.2	+91.8	+83.9	+81.3
6- and 7-year alfalfa rotations, manured:									
No. 61	Alfalfa (3 years), potatoes, oats (manure), sugar beets	296.3±19.18	277.7±15.46	395.4± 8.51	285.6±12.63	+72.4	+104.3	+109.1	+79.5	+91.3
No. 71	Alfalfa (3 years), potatoes, sugar beets (manure), sugar beets, oats (started 1920)		210.2±23.76	361.5±11.18	276.2±25.31		+39.3	+75.1	+70.2	+61.5
Mean		296.3	244.0	378.5	280.9	+72.4	+71.8	+92.1	+74.9	+76.4

As has occurred with oats and sugar beets, the lowest yields have been harvested from the continuously cropped potato plot, which for the 23-year period has a minus departure from the mean yield of 127.7 bushels per acre. The next lowest yielding group is the one including the four 2-year simple rotations, which have a minus departure of 65.8 bushels, with the 3-year untreated rotation third. Of the three remaining groups which include alfalfa and applications of farm manure, the largest mean departure is from the 6-year rotations including alfalfa, secondly from the two alfalfa rotations to which manure is applied, and thirdly the 4-year rotations including alfalfa. Applications of farm manure apparently have stimulated the yields of potatoes above the mean yields of all rotations to the extent of 15.8 bushels in the 2-year rotations and 36.4 bushels per acre in 3-year rotation no. 31.

A comparison of the results from the individual rotations shows that the highest yields of potatoes for any period and for the entire 23 years have been harvested from rotation no. 61, to which farm manure is applied. This rotation has a mean yield for the four periods of 313.8 bushels and a plus departure of 91.3 bushels per acre. However, this yield is only 17.2 bushels in excess of no. 60 having a similar period of alfalfa but not receiving the manurial treatment. In view of the fact that there is a relatively high standard error, this difference cannot be considered significant. The results obtained from no. 60 as compared with no. 61 are confirmed by those recorded from rotation no. 71, which has the manurial treatment. The benefits in the form of increased yields of potatoes from 3 years of alfalfa as compared with rotations nos. 40 and 44, having but 2 years, are clearly apparent, there being a mean departure difference in favor of the former of 31.4 bushels per acre.

Applications of farm manure have definitely stimulated potato yields. Rotations nos. 20 and 21 are similar as to crops, but the latter had an application of manure every other year and preceding the potato crop. The mean plus departure of 87.2 bushels per acre may be attributed to the manurial treatment. This is a slightly more favorable difference than the 73.2 bushels per acre between the 3-year rotations nos. 30 and 31. That rye plowed under has had a beneficial effect in stimulating the yields of potatoes is apparent when the yields from rotation no. 24 are compared with those from rotation no. 27, there being a difference of 47.1 bushels in favor of rotation 27. The mean yields for the 23-year period from rotations nos. 20 and 24 are quite comparable, but the potato-corn rotation, no. 26, has returned the lowest yield next to continuously cropped plot 4.

In the foregoing discussion of the results with potatoes in the rotations total yields have been recorded. Throughout the 23-year period there has been a marked variation as to the quality and size of the potatoes from the different rotations. Tubers harvested from the continuously cropped plots and the 2-year rotations showed definitely more scab injury, whereas in the longer rotations, particularly those including alfalfa, they were nearly free from the disease. These facts are not reflected in the yields reported. Throughout the period a record has been kept of the percent of cull potatoes based upon local standards. In order to afford an opportunity of observing the variation in the percentages which have occurred,

table 11 is included. This gives a description of the rotations and the percentage of cull potatoes.

TABLE 11.—*Percentage of cull potatoes produced in the irrigated rotations, Scotts Bluff Field Station, 1924–33*

Rotation no.	Crops in the rotation	Percent	Rotation no.	Crops in the rotation	Percent
4	Potatoes continuously	31	40	Potatoes, sugar beets, alfalfa (2 years)	7
20	Potatoes, sugar beets	18	44	Potatoes, oats, alfalfa (2 years)	7
21	Potatoes, sugar beets (manure)	10	60	Potatoes, oats, sugar beets, alfalfa (3 years)	7
24	Potatoes, oats	15	61	Potatoes, oats (manure), sugar beets, alfalfa (3 years)	6
25	Potatoes, oats (manure)	9	64	Potatoes, sugar beets, oats, alfalfa (3 years)	7
26	Potatoes, corn	18	71	Potatoes, sugar beets (manure), sugar beets, oats, alfalfa (3 years)	7
27	Potatoes, oats (followed by rye plowed under)	11			
30	Potatoes, oats, sugar beets	15			
31	Potatoes, oats (manure), sugar beets	11			

The results recorded in table 11 are for the 10-year period 1924–33. The year 1934 was not included as the data for that season were not complete. The earlier years were omitted, for it is believed that the recent conditions more nearly reflect what should be expected under farm conditions were these rotation practices in effect for a correspondingly long term of years. The highest percentage of culls has been harvested from continuously cropped plot 4. The next two highest percentages of cull potatoes were harvested from 2-year rotations nos. 20 and 26, each of which have 18 percent. These results indicate that applications of farm manure have reduced the percentage of cull potatoes in comparable 2-year rotations, as is evident when the cull percentages from untreated rotations nos. 20 and 24 are compared with those from manured rotations nos. 21 and 25. The lowest percentages of cull potatoes consistently have been harvested from the 4-, the 6-, and the 7-year alfalfa rotations.

WHEAT

Table 12 affords an opportunity to observe the effect of six different cropping systems on the yields of wheat. There are three plots continuously cropped to wheat, two 2-year untreated rotations, and one 4-year alfalfa rotation. In one of the continuously cropped plots the straw is returned to the land and plowed under preparatory to the next season's seeding. The other two plots include one devoted to spring wheat and the other to winter wheat. With the exception of alfalfa rotation no. 48, it was not anticipated that any of these cropping systems are of a nature to return satisfactory wheat yields, although it was believed that useful information would be developed as to the extent that wheat yields would be influenced by such farm practices.

The lowest yields have been harvested from the three plots continuously cropped to wheat, and only from alfalfa rotation no. 48 have reasonably satisfactory yields been obtained. For the 23-year period this rotation has returned a yield of 24.7 bushels per acre.

TABLE 12.—*Mean annual yields of wheat compared with the annual means of all rotations, showing the effect on wheat yields of continuous cropping, simple rotations, and alfalfa rotations at the Scotts Bluff Field Station, 1912–34*

Rotation	Crops in the rotation	Mean acre yields of wheat (bushels), 6- and 5-year periods								
		Periodic yields and standard error				Increase (+) or decrease (−) as compared with the periodic means of all rotations				Mean departures for the 4 periods
		1912–17	1918–23	1924–29	1930–34	1912–17	1918–23	1924–29	1930–34	
Continuous cropping:										
No. 3	Spring wheat	23.9±1.05	11.3±1.02	12.5±0.70	8.4±1.13	−1.6	−4.9	−3.1	−2.1	−2.9
No. 5	Winter wheat	24.3±2.84	16.4±1.81	14.7±1.50	7.5±1.60	−1.2	+.2	−.9	−3.0	−1.2
No. 7	Spring wheat (straw returned)	22.6±.82	12.0±.47	12.2±1.24	8.3±1.43	−2.9	−4.2	−3.4	−2.2	−3.2
Mean		23.6	13.2	13.1	8.1	−1.9	−3.0	−2.5	−2.4	−2.4
2-year rotations:										
No. 18	Spring wheat, sugar beets	27.8±1.66	19.4±1.31	16.0±.68	9.6±1.02	+2.3	+3.2	+.4	−.8	+1.3
No. 28	Spring wheat, oats	22.9±1.81	15.4±.41	12.1±.74	9.2±.76	−2.6	−.8	−3.5	−1.2	−2.0
Mean		25.4	17.4	14.1	9.4	−.2	+1.2	−1.6	−1.0	−.4
4-year alfalfa rotation:										
No. 48	Alfalfa (2 years), spring wheat, oats	31.4±1.10	22.8±1.71	25.0±1.53	19.7±4.08	+5.9	+6.6	+9.4	+9.2	+7.8

These results indicate that the wheat straw returned actually has had a slightly adverse effect on wheat yields, as no. 7, where this practice has been followed, has returned a 23-year mean yield of only 13.8 bushels, the lowest of any of the cropping systems. The next lowest yield is from continuously cropped spring wheat plot 3, with a yield for the complete period of 14.0 bushels; the 2-year spring wheat-oats rotation is third, with a mean yield of 14.9 bushels. Slightly better results were obtained with winter wheat continuously cropped, which has a mean periodic yield of 15.7 bushels. However, none of the difference existing among nos. 3, 5, 7, and 28 can be considered significant.

CORN

In table 13 are given the yields of corn in the five different cropping systems which include this crop. Corn is grown on one continuously cropped plot, on two 2-year simple rotations, on one 3-year simple rotation, and on 6-year alfalfa rotation no. 62.

As has occurred with the other crops discussed in this bulletin the lowest yields of corn have been harvested from the continuously cropped plot with the two untreated 2-year rotations the second lowest and the 3-year rotation third. The highest yield, 55.7 bushels of corn per acre, has been harvested from the 6-year alfalfa rotation no. 62. This is 29.3 bushels in excess of the yield from the continuously cropped plot, which returned a per acre yield of only 26.4 bushels. That corn yields are materially in excess of those harvested from the wheat plots is apparent when the results in table 12 giving the wheat yields are compared with those from corn recorded in table 13. The highest wheat yield, harvested from alfalfa rotation no. 48, totaled 24.7 bushels per acre, or 31.0 bushels less than the corn yields from rotation no. 62. There is a slight difference in the yields of corn between the two 2-year and the one 3-year rotation, but the differences which have occurred are slight and when compared with the standard errors are not considered significant.

COMPARATIVE VALUE OF THE DIFFERENT ROTATIONS

The foregoing pages have been devoted to a presentation of the results indicating the extent to which the various crop sequences and treatments have influenced the yields of oats, sugar beets, potatoes, wheat, and corn; but this method does not afford an opportunity of evaluating and comparing the various rotations when each is considered as a complete unit. It is apparent that the yields have fluctuated within wide limits as certain crop sequences have resulted in good yields while with others less satisfactory results have been obtained. Because of the higher production costs of the staple farm crops, irrigation farmers are forced to increase their yields proportionately if they are to compete successfully with those engaged in similar enterprises on unirrigated land. While relatively large yields are essential to a successful irrigation agriculture, the actual and indirect costs incident to obtaining such yields are of equal importance. Sugar beets and potatoes are the chief cash crops produced on the North Platte project and for 23 years have proved to be the most profitable crops grown, but it should not be assumed that the cropping systems returning the highest yields of these crops are the most profitable.

TABLE 13.—*Mean annual yields of corn compared with the annual means of all rotations, showing the effect on corn yields of continuous cropping, simple rotations, and alfalfa rotations at the Scotts Bluff Field Station, 1912–34*

Rotation	Crops in the rotation	Mean acre yields of corn (bushels), 6- and 5-year periods								
		Periodic yields and standard error				Increase (+) or decrease (−) as compared with the periodic means of all rotations				Mean departures for the 4 periods
		1912–17	1918–23	1924–29	1930–34	1912–17	1918–23	1924–29	1930–34	
Continuous cropping:										
No. 6	Corn	38.1±3.35	27.3±2.45	20.9±2.69	19.2±2.50	−11.5	−8.3	−10.7	−8.7	−9.8
2-year rotations:										
No. 16	Corn, oats	54.1±1.41	29.6±1.89	21.9±2.32	19.2±1.32	+4.5	−6.0	−9.7	−8.7	−5.0
No. 26	Potatoes, corn	48.9±1.69	31.0±3.55	27.2±2.96	24.2±2.15	−.7	−4.5	−4.4	−3.8	−3.4
Mean		51.5	30.3	24.6	21.7	+1.9	−5.3	−7.1	−6.3	−4.2
3-year rotation:										
No. 32	Corn, oats, sugar beets	48.4±1.34	33.7±1.71	30.8±2.23	26.3±2.02	−1.2	−1.8	−.9	−1.7	−1.4
6-year alfalfa rotation:										
No. 62	Alfalfa (3 years), corn, oats, sugar beets	58.4±3.54	56.1±5.23	57.2±5.76	50.9±2.75	+8.8	+20.6	+25.6	+22.9	+19.5

Before this can be ascertained, information must be made available as to the estimated net returns from all crops included in the cropping program. In general, diversification of crops is to be commended, but the results recorded in the following tables emphasize that consideration must be given as to the expected returns from the enterprise as a whole if the farmer is to make the most of his opportunities.

In addition to affording an opportunity of ascertaining the merits of diversification insofar as this practice is followed in these various rotations, other significant comparisons may be made. It is possible to measure the value of stable manure when it is applied every year to the plot continuously in alfalfa, to ascertain the value of manure in a 2-year rotation, and whether manuring is more profitable in 2-year or in 3-year rotations. In rotation no. 61, which receives an application of stable manure every sixth year preceding sugar beets, it is possible to determine to what extent such a practice increases the net returns by comparing it with no. 60, which does not receive such treatment. The total value of each of a number of rotations in which alfalfa is included has been determined and may be compared with others where this crop is not included. Considering the initial high first-year cost of seed and seeding together with the low yield, some information is made available as to whether alfalfa should be left in for 2 or 3 years. In rotation no. 45 the harvesting of sweetclover by livestock has been practiced, which is followed by sugar beets for 2 successive years. A measure of the merits of this practice is possible.

The procedure followed in arriving at the estimated net returns for each rotation was as follows: The production costs were determined by using for the cultural-operation costs those recognized as somewhat standardized in the community, such for instance, as contract labor, hauling sugar beets, harvesting grain, plowing, taxes, and irrigation water. Other items of expense, such as disking, harrowing, and planting, were estimated, based partly on the experience in performing these operations at the station as well as observations made among the farmers on the project. In arriving at the costs of growing sugar beets, $18 was the figure used to cover contract labor costs. In all instances $11 per acre was allowed for water costs, tool maintenance, miscellaneous repairs, interest, and depreciation. The cost of applying farm manure was estimated as $7 per acre. The unit value placed on the different crops is believed not to be in excess of the average value of these crops for the 5 years, 1930–34, and is as follows: Alfalfa, $7 per ton; sugar beets, $6 per ton; oats, 40 cents per bushel; marketable potatoes, 50 cents per bushel, while culls were valued at 15 cents per bushel; corn, 60 cents per bushel; wheat, 75 cents per bushel. The net returns have been computed on only one rotation, no. 45, where harvesting with livestock has been practiced. Other expenses in connection with pasturing sweetclover in this rotation were the value of the grain or hay fed, together with the estimated costs incident to caring for the livestock, in this instance $7 per acre for the season. The returns were computed upon the net gain in weight and the value of the gains based on the prevailing price paid for such livestock to farmers in the community. In computing the returns, the mean yields for the 23-year period have been used. The results are given in table 14.

TABLE 14.—*Comparative value of the different rotations, Scotts Bluff Field Station*

Crops, treatments, and sequences	Rotation no.	Relative value [1]	Crops, treatments, and sequences	Rotation no.	Relative value [1]
Sugar beets (manure), potatoes	21	$28.23	Alfalfa (2 years), oats, sugar beets	42	$0.78
Oats (with sweetclover), sweetclover pastured, sugar beets (2 years)	45	24.26	Alfalfa (2 years), potatoes, oats	44	4.46
Alfalfa (3 years), potatoes, sugar beets (manure), sugar beets, oats	71	21.45	Potatoes, oats, sugar beets	30	2.55
Oats (manure), sugar beets	23	21.32	Oats (rye plowed under), potatoes	27	.00
Alfalfa (2 years), potatoes, sugar beets	40	21.05	Sugar beets, potatoes	20	.65
Potatoes, oats (manure), sugar beets	31	20.80	Oats, sugar beets	22	.13
Alfalfa (3 years), potatoes, oats (manure), sugar beets	61	20.44	Spring wheat, sugar beets	18	−.39
Alfalfa (3 years), potatoes, sugar beets, oats	64	19.15	Corn, oats, sugar beets	32	−1.26
Alfalfa (3 years), potatoes, oats, sugar beets	60	13.11	Alfalfa (2 years), spring wheat, oats	48	−3.10
Oats (manure), potatoes	25	8.94	Sugar beets continuously	2	−4.71
Alfalfa continuously	8	7.60	Oats, potatoes	24	−5.09
Alfalfa (3 years), corn, oats, sugar beets	62	6.05	Corn, oats	16	−6.53
			Potatoes, corn	26	−7.66
			Corn continuously	6	−8.0[illegible]
			Oats continuously	1	−10.61
			Spring wheat, oats	28	−11.83
			Winter wheat continuously	5	−12.03
			Spring wheat continuously	3	−13.05
			Spring wheat, straw returned	7	−13.1[illegible]
			Potatoes continuously	4	−28.08

[1] The minus sign (−) indicates loss.

The rotation indicating the highest net return is no. 21 devoted to potatoes and sugar beets, the chief cash crops of the area. While this rotation was the highest in respect to net returns, there were eight rotations returning higher yields of potatoes, and five from which larger yields of sugar beets were harvested. The cropping program which has proved to be the second most profitable is no. 45, which has 2 years of sugar beets and includes sweetclover pastured. Of the eight rotations indicating a satisfactory net return of $19 or more per acre, five of them have received applications of farm manure, one has pasturing, and the other two include alfalfa. There are five pairs of comparable rotations, the only difference being that one in each instance has an application of farm manure during its cycle, whereas the other does not have this treatment. The difference in the net returns provide an opportunity of ascertaining the value of the manurial treament. This treatment has increased the differences between rotations nos. 20 and 21, $27.58; nos. 22 and 23, $21.19; nos. 24 and 25, $14; nos. 30 and 31, $18.31; and nos. 60 and 61, $7.33 per acre. It is evident that applications of stable manure have increased substantially the per acre net returns for exclusive alfalfa rotations, nos. 60 and 61; there is a mean per acre value increase for the remaining four pairs of $20.27 per acre, which may be attributed to this soil amendment. Similar comparisons may be made with three pairs of rotations, one of which in each instance includes alfalfa and the other does not include this crop. These three pairs are nos. 20–40, 22–42, and 24–44. The mean value increase which may be credited to alfalfa is $12.20 per acre. Similar comparisons may be made with the two 6-year rotations, which have 3 years of alfalfa and indicate a per acre value increase of $18.77. With the exception of alfalfa, all crops grown continuously on the same land year after year indicate losses, the maximum of $28.08 having occurred with potatoes. Furthermore, all simple 2- and 3-year rotations either show a loss or a very slight profit.

SUMMARY

This bulletin records the results from a series of rotation experiments conducted at the Scotts Bluff (Nebr.) Field Station, located on the North Platte reclamation project.

It is not to be expected that an irrigated agriculture where staple farm crops are produced can be successfully maintained unless the yields harvested are relatively high. It is well recognized that the adoption of a proper crop rotation or treatment of the soil is one of the more important prerequisites to obtaining crop yields of a high order.

The Scotts Bluff area has an elevation of about 4,000 feet above sea level. The climate is semiarid, with a mean annual rainfall of slightly more than 14 inches and a mean frost-free period of 133 days.

The chief crops grown in the area are sugar beets, potatoes, alfalfa, corn, and small grains. Dairying is an important farm enterprise, and winter feeding of range stock is somewhat generally practiced.

The soils in the Scotts Bluff area largely range from a sandy loam to a loamy very fine sand, with the Mitchell, a very fine sandy loam, predominating.

There are 34 different cropping systems included in the series herein discussed.

The cultural methods followed, which are briefly discussed, have been the same for all rotations each year in order to avoid insofar as possible differences in yield due to factors other than the treatments to which the crops have been subjected.

The chief purpose of these rotations was to obtain information that would be useful to persons engaged in crop production on the project and also to those engaged in similar agricultural enterprises on adjoining irrigated areas having comparable soil and climatic conditions. This information was sought by comparing the yields from certain crops grown continuously on the same land with numerous crop sequences in which the rotations were otherwise untreated, ascertaining the effect of applications of stable manure in 2- and 3-year rotations, and determining the value of alfalfa when included in certain cropping systems. The effect on crop yields of harvesting certain crops with livestock instead of in the customary manner may be observed in certain rotations; the value of rye as a green-manure crop may be observed in one rotation; the effect of an application of manure in a cropping system including alfalfa may be compared with others not so treated.

The mean annual yields of oats, sugar beets, potatoes, corn, wheat, and alfalfa are given for the years 1912–25, followed by the annual yields of these crops from 1926 to 1934 together with the mean for this 9-year period.

To afford an opportunity of observing the annual fluctuations of the mean yields for the six crops, a table is presented expressing the yield fluctuations in percentages. The lowest mean recorded from 1926 to 1934 occurred in 1934 and the highest percentage in 1928. When computed on the basis of periods the highest percentage, 122, was for the first 6-year period, 1912–17, and the lowest, 77 percent, occurred in the last 5-year period, 1930–34.

The yields from the different crops are summarized and compared for the purpose of determining yield trends and to what extent production has been influenced by the different cropping systems throughout the 23 years.

The lowest mean yields of oats have been from the plot continuously in oats and from the 2-year untreated rotations, while the highest mean yields have been harvested from manured alfalfa rotations 61 and 71.

Sugar-beet yields have been the most favorably influenced by applications of farm manure and by harvesting one or more crops in the

rotation by livestock. While alfalfa has definitely increased beet yields, the increases have not been so great as has resulted from the manurial treatment or when pasturing has been practiced.

Contrary to the results obtained with sugar beets, alfalfa has exerted a more favorable influence on the yields of potatoes than have applications of farm manure. The highest mean yields of potatoes have been harvested from the two 6-year alfalfa rotations, secondly, from the two alfalfa rotations to which manure was applied; and thirdly, from the two 4-year alfalfa rotations.

The effect of the different rotational treatments on the quality of potatoes is discussed. A table is included giving the mean percentage of cull potatoes for the period 1924–33. The highest percentage of culls has come from the continuously cropped plot. In every instance the lowest percentages of cull potatoes have been harvested from the rotations including alfalfa.

Due to the types of rotations, the yields of wheat have been quite low. The highest mean yield, 24.7 bushels per acre, for the 23 years was harvested from 4-year alfalfa rotation no. 48.

Yields of corn have been distinctly higher than wheat. The highest mean yield of corn, 55.7 bushels per acre, came from 6-year alfalfa rotation no. 62.

The comparative value of the different rotations has been determined. This affords an opportunity of determining the merits of the different cropping systems as a complete unit. The highest net return is from manured rotation no. 21, devoted to sugar beets and potatoes, the chief cash crops of the area. The next highest return is from pastured rotation no. 45. Of the 8 rotations indicating a net return of $19 or more per acre, 5 of them receive applications of farm manure, 1 includes pasturing, and the other 2 are alfalfa rotations.

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