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IRRIGATED CROP ROTATIONS IN WESTERN NEBRASKA

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INTRODUCTION

The experiments here reported were conducted at the Scotts Bluff Field Station on the North Platte reclamation project in western Nebraska. This field station is located about 8 miles northwest of the town of Scottsbluff and 6 miles east of the town of Mitchell. It is supported cooperatively by the Nebraska Agricultural Experiment Station, the Bureau of Reclamation, and the Bureau of Plant Industry. The soil of the field station is typical of that covering the sloping bench lands that parallel the North Platte River on the north side. It is a friable sandy loam overlying a fissured yellow clay known locally as Brule clay. Although this clay subsoil comes close to the surface or is exposed in some places on the irrigated land of the district, it is so deeply covered at the site of the field station as not to be a part of the soil horizon. The soil profile is readily permeable to water and well drained.

The agricultural area represented by the Scotts Bluff Field Station lies near the western edge of the region where dry farming is practicable. The elevation is 4,000 feet above sea level, and the annual precipitation is approximately 15 inches. Irrigation is used on approximately 375,000 acres of land in that section, the North Platte River being the chief source of supply. The more important crops of the region include alfalfa, sweet clover, sugar beets, small grains, corn, and potatoes. The forage and grain crops are largely consumed locally for feeding to sheep and beef cattle shipped in from adjacent range lands and to dairy cattle and hogs produced on the farms. Sugar beets and potatoes are the crops chiefly grown for sale. Of these the beet crop is by far the more extensively grown.

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The Scotts Bluff Field Station was established in 1910. The land had not previously been cultivated. The native plant cover consisted of grasses and other herbaceous plants, without trees or brush of any kind. The field devoted to the irrigated rotations was broken late in 1910, backset, and sown to oats in the spring of 1911. In the fall of that year the field was laid out in five series of plots. The series run north and south and are separated by roadways 40 feet wide with an irrigation ditch in the middle of each roadway. In each series there are 18 plots, each of one-fourth acre. 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 entire five 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 also a 7-year rotation was begun on seven plots at the south end of a series adjoining Series I on the west. These plots were designated series 0, and the plots involved in the new rotation, No. 71, are numbered 12 to 18, inclusive.

The rotation experiments conducted at the Scotts Bluff Field Station are similar in scope and character to experiments begun at the same time at the Belle Fourche Field Station near Newell, S. Dak., and at the Huntley Field Station near Huntley, Mont.[1] These three sets of rotation experiments were planned and inaugurated by the senior writer in collaboration with F. D. Farrell. The field work at the Scotts Bluff station has been supervised and reported by the junior writer.

PLAN OF THE ROTATIONS

These rotation experiments were planned to ascertain the following points: (1) The effect on crop yields of growing crops in 2-year and 3-year rotations as compared with growing the same crops continuously on the same land; (2) the effect on crop yields of applying barnyard manure to the land for one crop in a rotation, comparison being made with similar rotations in which manure is not used; (3) the effect on crop yields of incorporating alfalfa as a crop in the rotation, comparison being made with similar rotations in which alfalfa is not grown.

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 region; (2) the effect on the yields of spring wheat, grown continuously, of 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 green-manure crop; and (4) a comparison of the values obtained from a rotation including alfalfa and corn

[1] SCOFIELD, C. S. EFFECT OF FARM MANURE IN STIMULATING THE YIELDS OF IRRIGATED FIELD CROPS. Jour. Agr. Research 15: 493–503. 1918.
——— EFFECT OF ALFALFA ON THE SUBSEQUENT YIELDS OF IRRIGATED FIELD CROPS. U. S. Dept. Agr. Bul. 881, 13 pp. 1920.

where hogs are used to pasture the alfalfa and the corn, as related to the values obtained when these crops are harvested in the ordinary way.

The following crops were included in the original series of rotations started in 1912:[2] (1) Oats, (2) sugar beets, (3) spring wheat, (4) potatoes, (5) winter wheat, (6) corn, (8) alfalfa, (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: (16) Corn and oats; (18) spring wheat and sugar beets; (20) sugar beets and potatoes; (22) oats and sugar beets; (24) oats and potatoes; (26) potatoes and corn; (28) spring wheat and oats; (30) potatoes, oats, and sugar beets; (32) corn, oats, and sugar beets.

The following 2-year and 3-year rotations had manure applied in the sequence here indicated at the rate of 12 tons of manure per acre: (21) Sugar beets, manure, potatoes; (23) oats, manure, sugar beets; (25) oats, manure, potatoes; (31) potatoes, oats, manure, sugar beets.

In the following rotations alfalfa was grown for the period and in the sequence indicated: (40) Alfalfa (2 years), potatoes, sugar beets; (42) alfalfa (2 years), oats, sugar beets; (44) alfalfa (2 years), potatoes, oats; (48) alfalfa (2 years), spring wheat, oats; (60) alfalfa (3 years), potatoes, oats, sugar beets; (62) alfalfa (3 years), corn, oats, sugar beets. In addition to the foregoing, one rotation included both manure and alfalfa; (61) alfalfa (3 years), potatoes, oats, manure, sugar beets.

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

The preceding list of rotations includes those that were started in 1912. In 1920 three additional rotations were begun as follows: (45) Oats, sweet clover, sugar beets, sugar beets (the sweet clover was seeded with the oats and pastured with sheep); (64) oats, alfalfa (3 years), potatoes, sugar beets; (71) oats, alfalfa (3 years), potatoes, sugar beets, manure, sugar beets. The purpose of rotation 45 is to determine the possibility of keeping up the yields of sugar beets in a short rotation with sweet clover. This rotation is not directly comparable to any other in the series; it is rather to be grouped with the subordinate rotations 27 and 65. Rotation 64 may be compared with rotation 30, though it differs from the latter in two respects, namely, in that it includes three years of alfalfa and that the sequence of the other crops is not the same. In rotation 30 the sequence is potatoes, oats, sugar beets, whereas in rotation 64 the sequence is potatoes, sugar beets, oats. This rotation may be compared also with rotation 60, from which it differs only in one respect, namely, in the sequence of the crops other than alfalfa. Rotation 71 is comparable with rotation 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.

[2] A number in parenthesis is used to identify each cropping sequence or rotation, and the same number is used in this sense in the text and tables that follow.

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

Two-year rotations

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

Three-year rotations

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

Four-year rotations

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

Six-year rotations

60. Alfalfa (3 years), potatoes, oats, sugar beets.
61. Alfalfa (3 years), potatoes, oats, sugar beets (manured).
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.

Seven-year rotation

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

The location of these rotations with reference to one another in the field is shown in the accompanying diagram (fig. 1).

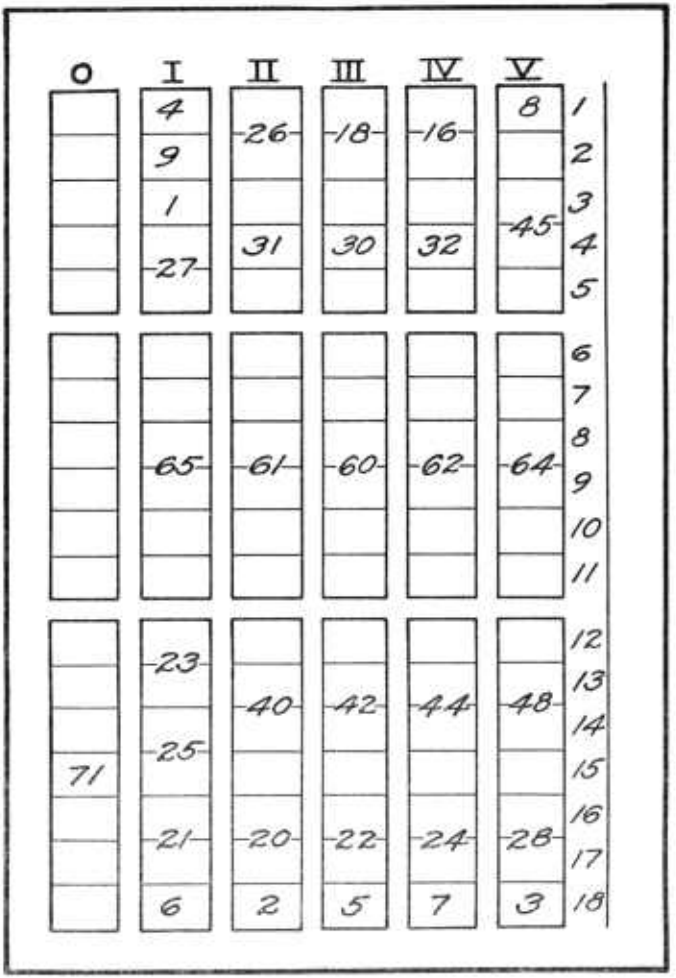

FIG. 1.—Diagram showing the field location of the irrigated rotations at the Scotts Bluff Field Station

CULTURAL METHODS AND CROP VARIETIES

In view of the fact that the aim of these experiments has been to ascertain the effect of rotations on crop yields, it has been the practice to give the same cultural treatment to all plots of the same crop so far as the conditions of the rotation would permit. The same crop varieties have been used on all plots of the same crop each year, though it has been found advisable to change the variety in the case

of some of the crops. In general the cultural treatment has been such as is called for in good farming and is generally practiced in the neighborhood.

In those 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 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, this method of seeding has given good results. When grasshopper injury has been severe it has been necessary to plow the oat stubble the following spring and to reseed the alfalfa. 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 up 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 fairly deep after growth starts in the spring.

Sugar beets were seeded on fall-plowed land where the crop followed small grain and on spring-disked land where it followed potatoes or beets. Seed of the Kleinwansleben variety 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 1917, and the Kherson (Nebraska No. 21) variety was used from 1918 to 1925.

Spring wheat was sown on fall-plowed land, except in rotations 18 and 48. In rotation 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 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 1925.

The plot used for winter wheat was plowed and harrowed about a week before seeding time. The Turkey variety has been used continuously. Flax of the variety known as Minnesota No. 25 has been used. In rotation 9 the land was fall plowed, whereas in rotation 65 it was disked in the spring. This crop has not done well at Scotts Bluff, no yield having been obtained for several seasons, chiefly because of poor growth and weeds.

The plots to be used for potatoes were fall plowed for rotations 24 and 25 and spring plowed for the others. In rotation 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 was used from 1912 to 1918, the Downing in 1919, and the Bliss Triumph from 1920 to 1925.

The plots for corn were all spring plowed. A local variety of Calico corn was used from 1912 to 1921 and a local white variety from 1922 to 1925.

The program of irrigation and cultivation has been adjusted each season in relation to climatic conditions and the needs of the crops. As far as practicable, crops of the same kind have had the same

cultural treatment. In some instances injury by storms or insect pests has necessitated the replanting of crops on some plots. The differences in such injury have been to some extent associated with the different systems of crop rotation and to that extent are properly given full weight in the final results. There have been, in addition, certain accidental injuries which have not been suffered uniformly and which could not be allowed for in the final results because the effects could not be definitely measured.

BASIC YIELD DATA

In presenting the results of these rotation experiments it appears to be desirable to give in detail the basic facts as to the crop yields obtained. These facts may be summarized and compared in a number of different ways. Some of these comparisons and summaries accompany and follow the tables of yields. But other investigators may have occasion to make still other interpretations or to evaluate the conclusions here drawn.

The details as to crop yields are given in a series of tables, one table for each crop. The yields per acre are given for each year and for each rotation. Mean yields are given both for all plots of the same crop for each year and for each rotation for the period of 14 years covered by the experiments. In addition, the mean yields for the last 5 years of the experiments are reported.

TABLE 1.—*Yields of oats in irrigated rotations at the Scotts Bluff Field Station, 1912 to 1925, inclusive*

Rotation	Acre yields (bushels)															
	1912	1913	1914	1915	1916	1917	1918	1919	1920	1921	1922	1923	1924	1925	Mean, 14 years	Mean, last 5 years
No. 1	90.8	72.8	71.9	12.6	39.6	60.4	48.1	27.1	33.4	14.4	49.3	48.7	35.6	48.3	46.6	39.3
No. 16	86.4	58.8	56.6	18.6	57.6	59.5	50.8	43.1	41.5	42.1	36.6	46.3	40.2	35.6	48.1	40.2
No. 22	97.6	90.0	75.8	16.2	49.1	75.0	53.4	42.1	44.0	44.0	49.0	62.3	30.4	29.0	54.1	42.9
No. 23	93.7	88.8	89.4	15.0	51.3	78.5	59.8	59.3	69.3	45.0	68.6	76.3	52.8	63.4	65.1	61.2
No. 24	108.1	95.8	69.4	18.9	56.0	65.3	50.5	52.3	34.0	43.5	45.5	48.1	35.3	51.0	55.3	44.7
No. 25	82.4	94.1	83.6	11.1	35.5	75.3	69.7	44.8	57.6	48.1	73.0	72.0	64.2	66.3	62.7	64.7
No. 27	97.5	99.3	84.6	20.0	53.1	96.9	69.8	39.4	50.5	34.0	66.0	63.2	33.8	64.3	62.3	52.3
No. 28	112.2	72.0	65.2	8.9	33.0	52.6	43.6	37.5	29.6	25.6	38.8	35.3	30.1	35.3	44.3	33.0
No. 30	81.3	86.5	78.8	16.5	63.7	65.4	69.0	59.4	43.0	47.1	57.5	60.3	48.5	49.3	59.0	52.5
No. 31	99.6	94.3	86.4	20.0	71.4	88.0	70.9	56.6	73.4	54.4	89.2	80.1	62.5	71.6	73.4	71.6
No. 32	82.4	56.4	51.1	10.5	68.2	60.8	59.8	39.9	40.9	42.5	41.7	36.5	36.1	29.9	46.9	37.3
No. 42	94.4	101.3	95.4	15.6	54.6	79.5	70.9	54.4	74.6	40.0	74.3	67.6	63.6	89.1	69.7	66.9
No. 44	117.0	90.3	94.9	20.0	61.7	68.6	72.1	48.6	62.9	51.2	83.5	79.0	72.6	89.1	72.2	75.1
No. 45									51.9	53.6	60.4	61.0	52.7	54.0		56.3
No. 48	118.5	76.8	83.4	22.0	41.0	60.7	59.3	52.3	67.0	55.0	73.6	74.0	76.9	84.6	67.5	72.8
No. 60	88.8	89.6	83.7	17.6	56.4	73.6	77.4	55.2	70.9	56.0	79.6	73.2	78.6	100.8	71.5	77.6
No. 61	97.6	86.8	82.6	19.4	55.7	75.9	90.5	57.9	74.6	52.0	89.6	73.8	92.2	113.8	75.9	84.3
No. 62	84.5	52.5	69.8	12.5	48.2	65.1	79.5	56.6	68.4	52.1	66.0	70.0	70.0	96.6	63.7	70.9
No. 64									68.6	54.2	62.2	74.8	68.0	80.5		67.9
No. 65	98.6	86.5	69.0	14.0	66.7	87.5	76.9	46.9	85.9	53.0	93.0	81.2	64.5	94.5	72.7	77.2
No. 71										54.4	62.0	67.2	58.5	79.6		64.3
Annual mean	96.2	82.9	77.3	16.1	53.5	71.6	65.6	48.5	57.1	45.8	64.7	64.3	55.6	67.9	61.9	59.6
Maximum	118.5	101.3	95.4	22.0	71.4	96.9	90.5	59.4	85.9	56.0	93.0	81.2	92.2	113.8		
Range	37.2	48.8	44.3	13.9	38.4	44.3	46.9	32.3	56.3	41.6	56.4	45.9	62.1	84.8		

Table 1 gives the yields of oats from all rotations. There are 18 plots from which yields are reported for the full period of 14 years. Two additional plots have been included beginning with 1920 and one with 1921. The mean yield of the 18 plots for the 14-year period

has been just under 62 bushels per acre, which indicates generally favorable conditions for this crop. The largest yield reported is at the rate of 118.5 bushels per acre. In 1915 a severe hailstorm occurred a few days before the crop was ready to harvest. The yields reported for that year are consequently not very significant. The range in annual yields, that is, the difference between the highest yield and the lowest yield, has increased with the progress of the experiments.

Table 2 gives the yields of sugar beets. There are 14 plots reported for the 14-year period and 5 plots for the years beginning with 1920. The mean yield of the 14 plots for 14 years was 14.8 tons per acre. The largest yield reported for any plot was at the rate of 25.5 tons per acre. In 1916 a severe storm of wind, rain, and hail occurred early in June, causing serious injury to the young beets. On some plots the losses were so great that it was thought advisable to reseed. On other plots the stand, though irregular, was thought to be such as to promise better results than reseeding. This storm injury accounts for the irregular and low average yields of that year. In other years there have been losses of stand through wind or rain injury on certain plots, and occasionally reseeding has been resorted to. Some of the low yields reported in the table are owing to such injuries.

TABLE 2.—*Yields of sugar beets in irrigated rotations at the Scotts Bluff Field Station, 1912 to 1925, inclusive*

Rotation	Acre yields (tons)															Mean, 14 years	Mean, last 5 years
	1912	1913	1914	1915	1916	1917	1918	1919	1920	1921	1922	1923	1924	1925			
No. 2	12.68	16.03	13.35	8.23	4.93	9.76	11.74	8.25	5.86	8.51	6.73	5.83	9.07	8.62		9.26	7.75
No. 18	19.47	18.09	16.57	12.23	9.98	11.33	11.09	4.52	6.24	8.98	10.73	9.68	11.08	12.62		11.61	10.62
No. 20	15.29	19.55	14.50	10.58	5.77	13.03	15.26	11.23	4.22	10.88	11.20	8.96	12.56	13.34		11.88	11.39
No. 21	13.46	20.83	17.24	13.13	6.36	16.97	19.52	15.81	12.26	17.01	18.80	17.04	19.66	21.84		16.42	18.87
No. 22	13.88	18.31	14.20	12.00	7.33	11.15	14.30	8.05	6.76	10.15	11.38	8.03	11.09	11.56		11.30	10.44
No. 23	19.41	21.41	19.87	15.92	9.39	18.55	23.17	15.29	14.40	15.60	19.96	20.13	20.19	21.42		18.19	19.45
No. 30	17.63	17.03	13.94	10.20	9.76	9.13	10.62	7.69	8.06	10.02	12.52	10.68	12.30	13.68		11.66	11.84
No. 31	21.44	23.80	17.44	15.56	15.07	15.96	20.22	14.16	12.72	15.17	19.70	19.32	17.68	21.70		17.85	18.71
No. 32	15.82	17.23	14.62	10.14	8.80	10.82	8.92	9.07	7.23	9.42	12.11	11.32	10.43	12.84		11.34	11.22
No. 40	18.72	21.15	21.17	16.32	10.41	17.74	21.80	20.17	15.24	12.52	22.24	15.77	19.71	19.16		18.01	17.88
No. 42	14.26	15.41	20.67	16.35	7.26	14.55	21.95	17.25	14.89	11.65	19.61	16.76	16.60	14.82		15.86	15.89
No. 45-1	----	----	----	----	----	----	----	----	10.42	15.16	20.32	18.67	22.68	23.12		----	19.99
No. 45-2	----	----	----	----	----	----	----	----	9.64	15.89	12.13	18.34	17.34	19.16		----	16.57
No. 60	17.26	17.19	14.78	12.48	7.53	15.31	16.04	13.90	13.25	11.19	18.70	14.87	18.22	20.30		15.08	16.67
No. 61	22.41	23.39	18.49	15.32	11.90	19.46	23.28	17.78	16.92	13.76	22.22	20.15	22.65	25.50		19.52	20.86
No. 62	17.87	16.89	14.33	13.32	6.79	15.45	16.53	14.22	10.85	12.32	17.33	15.19	16.60	17.94		14.68	15.88
No. 64	----	----	----	----	----	----	----	----	8.16	15.54	18.43	17.16	21.59	21.00		----	18.74
No. 71-1	----	----	----	----	----	----	----	----	12.31	17.48	19.66	18.27	19.26	20.82		----	19.10
No. 71-2	----	----	----	----	----	----	----	----	14.82	16.15	17.93	21.86	19.69	20.68		----	19.26
Annual mean	17.11	19.02	16.51	12.98	8.66	14.23	16.75	12.67	10.75	13.02	16.41	15.16	16.76	17.90		14.85	15.85
Maximum	22.41	23.80	21.17	16.35	15.07	19.46	23.28	20.17	16.92	17.48	22.24	21.86	22.68	25.50		----	----
Range	9.73	8.39	7.82	8.12	10.14	10.33	14.36	15.65	12.70	8.97	15.51	16.03	13.61	16.88		----	----

Table 3 gives the total yield of potatoes. There are 13 plots reported for the 14-year period and two additional plots from 1921 are included. The mean yield of the 13 plots for the full period of the experiment is 214.5 bushels per acre. The largest single yield reported was at the rate of 441.3 bushels per acre. In 1915 the potato tops were badly cut by the hailstorm that injured the oats that year, and yields were materially reduced. In 1918 the yields were low and

irregular, but no adequate cause is known. In 1923 the crop suffered from an attack of early blight and the yields were low, though less irregular than in 1918.

TABLE 3.—*Yields of potatoes in irrigated rotations at the Scotts Bluff Field Station, 1912 to 1925, inclusive*

Rotation	Acre yields (bushels)														Mean, 14 years	Mean, last 5 years
	1912	1913	1914	1915	1916	1917	1918	1919	1920	1921	1922	1923	1924	1925		
No. 4	192.3	192.0	119.2	65.1	128.6	61.6	14.5	50.3	72.7	81.0	98.0	38.0	144.0	145.7	100.2	101.3
No. 20	194.5	398.4	146.0	87.6	142.5	131.1	87.4	133.7	93.4	132.0	133.4	68.3	172.3	178.7	150.0	136.9
No. 21	230.0	316.2	236.9	147.2	154.7	187.3	94.5	194.2	214.7	74.1	250.0	99.7	339.7	397.3	209.7	232.2
No. 24	252.3	234.6	146.2	109.1	217.5	134.1	150.0	158.5	139.4	42.0	161.3	74.7	213.3	213.3	160.4	140.9
No. 25	230.3	348.4	253.5	147.6	216.5	181.9	192.3	196.2	216.7	151.1	262.1	130.0	264.0	411.3	228.7	243.7
No. 26	221.2	241.2	142.5	100.7	226.7	122.1	66.1	199.8	122.7	128.0	125.3	57.6	174.7	203.0	145.8	137.7
No. 27	241.3	169.2	131.1	126.9	245.5	219.1	143.1	133.0	158.0	159.3	213.2	106.7	271.3	289.7	186.2	208.0
No. 30	268.2	329.5	216.0	145.8	226.2	166.6	79.2	117.3	188.7	121.1	183.3	101.4	216.5	214.7	183.9	167.4
No. 31	250.0	353.1	243.3	175.0	243.9	211.5	81.1	184.5	266.7	200.1	259.3	121.3	326.7	348.7	233.2	251.2
No. 40	171.8	403.2	280.0	205.6	285.5	273.4	179.0	251.9	309.4	257.0	283.3	171.4	369.3	428.7	276.4	301.9
No. 44	226.2	401.6	319.3	227.7	307.6	290.4	226.7	195.7	329.3	132.0	268.7	138.6	345.3	441.3	275.0	265.2
No. 60	244.6	322.1	272.2	231.5	318.8	281.2	237.8	211.5	360.0	263.0	326.1	154.0	382.0	368.0	283.8	298.6
No. 61	225.6	380.4	299.4	220.2	305.6	346.5	249.2	286.3	362.7	297.0	314.6	156.4	429.0	392.0	304.6	317.8
No. 64	.....	.....	.....	.....	.....	.....	.....	.....	.....	224.0	314.0	187.7	390.7	432.7	.....	369.8
No. 71	.....	.....	.....	.....	.....	.....	.....	.....	.....	193.0	318.6	119.0	410.0	389.7	.....	286.1
Annual mean	226.8	314.6	215.8	253.1	232.3	200.5	138.5	171.0	218.0	163.6	234.1	115.0	296.6	323.7	214.5	266.6
Maximum	268.2	403.2	319.3	231.5	318.8	346.5	249.2	286.3	362.7	297.0	326.1	187.7	429.0	441.3	.....	.....
Range	96.4	234.0	200.1	166.4	190.2	284.9	234.7	236.0	290.0	255.0	228.1	149.7	285.0	295.6	.....	.....

Table 4 gives the yields of wheat. The yields reported for rotation 5 are of winter wheat; the others are spring wheat. The spring-wheat crop of 1915 was severely injured by the same hailstorm that affected the oat crop. The winter wheat had been harvested before that storm. The winter wheat crop of 1916 was destroyed by a hailstorm on June 12, and the spring wheat that year was severely injured by rust. The mean yield of wheat from all six plots for the 14-year period was 20.6 bushels, which is relatively low as compared with the mean yield of oats. This may be accounted for in part by the fact that three of the six plots are continuously cropped to wheat, one is in rotation with oats, and another is in rotation with sugar beets. Thus five of the six plots are in what may be designated as poor rotations.

TABLE 4.—*Yields of wheat in irrigated rotations at the Scotts Bluff Field Station, 1912 to 1925, inclusive*

Rotation	Acre yields (bushels)														Mean, 14 years	Mean, last 5 years
	1912	1913	1914	1915	1916	1917	1918	1919	1920	1921	1922	1923	1924	1925		
No. 3	47.2	28.3	25.8	10.7	5.6	25.5	15.7	10.5	14.1	6.2	13.9	7.5	16.1	13.3	17.2	11.4
No. 5	41.0	30.6	18.8	27.0	.....	28.3	27.2	14.0	15.3	13.7	14.1	14.1	21.7	15.3	20.1	15.8
No. 7	44.2	25.9	22.7	9.9	6.5	26.4	19.0	11.5	17.2	6.9	11.0	6.5	13.2	13.7	16.8	10.3
No. 18	42.1	33.3	28.0	16.4	8.0	39.0	23.2	17.5	29.1	18.3	19.1	8.9	21.9	18.6	23.1	17.4
No. 28	50.0	23.2	24.9	9.3	6.0	23.7	23.0	13.1	22.1	10.4	16.9	6.7	20.3	10.5	18.6	13.0
No. 48	52.5	38.0	30.0	17.3	10.4	40.2	31.2	23.3	33.0	13.7	26.0	9.5	37.2	28.3	27.9	22.9
Annual mean	46.2	29.9	25.0	15.1	6.1	30.5	23.2	15.0	21.8	11.5	16.8	8.9	21.7	16.6	20.6	15.1
Maximum	52.5	38.0	30.0	27.0	10.4	40.2	31.2	23.3	33.0	18.3	26.0	14.1	37.2	28.3	.....	.....
Range	11.5	14.8	11.2	17.7	4.8	16.5	15.5	12.8	18.9	12.1	15.0	7.6	24.0	17.8	.....	.....

Table 5 gives the yields of corn. The mean yield of the five plots for the 14-year period was 42.2 bushels per acre. The largest single yield reported was 82.6 bushels per acre. The low yields of 1915 are assignable to the hailstorm already mentioned. Owing to the high altitude and the consequent short growing season, the production of corn at the Scotts Bluff Station is possible only with quick-maturing varieties. Such varieties do not give as large yields as those having a longer growing season. Furthermore, with these corn plots the situation is similar to that remarked above in reference to the wheat plots; four of the five plots occur in rotations that would be classed as poor.

TABLE 5.—*Yields of corn in irrigated rotations at the Scotts Bluff Field Station, 1912 to 1925, inclusive*

Rotation	Acre yields (bushels)														Mean, 14 years	Mean, last 5 years
	1912	1913	1914	1915	1916	1917	1918	1919	1920	1921	1922	1923	1924	1925		
No. 6	52.1	49.2	41.4	4.3	43.6	37.7	28.9	25.6	22.2	41.5	22.5	22.9	18.2	37.0	32.0	28.4
No. 16	60.1	69.2	73.9	22.2	50.6	48.5	33.3	30.6	23.3	31.3	30.1	28.9	17.1	40.3	40.0	29.5
No. 26	58.3	67.6	70.3	14.2	40.7	42.1	48.9	26.2	29.4	30.7	22.5	28.5	39.1	37.0	39.7	31.6
No. 32	57.9	68.4	61.8	15.0	39.3	48.0	39.4	18.7	31.1	40.7	36.2	36.3	22.3	45.0	40.0	36.1
No. 66	51.5	82.6	78.0	15.5	56.0	66.5	53.9	39.5	35.0	68.0	79.8	60.6	65.6	75.3	59.2	69.9
Annual mean	56.1	67.4	65.1	14.2	46.0	48.6	40.9	28.1	28.2	42.4	38.2	35.4	32.5	46.9	42.2	39.1
Maximum	60.1	82.6	78.0	22.2	56.0	66.5	53.9	39.5	35.0	68.0	79.8	60.6	65.6	75.3	-------	-------
Range	8.0	33.4	36.6	17.9	16.7	28.8	25.0	20.8	12.8	37.3	57.3	37.7	48.5	38.3	-------	-------

Table 6 gives the yields of flax obtained from two plots. The crop was a complete failure for 7 of the 14 years, and the plot that is cropped continuously gave no crop in 1916. It is clear from these results that conditions at the Scotts Bluff Station are not favorable for flax. The crop has been continued in the rotation experiments chiefly because identical rotations are being conducted at the Belle Fourche and Huntley Field Stations and because the other crops in the rotation are giving information of value.

TABLE 6.—*Yields of flax in irrigated rotations at the Scotts Bluff Field Station, 1912 to 1925, inclusive*

Rotation	Acre yields (bushels)														14-year mean
	1912	1913	1914	1915	1916	1917	1918	1919	1920	1921	1922	1923	1924	1925	
No. 9	26.8	16.6	7.5	4.0	0	3.2	0	0	0	0	0	0	4.2	0	4.4
No. 65	26.5	17.1	11.4	13.4	4.9	13.6	0	0	0	0	0	0	15.0	0	7.3
Annual mean	26.6	16.8	9.4	8.7	2.4	8.4	0	0	0	0	0	0	9.6	0	5.8

Table 7 gives the yields of alfalfa in the irrigated rotations. Although the yields of alfalfa are reported in the same manner as the yields of other crops, it should be recognized that the primary purpose of including alfalfa in these rotations was to measure the effect of growing alfalfa on the subsequent yields of the other crops. One plot, rotation 8, has been in alfalfa continuously without reseeding. Its mean yield for the 14-year period is just under 5 tons per acre.

There are 10 rotations in which one plot is newly seeded each year. Of these 10 rotations, 8 have been carried for the full period of 14 years. The other 2 were started in 1920, but 1 of them, No. 71, was started on a group of plots that were already established in alfalfa, so that comparable rotation yields of alfalfa were not reported until 1924. The age of the alfalfa stand is indicated by the figure following the rotation number, for example, 40–1 implies the first year of alfalfa in rotation 40. In those rotations where alfalfa followed sugar beets the crop was seeded in the spring without a nurse crop. Where it followed oats it was seeded in the stubble following the oat harvest, except in rotations 64 and 71, where it was seeded with the oats the preceding spring. These different methods of seeding the crop have resulted in differences in the yields reported as of the first crop year.

TABLE 7.—*Yields of alfalfa in irrigated rotations at the Scotts Bluff Field Station, 1912 to 1925, inclusive*

Rotation	Acre yields (tons)														
	1912	1913	1914	1915	1916	1917	1918	1919	1920	1921	1922	1923	1924	1925	14-year mean
No. 8	2.39	5.38	6.40	4.57	6.24	4.83	4.86	6.70	5.14	4.10	4.36	4.05	5.46	5.23	4.98
No. 40–1	2.78	1.28	3.10	1.69	-----	.52	-----	2.42	.73	-----	-----	-----	-----	1.10	.97
No. 40–2	2.62	5.63	7.20	5.00	5.06	3.23	4.36	2.82	5.23	3.18	4.84	3.10	5.29	5.82	4.53
No. 42–1	2.76	1.20	2.86	1.76	-----	.53	-----	2.94	1.01	-----	-----	-----	-----	.74	.99
No. 42–2	2.48	5.37	6.92	4.84	4.94	2.68	4.41	3.57	5.46	3.12	3.70	3.00	5.02	5.30	4.34
No. 44–1	2.69	3.58	5.99	3.98	3.45	2.50	1.74	2.10	1.50	-----	-----	-----	-----	1.42	2.07
No. 44–2	2.78	5.87	6.71	3.88	5.65	5.40	4.19	6.25	4.23	2.26	3.60	3.19	3.74	4.27	4.43
No. 48–1	2.73	3.65	5.77	3.39	3.62	4.04	2.26	1.20	1.31	-----	-----	-----	-----	2.90	2.29
No. 48–2	2.52	5.57	7.21	4.17	5.35	4.34	3.97	4.95	2.58	1.92	2.93	3.00	2.23	3.52	3.88
No. 60–1	2.69	1.30	2.87	1.50	-----	.27	-----	2.53	1.23	-----	-----	-----	-----	.82	.94
No. 60–2	2.61	5.01	6.58	4.93	5.63	2.83	4.27	4.82	4.80	3.54	4.59	3.23	4.25	5.50	4.47
No. 60–3	2.49	5.54	6.66	4.57	5.85	4.00	4.32	7.73	5.35	4.80	5.94	5.18	4.98	6.09	5.25
No. 61–1	2.76	1.38	3.20	1.61	-----	.35	-----	2.50	1.49	-----	-----	-----	-----	.76	1.00
No. 61–2	2.92	5.41	6.99	5.11	6.11	3.53	4.49	2.11	5.00	3.64	4.84	3.29	5.28	5.93	4.62
No. 61–3	2.42	5.53	6.76	4.70	6.60	5.62	4.43	7.47	4.76	5.38	4.88	5.39	5.97	6.71	5.47
No. 62–1	2.58	1.19	2.95	1.43	-----	.43	-----	2.81	1.54	-----	-----	-----	-----	.54	.96
No. 62–2	2.46	5.30	7.16	4.90	5.42	3.26	3.96	4.75	5.18	3.92	4.57	3.28	3.99	4.89	4.50
No. 62–3	2.36	5.10	6.22	4.66	5.63	4.82	4.59	7.58	5.03	4.92	5.34	5.36	5.63	6.02	5.23
No. 64–1	-----	-----	-----	-----	-----	-----	-----	-----	2.23	4.14	2.24	4.13	4.17	5.35	-----
No. 64–2	-----	-----	-----	-----	-----	-----	-----	-----	2.37	4.60	6.57	4.22	5.72	6.52	-----
No. 64–3	-----	-----	-----	-----	-----	-----	-----	-----	2.63	4.12	6.47	5.22	5.69	6.50	-----
No. 65–1	2.72	4.99	5.80	4.38	3.47	2.56	-----	-----	1.27	-----	-----	-----	-----	.84	1.86
No. 65–2	2.62	5.82	6.54	4.69	6.89	5.73	4.34	6.72	.87	2.94	4.10	4.04	4.01	4.81	4.58
No. 71–1	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	4.15	5.13	-----
No. 71–2	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	3.56	4.71	-----
No. 71–3	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	5.08	6.07	-----
Annual mean:															
1st year	2.71	2.32	4.07	2.47	1.32	1.40	.50	2.06	1.37	.46	.25	.46	.83	1.96	1.58
2d year	-----	5.50	6.91	4.69	5.63	3.87	4.25	4.50	3.97	3.24	4.42	3.37	4.31	5.13	4.61
3d year	-----	-----	6.51	4.62	6.08	4.82	4.55	7.37	4.58	4.66	5.40	5.04	5.47	6.10	5.43

In general, seeding in the spring without a nurse crop has given the lowest first-year yield. Seeding the previous fall has given larger first-year yields, whereas seeding the preceding spring with oats as a nurse crop has given the largest first-year yields. In 7 of the 14 years of the rotation experiment the newly fall-seeded alfalfa has been so seriously injured by grasshoppers that it has been necessary to reseed the plots the following spring to obtain a stand. As a consequence the first-year yields have not been reported for those years. The spring-seeded plots have produced some alfalfa, but the growth of weeds has necessitated frequent clipping, and the crop has not been

recorded. In summarizing the annual yields in the table, the age groups have been averaged separately. The yields from rotation 8 have been included in the mean of the third-year yields. The mean yield of this third-year class for the 12-year period, including the continuously cropped plot, was 5.43 tons per acre. The largest yield reported was at the rate of 7.75 tons per acre.

These detailed yield results indicate that the land used for these rotation experiments is of fairly high productivity. Except for flax, which occurs only twice in the series, the crops used are sufficiently well adapted to the region to serve fairly as indicators of the productivity of the soil. Despite the fact that irrigation water is used to overcome the limitations imposed by drought, other climatic hazards have influenced crop yields without direct relation to soil productivity. Insect pests and plant diseases have also been factors in reducing crop yields. In some measure there may be a relationship between a rotation system and plant diseases, or in the control of weeds, and, as in the case of establishing alfalfa, even between a rotation system and the effect of insect ravages. But aside from these relationships, it is probable that injuries from storms and adverse temperatures, from insects, and from many plant diseases are not influenced by the rotation system. On the other hand, the injurious effects of these agencies may not operate uniformly on the crops used in the rotation experiment, and in any event their effects tend to mask or minimize differences in yield that might otherwise occur as a result of differences in the potential productivity of the soil.

ANNUAL FLUCTUATIONS IN YIELD

During the 14 years of these rotation experiments the conditions that influence crop yields have been extremely variable. There have been good seasons and poor seasons. Because of the variety of factors that have entered into these seasonal conditions, the final effect has not been the same on all of the crops. Some measure of the effect of seasonal conditions on the yields of any crop may be obtained by comparing the mean annual yield for that crop with the mean of these annual yields for the entire period of the experiments. Such a comparison is made for five of the crops in Table 8, where the mean annual yield of a crop is expressed as a percentage of the mean yield for the 14-year period. This table shows that for the years 1915 and 1919 the annual means were all below normal, while only in the first three years of the period were the mean yields all above normal. It may be assumed that the high yields for the first three years were due in part at least to the high productivity of the virgin soil. The yield of oats, wheat, and corn were particularly high during this early period. The last column of the table gives the mean of the annual percentages for the last five years. During this period the mean yields of oats, wheat, and corn have been below normal, and those of sugar beets and potatoes have been above normal.

The annual mean yield of each crop affords not only a measure of the effect of seasonal conditions but also a basis for comparing each year the effect of rotation treatment. For the purpose of such a comparison the yields from the untreated rotations, including the continuously cropped plot, may be taken as one group, and the yields from the rotations that include manure and alfalfa or both

may be taken as the other or treated group. There are three of the crops—oats, sugar beets, and potatoes—for which there are a sufficient number of rotations in each group to justify such comparisons. With oats there are 7 untreated rotations and 10 that include manure or alfalfa. For sugar beets there are 6 untreated and 8 treated rotations, and for potatoes there are 5 untreated and 7 treated rotations that may be used. Rotation 27 is not included in either group.

TABLE 8.—*Seasonal mean yields of each crop, except alfalfa and flax, in irrigated rotations at the Scotts Bluff Field Station, 1912 to 1925, inclusive*

[The mean acre yield of each crop is expressed as a percentage of the mean yield of all plots for the 14-year period]

Crops	1912	1913	1914	1915	1916	1917	1918	1919	1920	1921	1922	1923	1924	1925	Mean, 1921 to 1925
Oats	155	134	125	26	86	115	106	78	92	74	104	104	90	110	96
Sugar beets	115	128	111	87	58	96	113	85	72	88	111	102	113	121	107
Potatoes	105	146	100	71	108	93	64	80	102	76	109	54	138	151	106
Wheat	224	146	121	73	30	148	112	73	106	56	82	43	105	81	73
Corn	133	160	154	34	109	115	97	67	67	101	91	84	77	111	93
Mean	146	143	122	58	78	113	98	77	88	79	99	77	105	115	95

The average annual yields from the untreated and treated rotations for each of the three crops are given in Table 9, expressed as percentages of the average yield of all the plots of each crop each year. This table shows that the yields from the untreated rotations have tended to fall farther below the annual mean as the experiments progressed, whereas the yields from the treated rotations have been consistently and increasingly higher.

TABLE 9.—*Mean annual yields of oats, sugar beets, and potatoes in untreated rotations and in manured and alfalfa rotations at the Scotts Bluff Field Station, 1912 to 1925, inclusive*

[The mean acre yield of each crop is expressed as a percentage of the mean annual yield of such crop in all rotations]

Crop	1912	1913	1914	1915	1916	1917	1918	1919	1920	1921	1922	1923	1924	1925
Oats:														
Untreated	98	92	91	91	98	87	82	90	67	81	71	75	66	59
Treated	101	104	108	103	101	105	112	109	123	111	122	116	125	128
Sugar beets:														
Untreated	92	93	88	81	90	76	70	64	59	74	66	60	66	68
Treated	106	105	109	114	108	118	121	127	128	105	120	115	113	113
Potatoes:														
Untreated	100	89	71	67	81	61	57	66	56	62	60	59	62	59
Treated	93	114	126	127	112	126	130	127	135	120	120	121	118	123

MEASURING THE EFFECT OF ROTATIONS ON CROP YIELDS

The plan of these rotation experiments is so arranged that the most obvious and direct comparison lies between the yields obtained from two plots of the same crop occurring in two different rotations. Thus the yields of oats obtained from a plot used continuously for oats (rotation 1) may be compared with the yields of oats obtained each year from one of two plots used for a rotation of oats and corn (rotation 16), as shown in Table 1. The mean acre yield of oats from rotation 1 for the 14-year period is reported as 46.6 bushels, whereas the mean yield from the oats plot of rotation 16 is given as

48.1 bushels, an average annual difference of 1.5 bushels in favor of the corn-oats rotation. But it might not be fair to rest the case with the simple statement that a 2-year rotation of corn and oats was better than the continuous production of oats by an average of 1.5 bushels per acre of oats. There are at least two other factors that should be considered. One of these has to do with the uniformity of the annual differences in yield, and the other has to do with the effect of the rotation on the yield of the other crop used in the rotation.[3]

The degree of the dependability of differences in yield may be expressed by computing the probable error of the mean of the differences. There are several methods of computing this probable error. The one here used is to multiply the sum of the departures from the mean by the quotient of $n\sqrt{n-1}$ into 0.8453, where n equals the number of yields involved.[4] By this method of computation the probable error of the mean difference in yield for the two plots of oats is 2.4, while the mean difference is 1.5. This large probable error indicates that the mean difference is too small to be significant. In other words, there is no significant difference between the yield of oats from the plot on which that crop is grown continuously and the yield from the plots on which the crop is grown in rotation with corn. It is clear from this showing that so far as the production of oats is concerned the rotation of corn with oats has not been beneficial. But it remains to determine what the effect of the rotation has been with respect to the yields of corn.

The annual and average yields of the corn plots are reported in Table 5. The average acre yield of the plot continuously in corn is 32 bushels, whereas the average for the corn plots in the corn-oats rotation is 40 bushels, an average annual difference of 8 bushels in favor of the rotation. The probable error of this mean difference is 1.6, so that the yields of corn from the rotation appear to be significantly higher than those from the continuously cropped plot. The full effect of rotation in this case may be stated as giving the following average annual increases in bushels per acre: For oats, 1.5 ± 2.4, for corn 8.0 ± 1.6.

In the following discussion the rotation results are first summarized by crops. Comparisons are made between the yields obtained from continuous cropping and those obtained from simple or untreated rotations. Further comparisons are then made between the yields of each crop obtained from the untreated rotations with the yields obtained from similar rotations in which barnyard manure is applied to the land once in each cycle of the rotation. Then comparisons are made between the yields from untreated rotations and from rotations involving the same crops but including also a period of alfalfa. Finally, a comparison is made between the yields from an untreated rotation and from a similar rotation in which both manure and alfalfa are used.

These comparisons all aim to show the differences in the productivity of the soil with respect to each crop as influenced by the rota-

[3] It should be noted that when there are significant differences in the productivity of the soil of different plots at the beginning of an experiment, that fact may need to be taken into account in deciding which cultural practices give best results. The yields on the different plots in the early years of these tests, as given in Tables 1 to 5, indicate that allowance might need to be made for this fact in interpreting these results, as well as for the two factors mentioned.—*Editor.*

[4] MERRIMAN, M. METHOD OF LEAST SQUARES. Ed. 8. New York. 1913.

tion or treatment. In order to obtain the simplest and most direct measure of the effect of the treatment on soil productivity, it has seemed advisable to compare the yields from the treated rotations with those from the untreated rotations rather than with those from the plot that is continuously cropped.

It seems unnecessary to stress the point that the rotation of crops is a desirable practice. It is generally recognized that the rotation of annual crops makes for better yields. The more obvious advantages of crop rotation are that it affords a means of controlling weeds, of lessening the injurious effects of certain plant diseases, and possibly of destroying certain insect pests that reside in the soil. The beneficial effects of such rotation treatments as the application of farm manure or the use of alfalfa are also well known; but there is need for information as to the relative benefits of each treatment and as to the possibilities of sustaining or increasing the productivity of the soil by the use of either one or both of them.

YIELDS OF OATS

The comparisons of the average annual yields of oats are shown in Table 10. The first comparison made is between the average yields for the full period, 1912 to 1925, and the average yields for the last 5-year period, 1921 to 1925. For the plot used for oats continuously and for the untreated rotations the average yields for the last five years are less than the average for the whole period. This might be taken as indicating that climatic or other conditions had been less favorable during recent years were it not for the fact that with the treated rotations the average of the recent yields is up to or slightly above that of the longer period.

Oats have been grown in 4 untreated 2-year rotations with corn, sugar beets, potatoes, and wheat (Nos. 16, 22, 24, and 28). In these rotations, the average yield of oats has not varied enough from the yield of the continuously cropped plot to indicate a measurable beneficial effect due to rotation. In rotation 28, where wheat is the alternate crop, the yield of oats has been slightly below that of the check plot. Of the 3-year rotations, one (No. 30) has given an increase in yield that is barely significant, whereas the other (No. 32) shows an insignificant decrease in yield.

Rotation 27 might properly be classed as a treated rotation and contrasted with rotation 24 rather than with rotation 1. It differs from rotation 24 in having rye sown in the oat stubble to be plowed under as green manure for the following potato crop. This treatment appears to have had some beneficial effect on the productivity of the soil as reflected in the subsequent crop of oats. On the whole, it may be said that in this series of experiments the simple rotation of other crops with oats has not resulted in giving much increase in yields of oats.

There were three rotations including oats, in which farm manure was applied at the rate of 12 tons per acre. In none of these was the manure applied immediately preceding the oats. In the 2-year rotations, Nos. 23 and 25, the manure was applied to the land before plowing for the sugar beets or for the potatoes. Thus the oat crop was grown on the plot the second year after the manuring. In rotation 31 there were two crops (sugar beets and potatoes) between the application of the manure and the sowing of the oats. Notwith-

standing the fact that the oats got only the second-year or third-year effect of the manure, the yields were significantly larger than those from the similar but unmanured rotations. The average increases for the last 5 years were substantially larger than for the 14-year period. Clearly the use of manure results in keeping up the productivity of the plots used for these rotations.

TABLE 10.—*Average annual yields of oats grown continuously on the same land, compared with yields obtained when the crop is grown in simple rotations and showing the effect of manure and of alfalfa, at the Scotts Bluff Field Station, 1912 to 1925, inclusive*

Rotation	Crops in the rotation	Average annual acre yields of oats (bushels)			
		Actual		Increase (+) or decrease (−) as compared	
		1912 to 1925	1921 to 1925	1912 to 1925	1921 to 1925
Continuous cropping:					
No. 1	Oats	47	39		
Untreated rotations (compared with continuous cropping):					
No. 16	Corn, oats	48	40	+1±2.4	+1±5.0
No. 22	Sugar beets, oats	54	43	+7±1.8	+4±6.0
No. 24	Potatoes, oats	55	45	+8±2.1	+6±4.1
No. 27	Potatoes, oats (rye)	62	52	+15±1.3	+13±2.6
No. 28	Wheat, oats	44	33	−3±1.4	−6±3.0
No. 30	Sugar beets, potatoes, oats	59	52	+12±2.1	+13±5.1
No. 32	Sugar beets, corn, oats	46	37	−1±2.9	−2±5.4
Manured rotations (compared with untreated rotations):					
No. 23	Sugar beets (manured), oats	65	61	+11±2.3	+18±3.6
No. 25	Potatoes (manured), oats	63	65	+8±3.4	+20±3.4
No. 31	Sugar beets (manured), potatoes, oats	72	71	+13±2.0	+19±2.8
Alfalfa rotations (compared with untreated rotations):					
No. 42	Sugar beets, alfalfa (2 years), oats	69	67	+15±3.1	+24±7.9
No. 44	Alfalfa (2 years), potatoes, oats	72	75	+17±3.2	+30±3.4
No. 48	Alfalfa (2 years), wheat, oats	67	73	+23±3.2	+40±2.6
No. 60	Sugar beets, alfalfa (3 years), potatoes, oats.	71	78	+12±2.7	+26±5.4
No. 62	Sugar beets, alfalfa (3 years), corn, oats	64	71	+18±3.4	+34±5.7
Manure and alfalfa rotation (compared with untreated rotations):					
No. 61	Sugar beets (manured), alfalfa (3 years), potatoes, oats.	76	84	+17±3.6	+32±6.6

There are five rotations in which the effect of alfalfa is shown. Three of these are 4-year rotations in which alfalfa occupied the land for two years, and two are 6-year rotations in which alfalfa was used for three years. The yields of oats from these rotations are definitely larger than from similar rotations in which alfalfa is not included, and here again the increased yields for the last five years have averaged larger than for the whole period. In one of these rotations, No. 42, oats followed directly after alfalfa. In the other rotations another crop came between, so that the oats got the second-year effect. A comparison of the increased yields of oats resulting from the use of farm manure and from growing alfalfa on the land for two or three years indicates that alfalfa is somewhat more effective than manure in keeping up the productivity of the soil.

In rotation 61 both manure and alfalfa are included. This rotation has given the highest average yields of oats for both periods, but the increased yields are not much larger than those obtained from either manure or alfalfa used alone.

YIELDS OF POTATOES

The summaries of the average annual yields of potatoes are shown in Table 11. Rotation 4, potatoes cropped continuously, has yielded at the rate of 100 bushels per acre. There are five untreated rotations, including No. 27 in which rye is used as a green-manure crop. In all of these the yields of potatoes have been significantly higher than those from the plot that was continuously cropped. Except for rotation 27, the yields for the last five years have averaged lower than those for the whole period.

TABLE 11.—*Average annual yields of potatoes grown continuously on the same land, compared with yields obtained when the crop is grown in simple rotations and showing the effect of manure and of alfalfa, at the Scotts Bluff Field Station, 1912 to 1925, inclusive*

Rotation	Crops in the rotation	Average annual acre yields of potatoes (bushels)			
		Actual		Increase as compared	
		1912 to 1925	1921 to 1925	1912 to 1925	1921 to 1925
Continuous cropping:					
No. 4	Potatoes	100	101		
Untreated rotations (compared with continuous cropping):					
No. 20	Sugar beets, potatoes	150	137	50± 6.8	36± 2.7
No. 24	Oats, potatoes	160	141	60± 4.9	40±13.7
No. 26	Corn, potatoes	146	138	46± 3.6	37± 5.4
No. 27	Oats, rye, potatoes	186	208	86± 9.1	107±11.2
No. 30	Oats, sugar beets, potatoes	184	167	84± 4.2	66± 4.7
Manured rotations (compared with untreated rotations):					
No. 21	Sugar beets, potatoes (manured)	210	232	60±12.2	95±28.2
No. 25	Oats, potatoes (manured)	236	244	76±10.0	103±16.3
No. 31	Oats, sugar beets (manured), potatoes.	233	251	49± 8.3	84±12.9
Alfalfa rotations (compared with untreated rotations):					
No. 40	Sugar beets, alfalfa (2 years), potatoes.	276	302	126±11.4	165±19.7
No. 44	Oats, alfalfa (2 years), potatoes	275	265	115±12.1	124±18.8
No. 60	Oats, sugar beets, alfalfa (3 years), potatoes.	284	299	100±11.6	132±13.1
Manure and alfalfa rotation (compared with untreated rotations):					
No. 61	Oats, sugar beets (manured), alfalfa (3 years), potatoes.	305	318	121±14.1	151±19.3

The production of potatoes continuously on the same land is clearly an undesirable practice, because the soil becomes infected with potato scab and possibly other diseases. In the short rotations, both manured and unmanured, the potatoes were also badly infected with scab, even though the seed pieces were disinfected before planting.

The manured rotations have given significantly larger average yields than similar rotations in which manure is not used. In rotations 21 and 25 the manure was applied just before the land was plowed for the potatoes. In the other rotation a crop of sugar beets intervened between the manuring and the potatoes. The yield results indicate that the first-year effect of manure is slightly greater than the second-year effect.

In the three alfalfa rotations where the potatoes are planted immediately following two years or three years of alfalfa, the acre yields have averaged 100 bushels or more in excess of those obtained from the rotations that do not include alfalfa. Furthermore, the increased yields have been larger during the last five years of the experiments. It is clearly indicated that alfalfa is more beneficial than manure as a rotation treatment for potatoes. Not only are the yields larger after alfalfa, but the crop is relatively free from scab. It is not clear whether this freedom from scab is due chiefly to the longer intervals between the recurring potato crops or to some reduction of the alkalinity of the soil resulting from an increase in the supply of fresh organic matter consequent upon the alfalfa crop.

The potato yields from rotation 61, which includes both manure and alfalfa, have been slightly higher than from the rotations in which alfalfa alone occurs, but the difference is less than the sum of the increases obtained where manure and alfalfa are used separately. In this rotation also the potatoes have been relatively free from scab.

YIELDS OF SUGAR BEETS

Sugar beets grown continuously on the same land have yielded slightly more than 9 tons per acre during the 14 years of the experiments, as shown in Table 12. In the five untreated rotations the yields have averaged about 2 tons larger, and in relation to their probable errors these increases appear to be significant. There is no indication that the kind of crop associated with sugar beets in these untreated rotations is influential on the yield of beets nor that the three-year rotations are superior to the two-year rotations. The average yields for the last five years have been approximately the same as those for the whole period.

In two of the manured rotations the manure was applied to the land just preceding the beet crop; in the other a crop of potatoes intervened. The yields from these manured rotations have averaged nearly 50 per cent higher than those from the unmanured rotations, and the averages from the last five years have been above those of the longer period.

The position of the sugar-beet crop in the alfalfa rotations has been rather less favorable than in the manured rotations. The beets have had the second-year or third-year effect of the stimulation. However, the increased yields shown by rotations 40 and 42 have been substantially the same as those from rotations 21 and 23. In rotations 60 and 62, where two other crops came between the alfalfa and the beets, the increases in yield have been rather less.

The rotation which includes both manure and alfalfa has again given the highest yields, though the increase is less than the sum of

the increases from manure and alfalfa used separately. The average yield from rotation 61 for the last five years is sufficiently higher than the average for the longer period to indicate that with this type of rotation the productivity of the soil is steadily increasing.

TABLE 12.—*Average annual yields of sugar beets grown continuously on the same land, compared with yields obtained when the crop is grown in simple rotations and showing the effect of manure and of alfalfa, at the Scotts Bluff Field Station, 1912 to 1925, inclusive*

Rotation	Crops in the rotation	Average annual acre yields of sugar beets (tons)			
		Actual		Increase as compared	
		1912 to 1925	1921 to 1925	1912 to 1925	1921 to 1925
Continuous cropping:					
No. 2	Beets	9.3	7.7		
Untreated rotations (compared with continuous cropping):					
No. 18	Wheat, sugar beets	11.6	10.6	2.3±0.48	2.9±0.55
No. 20	Potatoes, sugar beets	11.9	11.4	2.6± .27	3.7± .32
No. 22	Oats, sugar beets	11.3	10.4	2.0± .22	2.7± .37
No. 30	Potatoes, oats, sugar beets	11.7	11.8	2.4± .47	4.1± .58
No. 32	Corn, oats, sugar beets	11.3	11.2	2.0± .39	3.5± .79
Manured rotations (compared with untreated rotations):					
No. 21	Potatoes (manured), sugar beets	16.4	18.9	4.5± .61	7.5± .30
No. 23	Oats, sugar beets (manured)	18.2	19.4	6.9± .52	9.0± .67
No. 31	Potatoes, oats, sugar beets (manured)	17.8	18.7	6.1± .34	6.9± .54
Alfalfa rotations (compared with untreated rotations):					
No. 40	Alfalfa (2 years), potatoes, sugar beets.	18.0	17.9	6.1± .51	6.5± .93
No. 42	Alfalfa (2 years), oats, sugar beets	15.8	15.9	4.5± .73	5.5±1.03
No. 60	Alfalfa (3 years), potatoes, oats, sugar beets.	15.1	16.6	3.4± .61	4.8± .73
No. 62	Alfalfa (3 years), corn, oats, sugar beets.	14.7	15.9	3.4± .49	4.7± .43
Manure and alfalfa rotation (compared with untreated rotations):					
No. 61	Alfalfa (3 years), potatoes, oats, sugar beets (manured).	19.5	20.9	7.8± .68	9.1± .89

YIELDS OF ALFALFA

The detailed yields of alfalfa from the rotation plots, as given in Table 7, have not been summarized by rotation groups in a separate table, because the average yields are not comparable and the differences shown do not indicate rotation effects. In these experiments the aim has been to measure the effect on soil productivity of growing alfalfa in rotation with other crops, rather than to measure the effect of different systems of rotation on the yields of alfalfa.

Unlike the other field crops, alfalfa appears to maintain its yields for many years when grown on the same land. On one plot, rotation 8, the stand of alfalfa started in 1912 continues to yield good crops. The average acre yield for the last five years was 4.64 tons, as compared with 4.98 tons for the whole period. The third-year acre yields from plots that have been newly seeded from year to year have averaged 5.33 tons during the last five years, or about three-quarters of a ton more than the old stand. Although difficulties have been encountered in getting new seedings of alfalfa started,

the yields have been satisfactory every year after the plants have become established. The lowest average annual yield has been 4.5 tons per acre for the third-year crop.

YIELDS OF WHEAT

Wheat is not regarded as an important crop for the irrigated lands of the North Platte district, because the crop values are too low to justify its production on these lands. This is probably true also of oats. But both crops have a place in the farming system, partly because they fit into the rotation as nurse crops for alfalfa or sweet clover and partly because the grain is needed for local use in feeding livestock on the farms. Although both crops are subject to rust injury and to storm damage, hazards that reduce the yield regardless of the productivity of the soil, they are nevertheless useful in measuring that productivity.

Both winter wheat and spring wheat may be grown in the region represented by these experiments, and consequently both were included. The average yield of winter wheat, rotation 5, has been slightly higher than the comparable crop of spring wheat, rotation 3, as shown in Table 13. Furthermore, the yields of winter wheat have been rather better sustained during the last five years. This is probably due chiefly to the fact that these plots used continuously for the production of small grain become very weedy, and the earlier spring growth of the winter wheat gives the crop a better chance in competition with the weeds than has the spring-sown grain.

TABLE 13.—*Average annual yields of wheat grown continuously on the same land, compared with yields obtained when the crop is grown in simple rotations and showing the effect of manure and of alfalfa, at the Scotts Bluff Field Station, 1912 to 1925, inclusive*

Rotation	Crops in the rotation	Average annual acre yields of wheat (bushels)			
		Actual		Increase as compared	
		1912 to 1925	1921 to 1925	1912 to 1925	1921 to 1925
Continuous cropping:					
No. 3	Spring wheat	17	11	----------	----------
No. 5	Winter wheat	20	18	----------	----------
No. 7	Spring wheat (straw returned)	17	10	----------	----------
Untreated rotations (compared with continuous cropping):					
No. 18	Sugar beets, wheat	23	17	6±.85	6±1.04
No. 28	Oats, wheat	19	13	2±.74	2±1.03
Alfalfa rotation (compared with untreated rotations):					
No. 48	Oats, alfalfa (2 years), wheat (increase due to alfalfa).	28	23	9±1.03	10±2.5

Wheat is by far the most important crop grown on the dry lands surrounding the North Platte reclamation project. The methods of tillage and of crop rotation best suited to successful crop production on these lands are designed chiefly to conserve soil moisture and control weeds. There is, however, an interest in the relation of the supply of organic matter in the soil to sustained productivity. It is generally

believed that the tillage and rotation methods that best serve to conserve soil moisture and control weeds on the dry lands also tend to exhaust the supply of organic matter in the soil, and that this exhaustion in turn is reflected in reduced productivity. In order to ascertain whether an increased supply of organic matter in the soil would increase the yield of wheat under irrigated conditions, rotation 7 was included in the present series. The plot used for this experiment was used for spring wheat cropped continuously and was treated the same as the plot used for rotation 3 except that the straw produced each year was returned to the land after threshing and was plowed under. The crop yields resulting from this treatment, when compared with those obtained from rotation 3, do not indicate that the treatment has been of any value. The factors that chiefly limit the yields of spring wheat in this region appear to be rust and weeds.

The series of spring-wheat plots include two untreated rotations: No. 18, in which sugar beets alternate with wheat, and No. 28, in which oats is the alternate crop. The rotation of wheat with sugar beets affords a comparison as to the effect of weed control. This effect has been to give increased yields that appear to be significant. In rotation 28 the conditions of weed control are not essentially different from those of rotation 3, and average yields, though slightly larger, are not significantly so.

The effect of two years of alfalfa on the yield of the following crop of spring wheat is shown in rotation 48, where the yields are compared with those from rotation 28. The average annual increase in yield from the alfalfa rotation is large enough to be clearly significant. The fact that the average yield of wheat for the last 5 years is definitely lower than the average yield for the 14-year period in the whole series of comparisons may be taken to indicate that growth conditions for wheat have been less favorable during recent years. Even in rotation 48 the difference in period averages is shown. In this respect the yields of oats from this rotation showed a different tendency, the average of recent years having been higher.

YIELDS OF CORN

The average yields of corn from the five rotation plots are compared in Table 14. The low yields obtained from rotation 6 can not be explained as a result of weed competition, as has been done for wheat and oats. Nor is it known that corn in that region is subject to injury from a soil-inhabiting disease analogous to the scab disease of potatoes or the wilt disease of flax. Yet it is a fact that corn grown continuously on the same land has given lower average yields than when grown in rotation with other crops.

In the untreated rotations corn was grown in rotation with oats and with potatoes in a 2-year rotation, and with oats and sugar beets in a 3-year rotation. The average yields for the 14-year period from all three of the rotations is 8 bushels per acre higher than from the plot cropped continuously to corn. The average yields for the last five years would indicate that the corn-oats rotation is the least desirable of the three, but the differences shown may not be significant.

In rotation 62 corn occurs immediately following three years of alfalfa, and the average yields have been very good. The stimulating effect of the alfalfa treatment is unmistakable. Furthermore, it is

evident that the productivity of the plots involved in this rotation has increased, since the yields during the last five years have been higher than formerly.

TABLE 14.—*Average annual yields of corn grown continuously on the same land, compared with yields obtained when the crop is grown in simple rotations and showing the effect of manure and of alfalfa, at the Scotts Bluff Field Station, 1912 to 1925, inclusive*

Rotation	Crops in the rotation	Average annual acre yields of corn (bushels)			
		Actual		Increase as compared	
		1912 to 1925	1921 to 1925	1912 to 1925	1921 to 1925
Continuous cropping:					
No. 6	Corn	32	28		
Untreated rotations (compared with continuous cropping):					
No. 16	Oats, corn	40	29	8±1.27	1±2.29
No. 26	Potatoes, corn	40	32	8±2.0	4±3.48
No. 32	Oats, sugar beets, corn	40	36	8±1.42	8±2.01
Alfalfa rotation (compared with untreated rotations):					
No. 62	Oats, sugar beets, alfalfa (3 years), corn (increase due to alfalfa).	59	70	19±2.47	34±3.26

Corn was grown in another rotation in this series of experiments, but the crop was harvested in the field by hogs, so that an accurate determination of yields has not been possible. However, an attempt was made to estimate the yield by picking the ears from 1 plant in each 100. These ears were husked and weighed and then returned to the plot to be eaten by the hogs. In this rotation, No. 65, the corn crop also followed three years of alfalfa, as in rotation 62. The third-year crop of alfalfa was pastured by hogs. The estimated yields indicate that the corn yields from rotation 65 have been slightly higher than those from rotation 62. Such a result is to be expected in view of the fact that two of the six crops in the rotation were pastured off on the land, which results in manurial treatment fairly comparable to the direct application of manure to the land.

COMPARATIVE VALUES OF MANURE AND ALFALFA

In the preceding pages comparisons have been made to show the effect of rotation and of rotation treatment on the yields of the different crops. The facts available make it possible to estimate the values of manure and of alfalfa as expressed in the yields obtained from the complete rotation. In order to make such comparisons between rotations it becomes desirable to adopt a common measure of value. For this purpose certain arbitrary money values are assigned to the units of crop yield. The following money values are here used: Oats, 50 cents a bushel; potatoes, 50 cents a bushel; corn, 85 cents a bushel; sugar beets, $7 a ton. These values are assigned merely for convenience in making comparisons between rotation treatments; it is not implied that they represent either production costs or farm values.

The comparison here proposed may be made, for example, between rotations 20, 21, and 40. Rotation 20 includes potatoes and sugar beets. In rotation 21 the same crop sequence was followed, but farm manure was applied each year to the plot on which the potatoes were to be planted. Rotation 40 includes four plots, and the crop sequence was potatoes, sugar beets, alfalfa, two years. The average annual acre yield of potatoes in rotation 20 has been 150 bushels and that of sugar beets 11.9 tons. In rotation 21 the average acre yield of potatoes has been 210 bushels and that of sugar beets 16.4 tons. Thus the increases in yield resulting from the manure have been 60 bushels of potatoes and 4.5 tons of beets. At the unit values adopted, the increase in the value of the potatoes would be $30 and the increase in that of the sugar beets would be $31.50, making a total of $61.50 as the increase in product resulting from an annual application of 12 tons of manure.

In rotation 40 the average acre yield of potatoes has been 126 bushels above that of rotation 20, while that of sugar beets has been 6.1 tons higher. By the accepted values these increases would give $106 as the value of alfalfa for the rotation.

A similar series of comparisons may be made with rotations 22, 23, and 42, in which the two crops are oats and sugar beets. Here the yields from the manured rotation have an annual value of $54 more than the unmanured rotation, whereas in rotation 42 the increased value is $39. In the series of rotations involving oats and potatoes, Nos. 24, 25, and 44, the increase from manuring is worth $42, whereas the increase from alfalfa is worth $66.

Rotations 30, 31, and 60 when compared in the same way show an increased crop value of $74 from manuring and of $80 from alfalfa. The results of these four sets of comparisons may be brought into a single expression by taking the averages of the increased rotation values. This would give for manuring an average of $58 and for alfalfa an average of $72.

There are two other rotation comparisons that may be made to show the effect of alfalfa. One of these involves rotations 28 and 48, in which the test crops are oats and wheat. A valuation of $1 a bushel may be used here for wheat. The increased yields resulting from two years of alfalfa would average $20.50 for this rotation. This figure is much lower than those shown by rotations involving potatoes and sugar beets, chiefly because the crop values of oats and wheat are relatively low. Rotations 32 and 62 afford the second comparison of the value of the increased yield due to alfalfa. The three crops are oats, corn, and sugar beets, and the value of the increase is $49.

Rotation 61 is one in which both manure and alfalfa are included. The three crops other than alfalfa are oats, sugar beets, and potatoes. The first comparison is with rotation 30. The annual crop values of rotation 61 have averaged $124 higher than rotation 30, and this figure may be taken as the combined effect of manure and alfalfa. Another estimate of the value of alfalfa in stimulating crop yields may be made by comparing the returns from rotations 31 and 61, which differ only in that No. 61 includes alfalfa. This comparison shows an increase of $50 for the alfalfa in the rotation. By a similar comparison between rotations 60 and 61 another estimate may be obtained as to the value of manure. The annual values of rotation 61 are $44 higher than those of rotation 60.

By including the results from these last three sets of rotations the series shows five examples of the increased yields resulting from manure. These range from $42 to $74, with an average of $54. In other words, on the basis of the unit values used in these estimates, the application of 12 tons of farm manure has given an increase in crop return of $54, or the manure has been worth $4.50 per ton.

In the seven comparisons involving alfalfa the value of the increased yields has ranged from $20.50 to $106 with an average of $58. This stimulating effect of alfalfa has resulted from growing the crop either two or three years in each rotation. This increased return from the alfalfa rotations can not be regarded as net profit, because it is not probable that the value of the alfalfa hay produced in these short periods is sufficient to pay for the cost of production, together with a fair return on the value of the land. But even making a liberal allowance for some loss in return while the land is in alfalfa, there remains a substantial balance of profit to be credited to the alfalfa. The outstanding result of these experiments is that in a number of different systems of rotation the use of farm manure or of alfalfa has resulted in maintaining the productivity of this irrigated soil which was originally very productive. In rotation systems that were similar except that manure or alfalfa was not included, the productivity of the soil has declined appreciably during the 14 years of the experiments.

SUMMARY

The rotation experiments here reported were conducted on the Scotts Bluff Field Station in western Nebraska.

The experiments included the more important field crops of the region and were so arranged as to afford comparisons as to yield between continuous cropping and simple rotations, and between simple rotations and rotations to which farm manure was applied or in which alfalfa was included.

The crop varieties and the cultural methods have been the same for all rotations each year, in order to avoid differences in yield due to factors other than rotation or rotation treatment.

The detailed yields are given for each plot for each year. These show that except for wheat and flax the crop yields have been satisfactory. There have been instances of crop injury from storm, from plant diseases, and from insect pests, and these have tended to mask differences resulting from rotation effects.

The combined effect of seasonal conditions has been such as to cause generally low yields in some years and high yields in others, but with the progress of the experiments the differences between rotations have become more pronounced.

The effect of rotation and of rotation treatment upon crop yields has been measured in these experiments by comparing the yields from untreated rotations with those from plots that were cropped continuously and by comparing yields from treated rotations with those from similar but untreated rotations.

With oats the yields from simple rotations have not been much larger than from continuous cropping. The use of manure or alfalfa in the rotation has given substantial increases in yield, and of these two treatments alfalfa has been the better.

With potatoes the yields from the untreated rotations have been larger than from continuous cropping, though the differences have been less during the last five years than during the longer period. Both manuring and the use of alfalfa have given marked increases in yield, with the increases from alfalfa rather larger than those from manuring. The crops from the alfalfa rotations have also been less injured by scab than those from the other rotations.

The yields of sugar beets have been about 2 tons per acre higher from the untreated rotations than from the check plot. The use of manure in the rotation has resulted in pronounced increases of yield, and this is true also of alfalfa but to a less extent.

The yields of alfalfa, although reported in detail, have not been classified by rotations, because in these experiments this crop was used chiefly as a means of soil improvement.

A comparison of winter wheat with spring wheat, both grown continuously on the same land, shows larger yields for winter wheat. Spring wheat in rotation with sugar beets has yielded more than the same crop grown without rotation and more than when grown in rotation with oats. The practice of plowing under the straw has not increased the yield of spring wheat, but the incorporation of two years of alfalfa in a rotation of spring wheat and oats has given a substantial increase of yield.

It appears that corn grown in rotation with other crops gives better yields than when grown continuously on the same land. When grown in a rotation where it follows three years of alfalfa the yields are very satisfactory and appear to be increasing with the progress of the experiments.

By assigning an arbitrary scale of values to the units of crop yield it is possible to compare the effects obtained from treating this series of rotations with farm manure and using alfalfa in the rotation. A summary of five comparisons involving manure and seven comparisons involving alfalfa shows that by devoting the land to alfalfa for two or three years in each rotation the increased yields are substantially the same as those obtained from an application of manure at the rate of 12 tons per acre.

ORGANIZATION OF THE
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