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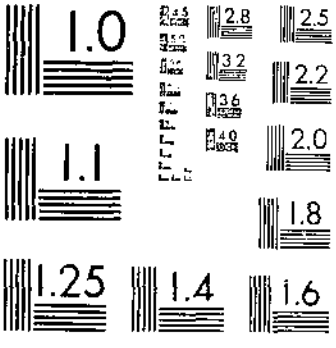

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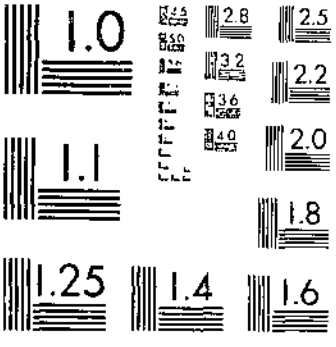

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EFFECT OF ALFALFA AND FARM MANURE ON YIELDS OF IRRIGATED CROPS IN THE GREAT PLAINS

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INTRODUCTION

It is essential to a successful irrigated agriculture that such a program of farm management be in effect that crop yields are maintained indefinitely and of a magnitude promising a profit on the enterprise. It has been often demonstrated by farmers, as well as by investigators, that, where staple farm crops are chiefly grown, this may be most effectively accomplished by crop rotation, including in the crop sequence either a leguminous crop, such as alfalfa, or the occasional application of stable manure. It has been found that most staple farm crops respond favorably to applications of stable manure. However, it is rarely available in adequate quantities to meet the requirements on irrigation projects where cash crops such as sugar beets, potatoes, and cotton are featured in the planting program. This condition has resulted in the inclusion of alfalfa, sweetclover, and certain other leguminous crops in the cropping program, because of the resulting benefits in the form of increased yields of subsequent crops. This practice has been followed so generally and with such beneficial effects on some crops under certain conditions that it is often believed to have more general and literal application than may be justified, although it is recognized that the inclusion of such leguminous crops as alfalfa in the cropping program has had a profoundly

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favorable effect in maintaining the productivity of the soil. More recent investigations have disclosed that serious losses have frequently resulted because of insufficient information relative to the effectiveness of leguminous crops as compared with applications of stable manure as aids in improving and maintaining soil productivity.

These as well as other agronomic problems confronting the settlers justified the establishment in 1910, by the Bureau of Plant Industry, of three field stations in the northern Great Plains as follows: (1) The Huntley station, located on the Huntley reclamation project, near the town of Huntley, in southeastern Montana; (2) the Belle Fourche station, located on the Belle Fourche reclamation project, near the town of Newell, in western South Dakota; (3) the Scotts Bluff station, located on the North Platte reclamation project, near the town of Mitchell, in western Nebraska. The conditions existing at these three locations are fairly representative of those found in the western part of the States of Nebraska and South Dakota and in adjoining States to the west and south as well as in a large portion of Montana where irrigation is practiced.

The average annual precipitation in this section of the northern Great Plains is about 14 inches. Consequently, the climate is essentially semiarid and irrigation is necessary if large crop yields are to be assured. The growing season between frosts is approximately 125 days, which permits the successful production of crops adapted to the more northern latitudes of the United States. The Scotts Bluff station has an elevation of 4,000 feet, while Belle Fourche and Huntley are approximately 3,000 feet above sea level.

The crops chiefly produced in the area are sugar beets, potatoes, alfalfa, sweetclover, corn, barley, oats, and wheat. For the past several years sugar beets have been the chief cash crop on the Huntley and Belle Fourche projects. On the North Platte project large acreages have been devoted to sugar beets, but during years when price prospects have appeared favorable substantial acreages of potatoes have been grown. Cereals are less extensively grown, their chief purpose being to supply the local feed requirements. There are extensive acreages of alfalfa on all three projects intended, in a large measure, to supply feed for livestock maintained on the farms, while the surplus is absorbed by local and adjoining markets. The acreage devoted to alfalfa has been stimulated still further because of the favorable effect this crop has had in increasing subsequent crop yields.

The soil at the Belle Fourche station is a heavy clay, known locally as "gumbo" and designated technically as Pierre clay in the United States Department of Agriculture, Bureau of Chemistry and Soils survey of the county. Such soils warm slowly in the spring, cannot be worked properly except when moisture conditions are favorable, and dry slowly particularly when temperatures are low. Cool, damp springs have so delayed planting or retarded plant growth that crop yields have been markedly depressed. It has been found that under such conditions vicissitudes of the climate from year to year have had a greater influence on crop yields than has occurred either at the Huntley or at the Scotts Bluff stations, which are located on less refractory soil types. The Pierre clay is developed from Pierre shale, a fissured and salt-bearing formation in which saline subsoil water accumulates from canal seepage.

The soil of the Huntley Field Station is a productive clay loam and lighter in character than that at the Belle Fourche station. In texture it is representative of extensive areas of the better lands under irrigation throughout the Northwest. It overlies a gravelly subsoil which is often filled with water under pressure from canal seepage.

The soil of the Scotts Bluff station is a friable fine sandy loam and is fairly productive when first broken from the native sod, but soon loses its productivity unless stable manure is applied or a leguminous crop is included in the cropping program. The soil responds very readily to various rotational treatments, such as the inclusion of alfalfa in the cropping program, and to applications of stable manure. Both the surface and subsoil take water readily, and there is sufficient elevation to provide adequate subsoil as well as surface drainage.

The irrigation supplies at the Huntley and Scotts Bluff Field Stations are of low salinity, while that of Belle Fourche is intermediate in this respect. The soils and subsoils at Belle Fourche contain a good deal of salt in spots; those at Huntley are less salty, though there are areas of saline soils on the project. At Scotts Bluff salinity of the soils is not an important factor except in low-lying areas near the North Platte River.

DESCRIPTION OF THE ROTATIONS

In 1912 a series of rotation experiments were inaugurated at these three field stations. At the time these investigations were included as a part of the program of the stations the object in view was to determine the cropping methods, crop sequences, and treatments, including applications of stable manure, best suited to improve and to maintain indefinitely the productivity of these lands. With the close of the year 1932 an opportunity was afforded to observe the various results obtained over a 21-year period. As the work has advanced a number of papers have been published relative to the results obtained (*1, 2, 3, 4, 5, 6, 7, 8, 9, 10*).[1]

Sugar beets, potatoes, and oats have been selected for the purpose of ascertaining to what extent alfalfa and applications of stable manure have influenced the yields of these crops in the different rotations on the three stations. In this series an opportunity is afforded of observing over a 21-year period (1) the influence of 2 years of alfalfa on the yields of these three crops in different sequences as compared with identical rotations not including alfalfa; (2) the extent to which the yields are affected when alfalfa is grown for 3 years; (3) how much yields have been stimulated by applications of stable manure; (4) the value of manure as compared with alfalfa in similar rotations; and (5) in two alfalfa rotations, 60 and 61, it is possible to observe the extent to which crop yields have been influenced by an application of stable manure every sixth year to a rotation including alfalfa. In all there are 21 pairs of rotations from which these results are obtained. In each pair the only difference is that one rotation includes alfalfa for 2 or 3 years while the other does not. In the cases where stable manure was applied and comparisons are made, each rotation included the same crops; one rotation received the manurial treatment while

[1] Italic numbers in parentheses refer to Literature Cited, p. 39.

the other did not. The crops involved, the sequences of the crops, and the indicated manurial treatment are as follows:

ROTATIONS WITHOUT ALFALFA COMPARED WITH THOSE WITH ALFALFA

20. Potatoes, sugar beets.
40. Potatoes, sugar beets, alfalfa, alfalfa.

22. Oats, sugar beets.
42. Oats, sugar beets, alfalfa, alfalfa.

24. Potatoes, oats.
44. Potatoes, oats, alfalfa, alfalfa.

22. Sugar beets, oats.
46. Sugar beets, oats, alfalfa, alfalfa.

28. Wheat, oats.
48. Wheat, oats, alfalfa, alfalfa.

30. Potatoes, oats, sugar beets.
60. Potatoes, oats, sugar beets, alfalfa, alfalfa, alfalfa.

31. Potatoes, oats (manure), sugar beets.
61. Potatoes, oats (manure), sugar beets, alfalfa, alfalfa, alfalfa.

32. Corn, oats, sugar beets.
62. Corn, oats, sugar beets, alfalfa, alfalfa, alfalfa.

34. Potatoes, sugar beets, oats.
64. Potatoes, sugar beets, oats, alfalfa, alfalfa, alfalfa.

ROTATIONS WITHOUT STABLE MANURE COMPARED WITH THOSE WITH MANURE

20. Potatoes, sugar beets.
21. Potatoes, sugar beets (manure).

22. Sugar beets, oats.
23. Sugar beets, oats (manure).

24. Potatoes, oats.
25. Potatoes, oats (manure).

30. Sugar beets, potatoes, oats.
31. Sugar beets, potatoes, oats (manure).

34. Oats, potatoes, sugar beets.
35. Oats (manure), potatoes, sugar beets.

60. Potatoes, oats, sugar beets, alfalfa, alfalfa, alfalfa.
61. Potatoes, oats (manure), sugar beets, alfalfa, alfalfa, alfalfa.

ROTATIONS WITH MANURE COMPARED WITH THOSE WITHOUT MANURE BUT INCLUDING ALFALFA

21. Sugar beets (manure), potatoes.
40. Potatoes, sugar beets, alfalfa, alfalfa.

23. Sugar beets, oats (manure).
42. Sugar beets, alfalfa, alfalfa, oats.

23. Sugar beets, oats (manure).
46. Sugar beets, oats, alfalfa, alfalfa.

25. Oats (manure), potatoes.
44. Oats, alfalfa, alfalfa, potatoes.

31. Sugar beets, potatoes, oats (manure).
60. Potatoes, oats, sugar beets, alfalfa, alfalfa, alfalfa.

35. Potatoes, sugar beets, oats (manure).
64. Potatoes, sugar beets, oats, alfalfa, alfalfa, alfalfa.

These series of rotations at present consist of 42 different cropping systems at Belle Fourche, 43 at Huntley, and 48 at Scotts Bluff. In connection with the other information being accumulated as a result

of these rotation experiments at the 3 stations it is possible in the following tables to observe the effect of alfalfa on the yields of sugar beets in 18 different combinations, the effect on sugar beets of applications of 12 tons of stable manure in 13 rotations, and the extent that sugar-beet yields have been influenced by stable manure as compared with alfalfa in 12 rotations. In the tables giving the results with potatoes there are involved the effect of alfalfa in 14 rotations, the applications of stable manure in 14, and the value of stable manure as compared with alfalfa in 11. With oats there are available 19 pairs of rotations where the effects of alfalfa on the yields are recorded, 14 of which indicate the value of stable manure, and 12 where the merits of alfalfa and stable manure are compared.

CULTURAL PRACTICES

In conducting these investigations throughout the 21-year period it has been the aim to adopt the best cultural practices used in the local community. Seed of the same variety of each crop is used each season at any one station, although in a few instances throughout the period it has been found advisable to change the variety. It is not believed that this substitution of varieties in the few instances it has occurred has influenced the results appreciably. The cultural treatments applied and the planting dates were as nearly identical at each station as conditions would permit.

At the Belle Fourche station all plots planted to sugar beets or potatoes were fall-plowed and left rough throughout the winter. All plots preceded by a cultivated crop were not plowed but were thoroughly disked in the spring preparatory to seeding. In the cases where oats followed alfalfa or another cereal the land was fall-plowed. Plots in alfalfa to be followed by sugar beets or potatoes were plowed in the fall, and in the spring the ground was worked with a spring-tooth harrow or duck-foot cultivator to kill as many of the plants as possible. In those rotations receiving farm manure the manure was plowed under.

At the Huntley station all plots to be planted to sugar beets or potatoes were fall-plowed to a depth of about 8 inches and left rough throughout the winter. In the instances where oats followed a cultivated crop the land was not plowed but was double-disked in the spring preparatory to planting. Where oats followed an uncultivated crop the land was fall-plowed. In the event alfalfa was the preceding crop the alfalfa was crowned, that is, the land was plowed to a depth of approximately 4 inches and after about a week or 10 days it was worked with a spring-tooth harrow and later plowed to the usual depth. In those rotations so treated the manure was applied before the second plowing.

During the first years of the experiment the practice at the Scotts Bluff station was to plant sugar beets and potatoes on fall-plowed land. In recent years these two crops have been planted on spring-plowed land except in rotations 24 and 25 where the oat-stubble land is still fall-plowed for potatoes. Where potatoes follow alfalfa the early practice was to fall-crown the alfalfa and then plow to a greater depth the following spring. Now the alfalfa land for potatoes is plowed in the spring after growth starts. Where oats follow sugar beets, corn, or potatoes the land was spring-disked before seeding.

When oats follow alfalfa the land was plowed in the spring shortly before seeding. Manure was applied just before plowing.

At all three of these field stations farm manure was applied at the rate of 12 tons per acre. In each case the plots are one-fourth acre in size and are laid out in series separated by 40-foot roads and the plots in the series by a 5-foot alley. At Belle Fourche the plots are 264 feet long by 41.25 feet wide; those at Huntley are 227 feet long by 48 feet wide; while those at Scotts Bluff are 132 feet long by 82.5 feet wide. Each rotation is so arranged that each crop in each rotation is grown each year. To carry out this plan it is necessary to have as many plots as there are years in the cycle of each rotation. By the adoption of this method it is possible to compare each year the yields from the same crops grown in each of the different rotations.

The responsibility for supervising the proper conduct of the field operations of these rotation experiments, taking the field notes, and compiling the data has been placed upon a station superintendent at each of the three locations.[2]

PRESENTATION OF THE DATA

In assembling the data for the 21 years the mean yields by 7-year periods are given rather than the detailed material required for recording individual annual yields. In each instance crop yields from rotations having the same major crops are compared, and the increase or decrease which may be attributed to the treatment is determined. The only difference is that one cropping system has an application of farm manure during its cycle or alfalfa is included, whereas the other has neither of these treatments. In the preparation of the tables and discussion it was found desirable to arrange the data according to crops rather than treatments. By this method an opportunity is afforded for observing directly the extent that yields have been influenced by application of farm manure, the inclusion of alfalfa in the cropping program, as well as direct comparisons of the effect of alfalfa and of manure.

EFFECT OF MANURE ON YIELDS OF SUGAR BEETS

In table 1 is recorded the extent to which applications of 12 tons of farm manure have influenced the yields of sugar beets, expressed in tons per acre by 7-year periods. In all instances the crop sequences and treatments have been the same, the only difference being that one rotation in each pair received the manurial treatment, whereas the other did not. The manure was applied to the land immediately preceding the beet crop except in the case of 2-year rotation 21 where the treatment was applied preceding the potatoes.

[2] At Belle Fourche, Beyer Auno has been superintendent since 1909. J. B. Lenty, N. L. Mattice, and George T. Ratliffe have aided at different times. Dan Hansen has been station superintendent at Huntley since 1910. At times during the period covered by these investigations he has been aided by J. M. Spain, J. W. Knorr, E. G. Noble, and D. A. Savage. From 1910 to 1910 Fritz Knorr was station superintendent at Scotts Bluff. James A. Holden was in charge of the rotations from 1912 until 1916, and since 1916 he has been station superintendent and continued the responsibility for these investigations.

TABLE 1.—*Effect of manure on the yields of sugar beets (tons per acre) at the Belle Fourche, Huntley, and Scotts Bluff Field Stations by 7-year periods, 1912–32*

BELLE FOURCHE

Rotation no.	Crop sequence	1912–18	1919–25	1926–32
		Tons	*Tons*	*Tons*
21	Sugar beets (manure), potatoes	12.0	17.4	16.9
20	Sugar beets, potatoes	11.0	13.8	11.1
	Difference in favor of manure	1.0	3.6	5.8
23	Sugar beets, oats (manure)	11.2	16.5	15.4
22	Sugar beets, oats	9.4	12.4	10.4
	Difference in favor of manure	1.8	4.1	5.0
31	Sugar beets, potatoes, oats (manure)	11.5	12.7	11.9
30	Sugar beets, potatoes, oats	7.7	8.4	6.6
	Difference in favor of manure	3.8	4.3	5.3
61	Sugar beets, alfalfa, alfalfa, alfalfa, potatoes, oats (manure)	10.9	13.6	15.1
60	Sugar beets, alfalfa, alfalfa, alfalfa, potatoes, oats	10.1	11.3	10.5
	Difference in favor of manure	.8	2.3	4.6

HUNTLEY

21	Sugar beets (manure), potatoes	13.8	16.2	18.0
20	Sugar beets, potatoes	12.3	12.4	10.4
	Difference in favor of manure	1.5	3.8	7.6
23	Sugar beets, oats (manure)	12.4	13.5	16.8
22	Sugar beets, oats	11.0	9.0	5.6
	Difference in favor of manure	1.4	4.5	11.2
31	Sugar beets, potatoes, oats (manure)	10.8	13.3	17.6
30	Sugar beets, potatoes, oats	7.4	8.7	8.0
	Difference in favor of manure	3.4	4.6	9.6
35	Sugar beets, oats (manure), potatoes	[1] 12.2	15.3	15.9
34	Sugar beets, oats, potatoes	[1] 11.5	12.4	6.3
	Difference in favor of manure	.7	2.9	9.6
61	Sugar beets, alfalfa, alfalfa, alfalfa, potatoes, oats (manure)	13.4	16.7	17.7
60	Sugar beets, alfalfa, alfalfa, alfalfa, potatoes, oats	10.5	14.0	13.6
	Difference in favor of manure	2.9	2.7	4.1

SCOTTS BLUFF

21	Sugar beets (manure), potatoes	15.4	17.5	17.4
20	Sugar beets, potatoes	13.4	10.3	8.6
	Difference in favor of manure	2.0	7.2	8.8
23	Sugar beets, oats (manure)	18.3	18.1	18.1
22	Sugar beets, oats	13.0	9.6	8.6
	Difference in favor of manure	5.3	8.5	9.5
31	Sugar beets, potatoes, oats (manure)	18.5	17.2	18.3
30	Sugar beets, potatoes, oats	12.6	10.7	8.7
	Difference in favor of manure	5.9	6.5	.6
61	Sugar beets, alfalfa, alfalfa, alfalfa, potatoes, oats (manure)	19.2	19.9	18.4
60	Sugar beets, alfalfa, alfalfa, alfalfa, potatoes, oats	14.4	15.8	13.3
	Difference in favor of manure	4.8	4.1	5.1

[1] For the period 1916–18 only.

In every 7-year period at all three stations the benefits from the application of farm manure were positive, the increased yields of the treated over the untreated rotations ranging from a minimum of 0.7 ton to a maximum of 11.2 tons per acre. When the trend of these yields is considered by 7-year periods it will be observed that there is a definite tendency for the differences to increase progressively, the only exception being the 6-year rotations 60 and 61. However, even in this instance where 3 years of alfalfa was included in the cropping program, an application of manure stimulated the yields of beets from a minimum of 0.8 ton to a maximum of 5.1 tons per acre. At the Scotts Bluff station the highest yields have been consistently those harvested from the alfalfa-manured rotation 61, where the yields ranged from a minimum of 18.4 to a maximum of 19.9 tons of sugar beets to the acre. In considering the yields from the untreated rotations it is apparent that when the yields from three 7-year periods are considered, the sugar-beet yields are scarcely being maintained at Belle Fourche and are decidedly reduced at Scotts Bluff and Huntley. It is emphasized that a better opportunity is afforded for observing yield trends of the treated compared to the untreated rotations by considering only the differences as the influence on yields of the seasonal variations is eliminated. Even when the hazards of a varying moisture supply are not a factor, as has been the case under the irrigated conditions where these investigations have been conducted, often one or more seasons have been unfavorable for obtaining satisfactory yields of beets during a 7-year period, which has depressed the mean; whereas throughout other cycles the seasons have been generally more favorable. This is apparent when the detailed sugar-beet yields for the second 7-year period at the Belle Fourche station are considered when the years 1922, 1923, and 1925 were very favorable for high-average yields as compared with average yearly yields during the other two periods.

EFFECT OF ALFALFA ON YIELDS OF SUGAR BEETS

Table 2 gives the detailed yields of sugar beets by 7-year periods for the three stations, indicating the influence of alfalfa on the yields of beets. In all rotations except no. 46 one or more crops intervened before the sugar beets were grown. The planting of sugar beets immediately following alfalfa ordinarily is not to be recommended, because, owing to the prevalence of the damping-off fungus, commonly called black root, it is difficult to obtain a satisfactory stand.

At the Belle Fourche station in all three rotations where alfalfa was grown for 2 years, only one period is found where beet yields have been stimulated as a result of including alfalfa. This occurred in the third 7-year period in rotation 40, where the increase was 0.7 ton per acre. On the other hand, 3 years of alfalfa in 6-year rotations 60, 61, and 62 reacted favorably on the yields of beets but in rotation 64 yields were reduced. It should be noted that these two rotations were not included in the series until 1917 and consequently are for 16 years only, whereas yields from all other 6-year rotations at this station are for the full 21 years. The most consistently favorable results have been obtained from rotation 60 when compared with rotation 30. While the sugar-beet yields from rotation 60 are not high, yet when compared with no. 30, which is similar except that it does not include

alfalfa, the increases in the yields of beets for the three 7-year periods are 2.4, 2.9, and 3.9 tons per acre, respectively.

TABLE 2.—*Effect of alfalfa on the yields of sugar beets (tons per acre) at the Belle Fourche, Huntley, and Scotts Bluff Field Stations by 7-year periods, 1912–32*

BELLE FOURCHE

Rotation no.	Crop sequence	1912–18	1919–25	1926–32
		Tons	*Tons*	*Tons*
40	Sugar beets, alfalfa, alfalfa, potatoes	10.6	13.0	11.8
20	Sugar beets, potatoes	11.0	13.8	11.1
	Difference in favor of alfalfa	−.4	−.8	.7
42	Sugar beets, alfalfa, alfalfa, oats	8.5	9.8	9.2
22	Sugar beets, oats	9.4	12.4	10.4
	Difference in favor of alfalfa	−.9	−2.8	−1.2
46	Sugar beets, oats, alfalfa, alfalfa	[1] 9.7	7.0	6.7
22	Sugar beets, oats	[1] 10.7	12.4	10.4
	Difference in favor of alfalfa	−1.0	−5.4	−3.7
60	Sugar beets, alfalfa, alfalfa, alfalfa, potatoes, oats	10.1	11.3	10.5
30	Sugar beets, potatoes, oats	7.7	8.4	6.6
	Difference in favor of alfalfa	2.4	2.9	3.9
61	Sugar beets, alfalfa, alfalfa, alfalfa, potatoes, oats (manure)	10.9	13.0	15.1
31	Sugar beets, potatoes, oats (manure)	11.5	12.7	11.9
	Difference in favor of alfalfa	−.6	.9	3.2
62	Sugar beets, alfalfa, alfalfa, alfalfa, corn, oats	8.1	8.8	9.8
32	Sugar beets, corn, oats	6.9	7.0	6.0
	Difference in favor of alfalfa	1.2	1.8	3.8
64	Sugar beets, oats, alfalfa, alfalfa, alfalfa, potatoes	[1] 12.2	13.4	16.9
34	Sugar beets, oats, potatoes	[1] 13.3	14.8	11.5
	Difference in favor of alfalfa	−1.1	−1.4	−.6

HUNTLEY

40	Sugar beets, alfalfa, alfalfa, potatoes	12.5	12.5	9.3
20	Sugar beets, potatoes	12.3	12.4	10.4
	Difference in favor of alfalfa	.2	.1	−1.1
42	Sugar beets, alfalfa, alfalfa, oats	10.2	11.5	7.5
22	Sugar beets, oats	11.0	9.0	5.6
	Difference in favor of alfalfa	−.8	2.5	1.9
46	Sugar beets, oats, alfalfa, alfalfa	[2] 10.6	11.6	5.7
22	Sugar beets, oats	[2] 10.9	9.0	5.6
	Difference in favor of alfalfa	−.3	2.6	.1
60	Sugar beets, alfalfa, alfalfa, alfalfa, potatoes, oats	10.5	14.0	13.6
30	Sugar beets, potatoes, oats	7.4	8.7	8.0
	Difference in favor of alfalfa	3.1	5.3	5.6
61	Sugar beets, alfalfa, alfalfa, alfalfa, potatoes, oats (manure)	13.4	16.7	17.7
31	Sugar beets, potatoes, oats (manure)	10.8	13.3	17.6
	Difference in favor of alfalfa	2.6	3.4	.1
64	Sugar beets, oats, alfalfa, alfalfa, alfalfa, potatoes	[2] 11.6	14.2	10.1
34	Sugar beets, oats, potatoes	[2] 11.5	12.4	6.3
	Difference in favor of alfalfa	.1	1.8	3.8

[1] For the period 1917–18 only.

[2] For the period 1916–18 only.

TABLE 2.—*Effect of alfalfa on the yields of sugar beets (tons per acre) at the Belle Fourche, Huntley, and Scotts Bluff Field Stations by 7-year periods, 1912–32*—Continued

SCOTTS BLUFF

Rotation no.	Crop sequence	1912–18	1919–25	1926–32
		Tons	*Tons*	*Tons*
40	Sugar beets, alfalfa, alfalfa, potatoes	18.2	17.8	14.9
20	Sugar beets, potatoes	13.4	10.3	8.6
	Difference in favor of alfalfa	4.8	7.5	6.3
42	Sugar beets, alfalfa, alfalfa, oats	15.8	16.0	15.3
22	Sugar beets, oats	13.0	9.6	8.6
	Difference in favor of alfalfa	2.8	6.4	6.7
60	Sugar beets, alfalfa, alfalfa, potatoes, oats	14.4	15.8	13.3
30	Sugar beets, potatoes, oats	12.6	10.7	8.7
	Difference in favor of alfalfa	1.8	5.1	4.6
61	Sugar beets, alfalfa, alfalfa, alfalfa, potatoes, oats (manure)	19.2	19.9	18.4
31	Sugar beets, potatoes, oats (manure)	18.5	17.2	18.3
	Difference in favor of alfalfa	.7	2.7	.1
62	Sugar beets, alfalfa, alfalfa, alfalfa, corn, oats	14.5	14.9	13.0
32	Sugar beets, corn, oats	12.3	10.3	9.2
	Difference in favor of alfalfa	2.2	4.6	3.8

At the Huntley Field Station the influence of alfalfa on the yields of sugar beets was somewhat more favorable, as is evidenced by comparisons between rotations including alfalfa with those not so treated. This condition is definitely more apparent in the 6-year rotations which include 3 years of alfalfa. With the exception of the 31 and 61 manured combinations, the differences in favor of alfalfa for the three 7-year periods increased progressively. These results indicate that applications of farm manure are having a cumulatively favorable influence on the yields of beets in rotation 31; although applications of both manure and alfalfa in a 6-year rotation may not be economically justified, as is evidenced by the differences in the yields between rotations 61 and 31 for the last 7-year period. In the case of all three 4-year rotations having only 2 years of alfalfa, the yields for the last 7-year period are materially less than those obtained for the second period, and when the mean of the difference is determined for this period there is but 0.3 ton per acre in favor of the rotations including alfalfa. On the other hand, the mean of the differences for the rotations having 3 years of alfalfa for the same period is 3.2 tons per acre in favor of the rotations including alfalfa.

At the Scotts Bluff station the effect of alfalfa on the yields of sugar beets has been quite different from that obtained at the other two stations. In considering the differences in yields in the five combinations, beneficial effects have been obtained in every period as a result of including alfalfa in the cropping program. This is particularly apparent in the rotations including 2 years of alfalfa. However, as has occurred at Belle Fourche and at Huntley, the yields of beets for the last 7 years from both the 4-year rotations are less than for the previous period.

EFFECT OF MANURE AS COMPARED WITH ALFALFA ON YIELDS OF SUGAR BEETS

Table 3 affords a direct comparison of the effect of stable manure and of alfalfa on the yields of sugar beets. In all instances except in rotations 21 and 35 manure was applied immediately preceding the beet crop, and it may be assumed that the stimulating effect on beet yields would be more pronounced than would have occurred had an intervening crop such as potatoes been grown. On the other hand, except in the case of rotation 46, at Belle Fourche and at Huntley 1 or more intervening crops were grown following alfalfa and preceding beets, and 2 intervening crops occur in rotation 60 at all 3 stations.

TABLE 3.—*Effect of manure and alfalfa on yields of sugar beets (tons per acre) at the Belle Fourche, Huntley, and Scotts Bluff Field Stations by 7-year periods, 1912–32*

BELLE FOURCHE

Rotation no.	Crop sequence	1912–18	1919–25	1926–32
		Tons	*Tons*	*Tons*
21	Sugar beets (manure), potatoes	12.9	17.4	16.9
40	Sugar beets, alfalfa, alfalfa, potatoes	10.6	13.0	11.8
	Difference in favor of manure	2.3	4.4	5.1
23	Sugar beets, oats (manure)	11.2	16.5	15.4
42	Sugar beets, alfalfa, alfalfa, oats	8.5	9.6	9.2
	Difference in favor of manure	2.7	6.9	6.2
23	Sugar beets, oats (manure)	[1] 16.3	16.5	15.4
46	Sugar beets, oats, alfalfa, alfalfa	[1] 9.7	7.0	6.7
	Difference in favor of manure	6.6	9.5	8.7
31	Sugar beets, potatoes, oats (manure)	11.5	12.7	11.0
60	Sugar beets, alfalfa, alfalfa, alfalfa, potatoes, oats	10.1	11.3	10.5
	Difference in favor of manure	1.4	1.4	1.4
35	Sugar beets, oats (manure), potatoes	[1] 16.5	16.4	13.5
64	Sugar beets, oats, alfalfa, alfalfa, alfalfa, potatoes	[1] 12.2	13.4	10.9
	Difference in favor of manure	4.3	3.0	2.6

HUNTLEY

21	Sugar beets (manure), potatoes	13.8	16.2	18.0
40	Sugar beets, alfalfa, alfalfa, potatoes	12.5	12.5	9.3
	Difference in favor of manure	1.3	3.7	8.7
23	Sugar beets, oats (manure)	[2] 12.0	13.5	16.8
46	Sugar beets, oats, alfalfa, alfalfa	[2] 10.6	11.5	5.7
	Difference in favor of manure	1.4	1.9	11.1
31	Sugar beets, potatoes, oats (manure)	10.8	13.3	17.6
60	Sugar beets, alfalfa, alfalfa, alfalfa, potatoes, oats	10.5	14.0	13.6
	Difference in favor of manure	.3	−.7	4.0
35	Sugar beets, oats (manure), potatoes	[2] 12.2	15.3	15.9
64	Sugar beets, oats, alfalfa, alfalfa, alfalfa, potatoes	[2] 11.6	14.2	10.1
	Difference in favor of manure	.6	1.1	5.8

[1] For the period 1917–18 only.
[2] For the period 1916–18 only.

TABLE 3.—*Effect of manure and alfalfa on yields of sugar beets (tons per acre) at the Belle Fourche, Huntley, and Scotts Bluff Field Stations by 7-year periods, 1912–32*—Continued

SCOTTS BLUFF

Rotation no.	Crop sequence	1912–18	1919–25	1926–32
		Tons	*Tons*	*Tons*
21	Sugar beets (manure), potatoes	15.4	17.5	17.4
40	Sugar beets, alfalfa, alfalfa, potatoes	18.2	17.8	14.9
	Difference in favor of manure	−2.8	−.3	2.5
23	Sugar beets, oats (manure)	18.3	18.1	18.1
42	Sugar beets, alfalfa, alfalfa, oats	15.8	16.0	15.3
	Difference in favor of manure	2.5	2.1	2.8
31	Sugar beets, potatoes, oats (manure)	18.5	17.2	18.3
60	Sugar beets, alfalfa, alfalfa, alfalfa, potatoes, oats	14.4	15.8	13.3
	Difference in favor of manure	4.1	1.4	5.0

The superiority of farm manure as compared with alfalfa is clearly apparent in table 3. For the last 7-year period manure has stimulated the yields of beets in excess of alfalfa, ranging from a minimum of 1.4 tons to a maximum of 11.1 tons per acre, with a mean increase of 5.3 tons. By individual stations, the mean superiority of manure over alfalfa for the same period is for Belle Fourche 4.8, for Huntley 7.4, and for Scotts Bluff 3.4 tons per acre. It has been shown that better results with sugar beets have occurred when at least one crop removed from alfalfa, preferably with a cultivated crop similar to potatoes intervening. Such a case occurs in rotation 64 at the Belle Fourche and Huntley stations. Even under such conditions when compared with rotation 35, with manure applied to the potatoes and the sugar beets immediately following, the superiority of the manurial treatment is apparent particularly for the last two 7-year periods.

EFFECT OF MANURE ON YIELDS OF POTATOES

The extent that farm manure influenced the yields of potatoes is indicated in table 4, which shows the yields and differences from comparable rotations. In only three instances was the manure applied directly preceding the potatoes; these were rotations 21, 25, and 35. In all other cases where 2- and 3-year rotations were involved the manure was applied to the sugar beets followed by potatoes. In rotation 61 the manure was applied to the sugar beets which were followed by 3 years of alfalfa, and then the potatoes were grown.

A comparison of the three periods indicates that there is an apparent tendency for applications of farm manure to increase the yields of potatoes at all three stations with the exception of the 60 and 61 rotations. In these 2 rotations not only are there 3 years of alfalfa preceding the potato crop, but 1 year of sugar beets and 3 years of alfalfa occur subsequent to the manurial treatment and before the potatoes are grown. These results indicate that stable manure applied to this rotation did not appreciably increase the yields of potatoes at any of the stations nor for any of the three 7-year periods. However, when the yields from rotation 31 are compared with those from rotation 30 at Huntley it appears that the manurial treatment has had a negative value for the first two 7-year periods.

TABLE 4.—*Effect of manure on yields of potatoes (bushels per acre) at the Belle Fourche, Huntley, and Scotts Bluff Field Stations by 7-year periods, 1912–32*

BELLE FOURCHE

Rotation no.	Crop sequence	1912–18	1919–25	1926–32
		Bushels	*Bushels*	*Bushels*
21	Potatoes, sugar beets (manure)	154	188	145
20	Potatoes, sugar beets	121	100	88
	Difference in favor of manure	33	88	57
25	Potatoes, oats (manure)	134	164	140
24	Potatoes, oats	115	138	116
	Difference in favor of manure	+19	26	33
31	Potatoes, oats (manure), sugar beets	149	188	157
30	Potatoes, oats, sugar beets	103	133	114
	Difference in favor of manure	46	55	43
35	Potatoes, sugar beets, oats (manure)	.....	210	150
34	Potatoes, sugar beets, oats	.....	159	130
	Difference in favor of manure	.....	51	20
61	Potatoes, oats (manure), sugar beets, alfalfa, alfalfa, alfalfa	114	140	133
60	Potatoes, oats, sugar beets, alfalfa, alfalfa, alfalfa	113	145	140
	Difference in favor of manure	1	−5	−7

HUNTLEY

21	Potatoes, sugar beets (manure)	279	200	249
20	Potatoes, sugar beets	266	185	138
	Difference in favor of manure	13	15	111
25	Potatoes, oats (manure)	355	202	202
24	Potatoes, oats	258	197	127
	Difference in favor of manure	97	125	105
31	Potatoes, oats (manure), sugar beets	200	147	182
30	Potatoes, oats, sugar beets	200	160	160
	Difference in favor of manure	−0	−13	22
35	Potatoes, sugar beets, oats (manure)	[1] 306	290	292
34	Potatoes, sugar beets, oats	[1] 317	247	177
	Difference in favor of manure	−11	40	115
61	Potatoes, oats (manure), sugar beets, alfalfa, alfalfa, alfalfa	333	290	323
60	Potatoes, oats, sugar beets, alfalfa, alfalfa, alfalfa	297	275	299
	Difference in favor of manure	36	15	24

SCOTTS BLUFF

21	Potatoes, sugar beets (manure)	195	224	276
20	Potatoes, sugar beets	170	130	146
	Difference in favor of manure	25	94	130
25	Potatoes, oats (manure)	224	233	287
24	Potatoes, oats	178	143	145
	Difference in favor of manure	46	90	142
31	Potatoes, oats (manure), sugar beets	323	244	312
30	Potatoes, oats, sugar beets	305	163	194
	Difference in favor of manure	18	81	118
61	Potatoes, oats (manure), sugar beets, alfalfa, alfalfa, alfalfa	290	320	348
60	Potatoes, oats, sugar beets, alfalfa, alfalfa, alfalfa	273	295	329
	Difference in favor of manure	17	25	19

[1] For the period 1916–18 only.

EFFECT OF ALFALFA ON YIELDS OF POTATOES

The influence of alfalfa on the yields of potatoes at the three stations in 14 instances is recorded in table 5. The potatoes immediately follow the alfalfa crop in all the rotations compared; hence the potato yields from the different combinations are directly comparable.

TABLE 5.—*Effect of alfalfa on the yield of potatoes (bushels per acre) at the Belle Fourche, Huntley, and Scotts Bluff Field Stations by 7-year periods, 1912–32*

BELLE FOURCHE

Rotation no.	Crop sequence	1912–18	1919–25	1926–32
		Bushels	*Bushels*	*Bushels*
40	Potatoes, sugar beets, alfalfa, alfalfa	116	155	123
20	Potatoes, sugar beets	121	100	88
	Difference in favor of alfalfa	−5	55	35
44	Potatoes, oats, alfalfa, alfalfa	139	180	167
24	Potatoes, oats	115	138	116
	Difference in favor of alfalfa	24	42	51
60	Potatoes, oats, sugar beets, alfalfa, alfalfa, alfalfa	113	145	140
30	Potatoes, oats, sugar beets	103	133	114
	Difference in favor of alfalfa	10	12	26
61	Potatoes, oats (manure), sugar beets, alfalfa, alfalfa, alfalfa	114	140	133
31	Potatoes, oats (manure), sugar beets	149	188	157
	Difference in favor of alfalfa	−35	−48	−24
64	Potatoes, sugar beets, oats, alfalfa, alfalfa, alfalfa	----------	112	130
34	Potatoes, sugar beets, oats	----------	159	139
	Difference in favor of alfalfa	----------	−47	−9

HUNTLEY

Rotation no.	Crop sequence	1912–18	1919–25	1926–32
40	Potatoes, sugar beets, alfalfa, alfalfa	269	259	272
20	Potatoes, sugar beets	266	185	138
	Difference in favor of alfalfa	3	74	134
44	Potatoes, oats, alfalfa, alfalfa	208	181	216
24	Potatoes, oats	258	167	127
	Difference in favor of alfalfa	−50	14	89
60	Potatoes, oats, sugar beets, alfalfa, alfalfa, alfalfa	297	275	299
30	Potatoes, oats, sugar beets	209	160	160
	Difference in favor of alfalfa	88	115	139
61	Potatoes, oats (manure), sugar beets, alfalfa, alfalfa, alfalfa	333	290	323
31	Potatoes, oats (manure), sugar beets	200	147	182
	Difference in favor of alfalfa	133	143	141
64	Potatoes, sugar beets, oats, alfalfa, alfalfa, alfalfa	[1] 308	272	343
34	Potatoes, sugar beets, oats	[1] 317	247	177
	Difference in favor of alfalfa	−9	25	166

[1] For the period 1916–18 only.

TABLE 5.—*Effect of alfalfa on the yield of potatoes (bushels per acre) at the Belle Fourche, Huntley, and Scotts Bluff Field Stations by 7-year periods, 1912–32*—Continued

SCOTTS BLUFF

Rotation no.	Crop sequence	1912–18	1919–25	1926–32
		Bushels	*Bushels*	*Bushels*
40	Potatoes, sugar beets, alfalfa, alfalfa	257	296	279
20	Potatoes, sugar beets	170	130	149
	Difference in favor of alfalfa	87	166	130
44	Potatoes, oats, alfalfa, alfalfa	286	264	270
24	Potatoes, oats	178	143	145
	Difference in favor of alfalfa	108	121	125
60	Potatoes, oats, sugar beets, alfalfa, alfalfa, alfalfa	273	295	329
30	Potatoes, oats, sugar beets	205	163	194
	Difference in favor of alfalfa	68	132	135
61	Potatoes, oats (manure), sugar beets, alfalfa, alfalfa, alfalfa	290	320	348
31	Potatoes, oats (manure), sugar beets	223	244	312
	Difference in favor of alfalfa	67	76	36

The results recorded in table 5 indicate that alfalfa increased the yields of potatoes materially for the 3 periods and in all 4 combinations at the Scotts Bluff station. At this station the smallest increase of 36 bushels per acre occurred in the 61 and 31 combinations, and the highest yields for the 3 periods were obtained from rotation 61, which has alfalfa and, in addition, an application of manure once during its 6-year cycle. At the Huntley station there were no consistent differences in favor of alfalfa during the first 7-year period. On the other hand, the differences are all in favor of alfalfa for the second and third 7-year periods for the 5 comparisons. Contrary to the results obtained at Scotts Bluff, the most favorable effects from alfalfa at the Huntley station occurred in the manured 61 and 31 rotations, where the yield differences in favor of alfalfa are 133, 143, and 141 bushels per acre, respectively, for the 3 periods. The results obtained at the Belle Fourche station have not been consistent, although the differences are in favor of alfalfa for the first 3 comparisons made for the second and third 7-year period. In comparing rotation 61 with rotation 31 at the Belle Fourche station, both of which had applications of manure, but the former having 3 years of alfalfa, the results indicate that the manurial treatment alone was more effective in maintaining the yields of potatoes at this station than was a combination of manure and alfalfa. When the mean yields from the 3 stations are compared it is evident that the heavier soils of the Belle Fourche station are not as favorable for large potato yields as are the somewhat lighter soils of the other 2 stations. Not only have the yields of potatoes been relatively low at Belle Fourche, but over the 21-year period the annual yields have fluctuated within wide limits, chiefly because of unfavorable weather. When such conditions occur the injury sustained by the different plots is often variable, and the yields recorded for such seasons do not reflect accurately the differences which under normal conditions may be attributed to rotational treatments.

EFFECT OF MANURE AS COMPARED WITH ALFALFA ON YIELDS OF POTATOES

In table 6 with 11 pairs of rotations it is possible to observe the effect of farm manure as compared with alfalfa on the yields of potatoes in similar rotations at the 3 stations. In rotations 21, 25, and 35, the manure was applied to the potato crop. In rotation 31 it was applied to sugar beets which crop immediately preceded potatoes in the rotation.

TABLE 6.—*Effect of manure as compared with alfalfa on yields of potatoes (bushels per acre) at the Belle Fourche, Huntley, and Scotts Bluff Field Stations by 7-year periods, 1912–32*

BELLE FOURCHE

Rotation no.	Crop sequence	1912–18	1919–25	1926–32
		Bushels	*Bushels*	*Bushels*
40	Potatoes, sugar beets, alfalfa, alfalfa	116	155	123
21	Potatoes, sugar beets (manure)	154	188	145
	Difference in favor of alfalfa	−38	−33	−22
44	Potatoes, oats, alfalfa, alfalfa	139	180	167
25	Potatoes, oats (manure)	134	164	149
	Difference in favor of alfalfa	5	16	18
60	Potatoes, oats, sugar beets, alfalfa, alfalfa, alfalfa	113	145	140
31	Potatoes, oats (manure), sugar beets	149	188	157
	Difference in favor of alfalfa	−36	−43	−17
64	Potatoes, sugar beets, oats, alfalfa, alfalfa, alfalfa	.....	112	130
35	Potatoes, sugar beets, oats (manure)	.....	210	159
	Difference in favor of alfalfa	.....	−98	−29

HUNTLEY

40	Potatoes, sugar beets, alfalfa, alfalfa	269	259	272
21	Potatoes, sugar beets (manure)	279	200	249
	Difference in favor of alfalfa	−10	59	23
44	Potatoes, oats, alfalfa, alfalfa	208	181	216
25	Potatoes, oats (manure)	355	292	292
	Difference in favor of alfalfa	−147	−111	−76
60	Potatoes, oats, sugar beets, alfalfa, alfalfa, alfalfa	297	275	299
31	Potatoes, oats (manure), sugar beets	200	147	182
	Difference in favor of alfalfa	97	128	117
64	Potatoes, sugar beets, oats, alfalfa, alfalfa, alfalfa	[1] 308	272	343
35	Potatoes, sugar beets, oats (manure)	[1] 306	296	292
	Difference in favor of alfalfa	2	−24	51

SCOTTS BLUFF

40	Potatoes, sugar beets, alfalfa, alfalfa	257	290	279
21	Potatoes, sugar beets (manure)	195	224	279
	Difference in favor of alfalfa	62	72	0
44	Potatoes, oats, alfalfa, alfalfa	286	264	270
25	Potatoes, oats (manure)	224	233	287
	Difference in favor of alfalfa	62	31	−17
60	Potatoes, oats, sugar beets, alfalfa, alfalfa, alfalfa	273	295	329
31	Potatoes, oats (manure), sugar beets	223	244	312
	Difference in favor of alfalfa	50	51	17

[1] For the period 1916–18 only.

The yields of potatoes at Belle Fourche, as a result of the manurial treatment, was in excess of the yields from rotations including alfalfa in all instances except in the 44 and 25 comparison, when the differences for all the periods are slightly in favor of alfalfa. At the Huntley station increases in the yields of potatoes resulting from 2 or 3 years of alfalfa as compared with farm manure have been neither consistent nor pronounced with the exception of the 60 and 31 comparison. A comparison of these 2 rotations by 7-year periods reveals a uniformly substantial difference in favor of the rotations including alfalfa. Only three pairs of rotations are available at the Scotts Bluff station. In all 7-year periods but 2, and they occur in the last period, alfalfa shows some superiority over stable manure in influencing the yields of potatoes. The superiority of alfalfa at this station is minimized, however, when the mean increases for the three 7-year periods are computed. Beginning with the 1912–18 period the mean increases are 58, 51, and 0 bushels per acre. This would indicate that the manurial treatment is developing a more favorable soil condition than is alfalfa. The trend of the potato yields in the different individual rotations tends to support this hypothesis.

EFFECT OF MANURE ON YIELDS OF OATS

In table 7 are recorded the yields of oats to show the influence of applications of farm manure on this crop in 14 comparisons at the 3 stations. In view of the fact that oats was not considered a major crop at the time these rotations were inaugurated, the manure was in no case applied directly preceding the oat crop, as had occurred in several instances with potatoes and sugar beets. One or more crops always intervened, and in rotation 61 five seasons elapsed between the time of application of manure and that when the oats were grown.

TABLE 7.—*Effect of manure on yields of oats (bushels per acre) at the Belle Fourche, Huntley, and Scotts Bluff Field Stations by 7-year periods, 1912–32*

BELLE FOURCHE

Rotation no.	Crop sequence	1912–18	1919–25	1926–32
		Bushels	*Bushels*	*Bushels*
23	Oats (manure), sugar beets	70	56	62
22	Oats, sugar beets	71	52	57
	Difference in favor of manure	−1	4	5
25	Oats (manure), potatoes	65	66	69
24	Oats, potatoes	71	60	57
	Difference in favor of manure	−6	6	12
31	Oats (manure), sugar beets, potatoes	77	62	61
30	Oats, sugar beets, potatoes	69	50	53
	Difference in favor of manure	8	12	11
35	Oats (manure), potatoes, sugar beets		50	49
34	Oats, potatoes, sugar beets		49	50
	Difference in favor of manure		1	−1
61	Oats (manure), sugar beets, alfalfa, alfalfa, alfalfa, potatoes	71	49	69
60	Oats, sugar beets, alfalfa, alfalfa, alfalfa, potatoes	67	52	65
	Difference in favor of manure	7	−3	4

TABLE 7.—*Effect of manure on yields of oats (bushels per acre) at the Belle Fourche, Huntley, and Scotts Bluff Field Stations by 7-year periods, 1912–32*—Continued

HUNTLEY

Rotation no.	Crop sequence	1912–18	1919–25	1926–32
		Bushels	*Bushels*	*Bushels*
23	Oats (manure), sugar beets	79	73	85
22	Oats, sugar beets	89	75	77
	Difference in favor of manure	−10	−1	8
25	Oats (manure), potatoes	92	84	96
24	Oats, potatoes	85	71	65
	Difference in favor of manure	7	13	31
31	Oats (manure), sugar beets, potatoes	78	72	96
30	Oats, sugar beets, potatoes	70	64	87
	Difference in favor of manure	8	8	9
35	Oats (manure), potatoes, sugar beets	[1] 83	86	74
34	Oats, potatoes, sugar beets	[1] 95	81	68
	Difference in favor of manure	−7	5	6
61	Oats (manure), sugar beets, alfalfa, alfalfa, alfalfa, potatoes	97	92	112
60	Oats, sugar beets, alfalfa, alfalfa, alfalfa, potatoes	91	94	110
	Difference in favor of manure	6	−2	2

SCOTTS BLUFF

23	Oats (manure), sugar beets	68	62	62
22	Oats, sugar beets	65	43	30
	Difference in favor of manure	3	19	32
25	Oats (manure), potatoes	65	61	50
24	Oats, potatoes	66	44	25
	Difference in favor of manure	−1	17	31
31	Oats (manure), sugar beets, potatoes	77	70	58
30	Oats, sugar beets, potatoes	66	52	29
	Difference in favor of manure	11	18	29
61	Oats (manure), sugar beets, alfalfa, alfalfa, alfalfa, potatoes	73	79	80
60	Oats, sugar beets, alfalfa, alfalfa, alfalfa, potatoes	70	74	71
	Difference in favor of manure	3	5	9

[1] For the period 1916–18 only.

A comparison of the differences between manured and untreated rotations at the Belle Fourche station for the three periods indicates that applications of manure did not increase the yields of oats appreciably except in the oats-potato rotations 24 and 25 and in 3-year rotations 30 and 31. The results for the three 7-year periods show that there has been a definite tendency for the oat yields to decrease in rotation 24, whereas there was a slight but progressive increase in the oat yields in rotation 25. Applications of farm manure influenced the yields of oats favorably in rotation 31 as compared with similar rotation 30, which was untreated. Significant differences in the yields of oats did not occur during any of the periods in 2-year rotations 22

and 23, 3-year rotations 34 and 35, nor in the 6-year rotations 60 and 61. At the Huntley station the manurial treatment did not materially increase the yields of oats, except in the case of oat-potato rotations 24 and 25 where the differences are significant. The results with oats at Scotts Bluff indicate that applications of stable manure over a long period may be expected to increase yields in crop sequences similar to those recorded here with the exception of 6-year alfalfa rotations comparable to 60 and 61. For the first 7-year period in the nonalfalfa rotations, in none of the comparisons was the difference in yields greatly in favor of the manure. The superiority of the manured rotations was definitely greater for the second 7-year period; and for the last 7-year period, 1926–32, the mean increase for the first 3 rotations was 31 bushels to the acre and within the narrow range of 29 to 32 bushels.

EFFECT OF ALFALFA ON YIELDS OF OATS

The extent to which alfalfa influenced the yields of oats at the 3 stations is recorded in table 8, which includes 19 comparisons. It will be noted that in rotation 42 the oat crop immediately follows alfalfa; whereas in other cases there is an intervening cultivated crop such as potatoes, which is usually considered a better farm practice.

TABLE 8.—*Effect of alfalfa on yields of oats (bushels per acre) at the Belle Fourche, Huntley, and Scotts Bluff Field Stations by 7-year periods, 1913–32*

BELLE FOURCHE

Rotation no.	Crop sequence	1913–18	1919–25	1926–32
		Bushels	*Bushels*	*Bushels*
42	Oats, sugar beets, alfalfa, alfalfa	48	39	44
22	Oats, sugar beets	71	52	57
	Difference in favor of alfalfa	−23	−13	−13
44	Oats, alfalfa, alfalfa, potatoes	83	51	72
24	Oats, potatoes	71	61	57
	Difference in favor of alfalfa	12	−9	15
48	Oats, alfalfa, alfalfa, spring wheat	82	52	50
28	Oats, spring wheat	35	23	23
	Difference in favor of alfalfa	47	29	30
60	Oats, sugar beets, alfalfa, alfalfa, alfalfa, potatoes	67	52	65
30	Oats, sugar beets, potatoes	69	50	53
	Difference in favor of alfalfa	−2	2	12
61	Oats (manure), sugar beets, alfalfa, alfalfa, alfalfa, potatoes	74	49	69
31	Oats (manure), sugar beets, potatoes	77	62	64
	Difference in favor of alfalfa	−3	−13	5
62	Oats, sugar beets, alfalfa, alfalfa, alfalfa, corn	62	39	51
32	Oats, sugar beets, corn	57	34	39
	Difference in favor of alfalfa	5	5	12
64	Oats, alfalfa, alfalfa, alfalfa, potatoes, sugar beets	.....	48	55
34	Oats, potatoes, sugar beets	.....	49	50
	Difference in favor of alfalfa	.....	−1	5

TABLE 8.—*Effect of alfalfa on yields of oats (bushels per acre) at the Belle Fourche, Huntley, and Scotts Bluff Field Stations by 7-year periods, 1912–32*—Continued

HUNTLEY

Rotation no.	Crop sequence	1912–18	1919–25	1926–32
		Bushels	*Bushels*	*Bushels*
42	Oats, sugar beets, alfalfa, alfalfa	86	90	101
22	Oats, sugar beets	89	79	77
	Difference in favor of alfalfa	−3	11	24
44	Oats, alfalfa, alfalfa, potatoes	78	86	97
24	Oats, potatoes	85	71	65
	Difference in favor of alfalfa	−7	15	32
46	Oats, alfalfa, alfalfa, sugar beets	[1] 87	90	99
22	Oats, sugar beets	[1] 92	79	77
	Difference in favor of alfalfa	−5	11	22
60	Oats, sugar beets, alfalfa, alfalfa, alfalfa, potatoes	91	94	110
30	Oats, sugar beets, potatoes	70	64	57
	Difference in favor of alfalfa	21	30	53
61	Oats (manure), sugar beets, alfalfa, alfalfa, alfalfa, potatoes	97	92	112
31	Oats (manure), sugar beets, potatoes	76	72	66
	Difference in favor of alfalfa	21	20	46
64	Oats, alfalfa, alfalfa, alfalfa, potatoes, sugar beets	[1] 87	89	89
34	Oats, potatoes, sugar beets	[1] 95	81	68
	Difference in favor of alfalfa	−8	8	21

SCOTTS BLUFF

42	Oats, sugar beets, alfalfa, alfalfa	73	66	68
22	Oats, sugar beets	65	43	30
	Difference in favor of alfalfa	8	23	38
44	Oats, alfalfa, alfalfa, potatoes	75	70	69
24	Oats, potatoes	66	44	25
	Difference in favor of alfalfa	9	26	44
48	Oats, alfalfa, alfalfa, spring wheat	66	69	60
25	Oats, spring wheat	55	33	21
	Difference in favor of alfalfa	11	36	39
60	Oats, sugar beets, alfalfa, alfalfa, alfalfa, potatoes	70	74	71
30	Oats, sugar beets, potatoes	66	52	29
	Difference in favor of alfalfa	4	22	42
61	Oats (manure), sugar beets, alfalfa, alfalfa, alfalfa, potatoes	73	79	80
31	Oats (manure), sugar beets, potatoes	77	70	58
	Difference in favor of alfalfa	−4	9	22
62	Oats, sugar beets, alfalfa, alfalfa, alfalfa, corn	59	69	68
32	Oats, sugar beets, corn	56	38	24
	Difference in favor of alfalfa	3	31	44

[1] For the period 1916–18 only.

Under the conditions at the Belle Fourche station the most consistently unsatisfactory results occurred where the oat crop immediately followed alfalfa in rotation 42 as compared with rotation 22.

The largest difference in favor of alfalfa for the three 7-year periods was in the oats-spring wheat rotations 28 and 48. It is worthy of note that in all 7 pairs, with the exception of the 22 and 42 rotations, the differences for the last 7-year period, even if slight in some instances, are in favor of the rotations having alfalfa. Including alfalfa in the cropping program at the Huntley station has had a uniformly beneficial effect on the yields of oats, as is evidenced by a comparison of the three 7-year periods. Even where the oat crop immediately follows alfalfa in rotation 42 as compared with rotation 22 the differences increased progressively for the 3 periods. The results at Huntley indicate further that the better yields of oats are to be expected in rotations like no. 60 having 3 years of alfalfa. That the oat yields in rotation 60 have tended to increase, whereas those harvested from rotation 30 have progressively decreased is shown by a comparison of the three 7-year periods. Alfalfa included in five of the rotations at the Scotts Bluff station had a definitely stimulating influence on the yields of oats in all rotations, particularly during the last two 7-year periods. At this station there have been no increased yields of oats as a result of 3 years of alfalfa as compared with 2 years.

EFFECT OF MANURE AS COMPARED WITH ALFALFA ON YIELDS OF OATS

The extent that alfalfa influenced the yields of oats as compared with applications of farm manure is shown in 12 comparisons in table 9. In all cases where the manurial treatment was applied one or more crops intervened between the treatment and the oat crop. On the other hand, in one instance (rotation 42) the oat crop immediately followed alfalfa, while in others a cultivated crop intervened between the alfalfa and the oat crops. In rotation 64 following alfalfa two cultivated crops were grown—potatoes and sugar beets.

TABLE 9.—*Effect of manure as compared with alfalfa on yields of oats (bushels per acre) at the Belle Fourche, Huntley, and Scotts Bluff Field Stations by 7-year periods, 1913–32*

BELLE FOURCHE

Rotation no.	Crop sequence	1913–18	1919–25	1926–32
		Bushels	*Bushels*	*Bushels*
42	Oats, sugar beets, alfalfa, alfalfa	43	39	44
23	Oats (manure), sugar beets	70	56	62
	Difference in favor of alfalfa	−22	−17	−18
44	Oats, alfalfa, alfalfa, potatoes	83	51	72
25	Oats (manure), potatoes	65	66	69
	Difference in favor of alfalfa	18	−15	3
60	Oats, sugar beets, alfalfa, alfalfa, alfalfa, potatoes	67	52	65
31	Oats (manure), sugar beets, potatoes	77	62	64
	Difference in favor of alfalfa	−10	−10	1
64	Oats, alfalfa, alfalfa, alfalfa, potatoes, sugar beets	----	48	55
35	Oats (manure), potatoes, sugar beets	----	50	49
	Difference in favor of alfalfa	----	−2	6

TABLE 9.—*Effect of manure as compared with alfalfa on yields of oats (bushels per acre) at the Belle Fourche, Huntley, and Scotts Bluff Field Stations by 7-year periods, 1912–32*—Continued

HUNTLEY

Rotation no.	Crop sequence	1912–18	1919–25	1926–32
		Bushels	*Bushels*	*Bushels*
42	Oats, sugar beets, alfalfa, alfalfa	86	90	101
23	Oats (manure), sugar beets	79	78	85
	Difference in favor of alfalfa	7	12	16
44	Oats, alfalfa, alfalfa, potatoes	78	86	97
25	Oats (manure), potatoes	92	84	96
	Difference in favor of alfalfa	−14	2	1
46	Oats, alfalfa, alfalfa, sugar beets	[1] 87	90	99
23	Oats (manure), sugar beets	[1] 78	78	85
	Difference in favor of alfalfa	9	12	14
60	Oats, sugar beets, alfalfa, alfalfa, alfalfa, potatoes	91	94	110
31	Oats (manure), sugar beets, potatoes	76	72	66
	Difference in favor of alfalfa	15	22	44
64	Oats, alfalfa, alfalfa, alfalfa, potatoes, sugar beets	[1] 87	89	89
35	Oats (manure), potatoes, sugar beets	[1] 88	86	74
	Difference in favor of alfalfa	−1	3	15

SCOTTS BLUFF

42	Oats, sugar beets, alfalfa, alfalfa	73	66	68
23	Oats (manure), sugar beets	68	62	62
	Difference in favor of alfalfa	5	4	6
44	Oats, alfalfa, alfalfa, potatoes	75	70	69
25	Oats (manure), potatoes	65	61	56
	Difference in favor of alfalfa	10	9	13
60	Oats, sugar beets, alfalfa, alfalfa, alfalfa, potatoes	70	74	71
31	Oats (manure), sugar beets, potatoes	77	70	58
	Difference in favor of alfalfa	−7	4	13

[1] 1910–18 only.

The results obtained thus far at the Belle Fourche station indicate that applications of manure increased the yields of oats more than the alfalfa for all 3 periods in the 42 and 23 comparison. When the results from the other three pairs of rotations are considered, the differences are not consistent or of a magnitude to be considered significant. At the Huntley station the differences in the oat yields for all three 7-year periods in the 42 and 23, the 46 and 23, and the 60 and 31 comparisons are more consistent and of a magnitude to indicate that alfalfa in such crop sequences is distinctly superior to farm manure. Negative results have occurred where oats and potatoes have been grown in the 44 and 25 rotations. For the last 7-year period the difference of 15 bushels per acre in oat yields in the 64 and 35 rotations indicates that the cumulative beneficial effect of alfalfa is in excess of that from stable manure. In all but 1 instance the differences in oat yields at the Scotts Bluff station for the three 7-year periods are in favor of alfalfa. However, these differences are not great.

RESULTS OF THE DIFFERENT TREATMENTS SUMMARIZED

While generally the beneficial effects on subsequent crop yields resulting from including a leguminous crop in the cropping program have been too long and too well recognized to require emphasis, the results of these investigations have disclosed that there is grave danger of overestimating the value of a leguminous crop such as alfalfa in stimulating crop yields as compared with applications of farm manure. The inadequacy of the information with respect to the merits of these two soil-improvement agencies has resulted in the too general assumption that the inclusion of alfalfa in the cropping program is, in a large measure at least, a satisfactory substitute for applications of farm manure. From these results it is apparent that there is need for more precise information regarding the comparative merits of the two agencies under varying soil conditions, as well as the frequency of their appearance and location in the cropping program. Furthermore, the application of manure is a laborious task, and, partly because of this fact, there is a tendency among many farmers to allow the accumulation of this valuable farm asset to waste with the expectation that their crop yields may be maintained satisfactorily by means of alfalfa. These investigations indicate that such an assumption is not always well founded, particularly when sugar beets are involved.

The effects of manure and of alfalfa on the yields of sugar beets, potatoes, and oats have been recorded in the foregoing tables by 7-year periods for the 21 years. By this method of presentation it is possible to show the actual mean yields harvested in the different rotations for the three periods and the yield trends, that is, the extent that yields of sugar beets, potatoes, and oats have been diminished or increased as a result of the use of manure or the inclusion of alfalfa in the rotations. The following tables and discussions are devoted to a summary of the results obtained from the different rotations and treatments in which the mean yields, the differences in yields, and the standard error are computed. These condensed tables have been compiled for the purpose of ascertaining and comparing the magnitude of the differences and its significance as expressed by the standard error. The yields from each of the 3 stations are given in each table in order to afford a direct comparison of results obtained at the 3 localities. In order to afford an opportunity to observe the extent to which the different treatments have influenced the yields of the 3 crops at the 3 stations, the combined mean differences for similar rotations have been computed.

In considering the summary of the results recorded in the following tables it should be recognized that the second and particularly the last 7-year period more accurately reflect the differences which may be attributed to the rotational treatments. It has become increasingly apparent that 7 years is too brief a period to afford reliable conclusions even for rotations as short as those having a 2-year cycle. When those having a 6-year cycle are involved it is obvious that but 3 complete cycles will have been completed at the end of the third 7-year period. In such instances it is evident that but little significance can be placed on the yields and differences recorded for the first two periods. While it is apparent that the mean yields for the combined 21 years completely mask yield trends, yet this method of presentation affords an opportunity to compare directly the 21-year mean

yields for the different treatments and the reliability of the results by determining the standard error at the 3 locations.

The extent that yields of sugar beets have been influenced at the 3 stations by applications of stable manure is given in table 10. The increases in yields have ranged from a minimum of 2.6 tons at the Belle Fourche station in the 61 and 60 6-year rotation, which includes 3 years of alfalfa, to a maximum of 7.8 tons at the Scotts Bluff in the 23 and 22 pair, which are 2-year rotations with oats the preceding crop. Not only are the increases in yields of beets appreciably due to applications of stable manure, but when the yield differences are compared with the standard error they are found to be significant in every instance.

TABLE 10.—*The influence of stable manure on the mean acre yields of sugar beets at the Belle Fourche, Huntley, and Scotts Bluff Field Stations for the period 1912–32*

Rotation no.	Crop sequence	Belle Fourche		Huntley		Scotts Bluff	
		Acre yield	Standard error	Acre yield	Standard error	Acre yield	Standard error
		Tons		*Tons*		*Tons*	
21	Sugar beets (manure), potatoes	15.7		16.0		16.8	
20	Sugar beets, potatoes	12.0		11.7		10.8	
	Difference in favor of manure	3.7	±0.59	4.3	±0.76	6.0	±0.75
23	Sugar beets, oats (manure)	14.4		14.2		18.2	
22	Sugar beets, oats	10.7		8.5		10.4	
	Difference in favor of manure	3.7	±.61	5.7	±1.14	7.8	±.64
31	Sugar beets, potatoes, oats (manure)	12.0		13.9		18.0	
30	Sugar beets, potatoes, oats	7.6		8.0		10.7	
	Difference in favor of manure	4.4	±.53	5.9	±.78	7.3	±.54
35	Sugar beets, oats (manure), potatoes			[1] 14.5			
34	Sugar beets, oats, potatoes			[1] 10.1			
	Difference in favor of manure			4.4	±1.12		
61	Sugar beets, alfalfa (3 years), potatoes, oats (manure)	13.2		15.0		19.2	
60	Sugar beets, alfalfa (3 years), potatoes, oats	10.6		12.7		14.5	
	Difference in favor of manure	2.6	±.67	3.2	±.73	4.7	±.27
	Mean difference of rotations 21 and 20, 23 and 22, 31 and 30, and 61 and 60	3.6		4.8		6.4	

[1] For the period 1916–32 only.

It will be observed from the results at the 3 stations that in every instance the increases have been the largest at the Scotts Bluff station, which has the lightest soil. At the Belle Fourche station, which has a heavy gumbo soil, the increases in yields attributed to the manurial treatment are consistently the lowest. The soil conditions at the Huntley station are intermediate between the other two, as are the differences. The mean differences in favor of manure for the 4 similar rotations are: Belle Fourche 3.6, Huntley 4.8, and Scotts Bluff 6.4 tons per acre, or an increase of about 55 percent for the Scotts Bluff station.

There are 7 pairs of rotations which indicate the effect of alfalfa on the yields of sugar beets. The results from 4 of these pairs have been accumulated over the entire 21-year period for all 3 stations. The mean yields and differences for the 3 stations are given in table 11.

TABLE 11.—*The influence of alfalfa on the mean acre yields of sugar beets at the Belle Fourche, Huntley, and Scotts Bluff Field Stations for the period 1912–32*

Rotation no.	Crop sequence	Belle Fourche		Huntley		Scotts Bluff	
		Acre yield	Standard error	Acre yield	Standard error	Acre yield	Standard error
		Tons		*Tons*		*Tons*	
40	Sugar beets, alfalfa (2 years), potatoes	11.8	.....	11.4	.....	17.0	.....
20	Sugar beets, potatoes	12.0	.....	11.7	.....	10.8	.....
	Difference in favor of alfalfa	−.2	±0.39	−.3	±0.69	6.2	±0.64
42	Sugar beets, alfalfa (2 years), oats	9.1	.....	9.7	.....	15.7	.....
22	Sugar beets, oats	10.7	.....	8.5	.....	10.4	.....
	Difference in favor of alfalfa	−1.6	±.46	1.2	±.74	5.3	±.77
46	Sugar beets, oats, alfalfa (2 years)	[1] 7.8	.....	[1] 9.3	.....	.....	.....
22	Sugar beets, oats	[1] 11.2	.....	[1] 8.5	.....	.....	.....
	Difference in favor of alfalfa	−3.4	±.57	.8	±.73	.....	.....
60	Sugar beets, alfalfa (3 years), potatoes, oats	10.6	.....	12.7	.....	14.5	.....
30	Sugar beets, potatoes, oats	7.6	.....	8.0	.....	10.7	.....
	Difference in favor of alfalfa	3.0	±.43	4.7	±.55	3.8	±.60
61	Sugar beets, alfalfa (3 years), potatoes, oats (manure)	13.2	.....	15.0	.....	19.2	.....
31	Sugar beets, potatoes, oats (manure)	12.0	.....	13.0	.....	18.0	.....
	Difference in favor of alfalfa	1.2	±.08	2.0	±.67	1.2	±.51
62	Sugar beets, alfalfa (3 years), corn, oats	8.0	.....	.....	.....	14.1	.....
32	Sugar beets, oats, corn	6.6	.....	.....	.....	10.6	.....
	Difference in favor of alfalfa	2.3	±.40	.....	.....	3.5	±.53
64	Sugar beets, oats, alfalfa (3 years), potatoes	[1] 12.2	.....	[1] 12.0	.....	.....	.....
34	Sugar beets, oats, potatoes	[1] 13.2	.....	[1] 10.1	.....	.....	.....
	Difference in favor of alfalfa	−1.0	±.50	1.9	±.71	.....	.....
	Mean difference of rotations 40 and 20, 42 and 22, 60 and 30, and 61 and 31	.6	.....	1.9	.....	4.1	.....

[1] For the period 1916–32 only.

The mean yields of the 4 rotations for the 3 stations show that only 0.6 of a ton increase may be attributed to alfalfa at Belle Fourche, 1.9 tons at Huntley, and 4.1 tons at the Scotts Bluff station. These mean results indicate that on the average alfalfa has not materially stimulated sugar-beet yields on the heavy gumbo soil at the Belle Fourche station, but at Huntley some increase is noted, while at the Scotts Bluff station definitely favorable results have been obtained. It should be noted that at Belle Fourche negative differences have been obtained in the yield of beets from each of the 4-year rotations having 2 years of alfalfa. On the other hand, when the differences are computed in the 6-year combinations having 3 years of alfalfa there is an increase in the yields in 3 cases out of the 4.

Somewhat comparable results have been obtained at the Huntley station. There were slight increases in the differences in 2 out of 3 instances in the rotations having 2 years of alfalfa, but in none of the combinations are the differences significant. At this station a definite increase in the yields of beets is apparent when rotation 60 is compared with rotation 30. However, in the other 2 combinations 3 years of alfalfa have had a less favorable influence on the yields of beets.

The yield differences from each of the combinations at the Scotts Bluff station in favor of alfalfa range from a minimum of 1.2 to a maximum of 6.2 tons of beets to the acre. Furthermore, contrary to the results obtained at the other 2 stations, at this station 2 years of alfalfa have materially stimulated the yields of beets, there being a mean difference of 5.8 tons per acre for these 2 rotations. The mean difference for the 2 pairs having 3 years of alfalfa and where the manurial treatment is not involved is only 3.7 tons, or a difference in favor of rotations having only 2 years of alfalfa of 2.1 tons of beets to the acre. From these results it might appear that 2 years were superior to 3 years of alfalfa. However, 2 crops come between the alfalfa and sugar beets in rotations 60 and 61, whereas there is only 1 crop in 4-year rotations 40 and 42.

For all 3 stations the second largest mean yield of beets, 14.6 tons per acre, is from rotation 31, to which farm manure was applied every third year to the beet crop. Rotation 61 is similar as to major crops and also as to manurial treatment, but 3 years of alfalfa is included between the beet and potato crops. The mean yield of rotation 61 for the 3 stations is 16.1 tons per acre, the largest yield of any of the 14 rotations listed in this table and 1.5 tons per acre in excess of the companion rotation 31. These results indicate that increases in beet yields may be expected even in rotations which include applications of stable manure by having alfalfa in the cropping program.

Table 12 affords comparison of the yields obtained from the 3 crops during the 21-year period from applications of farm manure as compared with alfalfa in otherwise similar crops and crop sequences. This table presents available evidence from 13 different combinations. In only 1, rotation 21 as compared with rotation 40 at Scotts Bluff, has alfalfa been as effective as the manure in increasing the yields of beets. When the mean differences for all the combinations for each of the 3 stations are considered it will be found that as compared with alfalfa the manurial treatment has increased the yields of beets 3.5 tons at Belle Fourche, 3.4 tons at Huntley, and 1.9 tons per acre at Scotts Bluff. However, in the 31 and 60 comparison it should be recognized that the manure is applied immediately preceding the beets in rotation 31, whereas 2 crops, potatoes and oats, come between the alfalfa and the beets in rotation 60. In this latter rotation it seems probable that the productivity of the soil may have been somewhat exhausted by the time the beets were grown.

The increase in the yields of beets as a result of the manurial treatment as compared with alfalfa ranged from a minimum difference of −0.2 ton from rotations 21 and 40 at Scotts Bluff to a maximum difference of 8.3 tons per acre from rotations 23 and 46 at Belle Fourche. The differences from both the Belle Fourche and Huntley stations indicate definitely the superiority of applications of farm manure as compared with alfalfa, particularly in the rotations having only 2 years of alfalfa. The manurial treatment at these two stations was superior to alfalfa even in the 31 and 60 and the 35 and 64 combinations, which had 3 years of alfalfa. It is possible to observe the effect on the yields of beets as compared with alfalfa in only 3 instances at the Scotts Bluff station. In 2 out of the 3 combinations the manurial treatment has proved to be superior to alfalfa, the yield increases

being 2.5 to 3.5 tons per acre for these 2 pairs of rotations. It is apparent that applications of the manure have been distinctly superior to alfalfa in stimulating the yields of sugar beets in these crop sequences at the three stations. From the 3 similar rotations increases are shown ranging from 12 percent at Scotts Bluff, 30 percent at Huntley, and 33 percent at Belle Fourche.

TABLE 12.—*The influence of stable manure as compared with alfalfa on the mean acre yields of sugar beets at the Belle Fourche, Huntley, and Scotts Bluff Field Stations for the period 1912–32*

Rotation no.	Crop sequence	Belle Fourche		Huntley		Scotts Bluff	
		Acre yield	Standard error	Acre yield	Standard error	Acre yield	Standard error
		Tons		*Tons*		*Tons*	
21	Sugar beets (manure), potatoes	15.7		16.0		16.8	
40	Sugar beets, alfalfa (2 years), potatoes	11.8		11.4		17.0	
	Difference in favor of manure	3.9	±0.63	4.6	±1.03	−.2	±0.78
23	Sugar beets, oats (manure)	11.4		14.2		18.2	
42	Sugar beets, alfalfa (2 years), oats	9.1		9.7		15.7	
	Difference in favor of manure	5.3	±.84	4.5	±1.14	2.5	±.84
23	Sugar beets, oats (manure)	[1] 16.1		[1] 14.1			
48	Sugar beets, oats, alfalfa, alfalfa	[1] 7.8		[1] 9.3			
	Difference in favor of manure	8.3	±.68	4.8	±1.37		
31	Sugar beets, potatoes, oats (manure)	12.0		13.9		18.0	
60	Sugar beets, alfalfa (3 years), potatoes, oats	10.6		12.7		14.5	
	Difference in favor of manure	1.4	±.42	1.2	±.73	3.5	±.56
35	Sugar beets, oats (manure), potatoes	[1] 15.5		[1] 14.5			
64	Sugar beets, oats, alfalfa (3 years), potatoes	[1] 12.2		[1] 12.0			
	Difference in favor of manure	3.3	±.52	2.5	±.84		
	Mean difference of rotations 21 and 40, 23 and 42, and 31 and 60	3.5		3.4		1.9	

[1] For the period 1916–32 only.

The extent to which applications of farm manure influenced the yields of potatoes is shown in 14 different instances in table 13. The mean increase which may be attributed to the manurial treatment for all the combinations at Belle Fourche is 32 bushels, at Huntley 50 bushels, and at Scotts Bluff 67 bushels per acre.

The yield increases of potatoes as a result of the manurial treatment ranged from —4 bushels per acre at Belle Fourche in the 61 and 60 rotations to a maximum of 129 bushels per acre at Huntley in the 25 and 24 rotations. In all but two instances significant increases in yields were obtained as a result of this treatment. For the 3 stations farm manure applied to rotation 61 resulted in the lowest increase, the mean being 14 bushels per acre. In this rotation 4 years elapse between the applications of manure and the potato crop. It is reasonable to assume that the favorable effects of the application of 12 tons of manure would not be so apparent after 4 years as would be the case if only one crop intervened or the application were made just prior to the potato crop.

TABLE 13.—*The influence of stable manure on the mean acre yields of potatoes at the Belle Fourche, Huntley, and Scotts Bluff Field Stations for the period 1912–32*

Rotation no.	Crop sequence	Belle Fourche		Huntley		Scotts Bluff	
		Acre yield	Standard error	Acre yield	Standard error	Acre yield	Standard error
		Bushels		*Bushels*		*Bushels*	
21	Potatoes, sugar beets (manure)	162		243		233	
20	Potatoes, sugar beets	103		196		150	
	Difference in favor of manure	59	±10.4	47	±15.2	83	±16.8
25	Potatoes, oats (manure)	149		313		248	
24	Potatoes, oats	123		184		155	
	Difference in favor of manure	26	±5.4	129	±12.1	93	±12.8
31	Potatoes, oats (manure), sugar beets	165		176		260	
30	Potatoes, oats, sugar beets	117		176		187	
	Difference in favor of manure	48	±7.0	0	±8.4	73	±13.5
35	Potatoes, sugar beets, oats (manure)	185		298			
34	Potatoes, sugar beets, oats	149		247			
	Difference in favor of manure	36	±10.6	51	±15.8		
61	Potatoes, oats (manure), sugar beets, alfalfa (3 years)	120		315		310	
60	Potatoes, oats, sugar beets, alfalfa (3 years)	133		290		290	
	Difference in favor of manure	−4	±5.6	25	±12.7	20	±6.0
	Mean difference of rotations 21 and 20, 25 and 24, 31 and 30, and 61 and 60	32		50		67	

The extent to which alfalfa influenced the yields of potatoes is indicated in table 14. There are 14 instances where the differences may be observed for the 21 years. The mean differences for similar rotations show that alfalfa has increased the yields of potatoes at Belle Fourche 12 bushels, at Huntley 85 bushels, and at Scotts Bluff 104 bushels per acre.

TABLE 14.—*The influence of alfalfa on the mean acre yields of potatoes at the Belle Fourche, Huntley, and Scotts Bluff Field Stations for the period 1912–32*

Rotation no.	Crop sequence	Belle Fourche		Huntley		Scotts Bluff	
		Acre yield	Standard error	Acre yield	Standard error	Acre yield	Standard error
		Bushels		*Bushels*		*Bushels*	
40	Potatoes, sugar beets, alfalfa (2 years)	131		267		277	
20	Potatoes, sugar beets	103		196		150	
	Difference in favor of alfalfa	28	±7.5	71	±16.2	127	±14.9
44	Potatoes, oats, alfalfa (2 years)	162		202		273	
24	Potatoes, oats	123		184		155	
	Difference in favor of alfalfa	39	±7.7	18	±18.2	118	±12.9
60	Potatoes, oats, sugar beets, alfalfa (3 years)	133		290		299	
30	Potatoes, oats, sugar beets	117		176		187	
	Difference in favor of alfalfa	16	±6.8	114	±12.0	112	±12.8
61	Potatoes, oats (manure), sugar beets, alfalfa (3 years)	129		315		310	
31	Potatoes, oats (manure), sugar beets	165		176		260	
	Difference in favor of alfalfa	−36	±10.3	139	±14.2	50	±11.2
64	Potatoes, sugar beets, oats, alfalfa (3 years)	121		308			
34	Potatoes, sugar beets, oats	149		247			
	Difference in favor of alfalfa	−28	±8.5	61	±21.9		
	Mean difference of rotations 40 and 20, 44 and 24, 60 and 30, and 61 and 31	12		85		104	

The maximum increase which may be attributed to the alfalfa of 139 bushels per acre occurred at Huntley in the 61 and 31 rotations, both of which had applications of farm manure. At Belle Fourche, involving the same pair, there is a —36-bushel decrease. In none of the five combinations did the increase exceed the 39 bushels per acre at Belle Fourche. On the other hand, at Huntley substantial increases are apparent in each of the 5 comparisons except in that involving the 44 and 24 pair, where the increase was only 18 bushels per acre, with a standard error of ±18.2. At Scotts Bluff substantial increases in the yields of potatoes occurred, ranging from a minimum of 59 bushels to a maximum of 127 bushels per acre.

In 11 different instances at the three stations an opportunity is afforded to compare the effect of alfalfa with applications of farm manure on the yields of potatoes. The mean differences in favor of alfalfa from the same rotations at all 3 locations indicate that alfalfa as compared with manure has influenced yields of potatoes to the extent of —17 bushels at Belle Fourche, 9 bushels at Huntley, and 36 bushels per acre at Scotts Bluff. The summary of the mean yields and the differences are given in table 15.

TABLE 15.—*The influence of alfalfa as compared with stable manure on the mean acre yields of potatoes at the Belle Fourche, Huntley, and Scotts Bluff Field Stations for the period 1912–32*

Rotation no.	Crop sequence	Belle Fourche		Huntley		Scotts Bluff	
		Acre yield	Standard error	Acre yield	Standard error	Acre yield	Standard error
		Bushels		*Bushels*		*Bushels*	
40	Potatoes, sugar beets, alfalfa (3 years)	131	.....	267	.....	277	.....
21	Potatoes, sugar beets (manure)	162	.....	243	.....	233	.....
	Difference in favor of alfalfa	−31	±7.5	24	±14.1	44	±13.3
44	Potatoes, oats, alfalfa (2 years)	162	.....	202	.....	273	.....
25	Potatoes, oats (manure)	149	.....	313	.....	248	.....
	Difference in favor of alfalfa	13	±9.2	−111	±15.8	25	±11.5
60	Potatoes, oats, sugar beets, alfalfa (3 years)	133	.....	290	.....	299	.....
31	Potatoes, oats (manure), sugar beets	165	.....	176	.....	260	.....
	Difference in favor of alfalfa	−32	±9.4	114	±14.2	39	±11.3
64	Potatoes, sugar beets, oats, alfalfa (3 years)	[1] 121	.....	[1] 308	.....	.....	.....
35	Potatoes, sugar beets, oats (manure)	[1] 185	.....	[1] 298	.....	.....	.....
	Difference in favor of alfalfa	−64	±12.8	10	±18.2	.....	.....
	Mean difference of rotations 40 and 21, 44 and 25, and 60 and 31	−17	.....	9	.....	36	.....

[1] For the period 1916–32 only.

In only 1 instance out of the 4 did alfalfa prove to be as effective with potatoes as applications of manure at Belle Fourche, and this occurred in the 44 and 25 pair where the increase totaled only 13 bushels per acre, accompanied with a high standard error. In the other three instances the differences are definitely in favor of the manurial treatment. At the Huntley station the mean differences are in favor of alfalfa with the exception of the 44 and 25 comparison. The lowest mean yield at this station, 202 bushels per acre, is from rotation 44 having oats and 2 years of alfalfa as the companion crops.

In a large measure the relatively low yields of potatoes harvested from rotation 44 as compared with the yields from the other alfalfa rotations is believed chiefly due to the fact that the soil where rotation 44 is located is less favorable for potato production. When the manure was applied to 2-year rotation 25 with oats as the companion crop, and the manure applied following the oat crop, 313 bushels of potatoes have been harvested, the highest mean yield recorded at this station, and 111 bushels per acre in excess of the yield from rotation 44. At Huntley only one observation is possible where an intervening crop was grown between the manurial application and the potatoes, and that is rotation 31 with a mean yield of 176 bushels per acre. This rotation may be compared with no. 35 having the same crops but in slightly different sequence, the manure being aplied directly preceding the potato crop, and a mean yield produced of 298 bushels, or 122 bushels per acre in excess of rotation 31. Yield increases which may be attributed to alfalfa as compared with manure at the Scotts Bluff station are moderate but consistent, the maximum being 44 and the minimum 25 bushels per acre.

In planning these rotation experiments the chief objective was to arrange the crop sequences and the time of applying the manure so that the two major cash crops, sugar beets, and potatoes, would be in a position to benefit most from the crop sequences and treatments. Oats were selected from among the cereals to be included in the rotation, partly for the purpose of observing the effect of a cereal on subsequent crop yields of both potatoes and sugar beets. At the same time it was recognized that the feed requirements of many farm enterprises are such that one of the cereals could be incorporated advantageously in the cropping program and that information concerning the effect the different treatments and crop sequences would have on oat yields would be highly useful in conducting the farming operations efficiently.

The mean acre yields of oats together with the standard error are given in table 16 as this crop appears in the different crop sequences where manure is applied as compared with those not so treated. The mean yield increases from comparable rotations for the three stations are: Belle Fourche 4 bushels, Huntley 6 bushels, and Scotts Bluff 15 bushels per acre.

Yield differences are recorded in 14 instances, and yield increases are positive in 13 of the 14. The differences range from 0 in the 35 and 34 pair at Belle Fourche to 19 bushels per acre in the 31 and 30 comparison at Scotts Bluff. At the Belle Fourche station the maximum increase of 11 bushels per acre occurs in the 31 and 30 comparison. The other 4 differences range from 0 to 4 bushels per acre. At this station applications of farm manure did not increase the yields of oats materially, although yield increases occurred in 4 of the 5 instances. When compared with the standard error they appear to be significant. At the Huntley station the maximum increase was 17 bushels and the minimum −1 bushel per acre, and in the 2 other rotations increases of only 2 bushels per acre occurred. In only 2 instances of the 5 are there significant differences when compared with the standard error. The yield differences recorded for the Scotts Bluff station indicate that in all instances the manurial treatment had a favorable influence on the yields of oats, ranging from 5

to 19 bushels per acre; although in the 61 and 60 comparison, both of which had 3 years of alfalfa, there was only a 5-bushel increase.

TABLE 16.—*The influence of stable manure on the mean acre yields of oats at the Belle Fourche, Huntley, and Scotts Bluff Field Stations for the period 1912–32*

Rotation no.	Crop sequence	Belle Fourche		Huntley		Scotts Bluff	
		Acre yield	Standard error	Acre yield	Standard error	Acre yield	Standard error
		Bushels		*Bushels*		*Bushels*	
23	Oats (manure), sugar beets	53	.....	81	.....	64	.....
22	Oats, sugar beets	60	.....	82	.....	46	.....
	Difference in favor of manure	3	±1.4	−1	±3.2	18	±3.3
25	Oats (manure), potatoes	67	.....	91	.....	61	.....
24	Oats, potatoes	63	.....	74	.....	45	.....
	Difference in favor of manure	4	±2.5	17	±3.3	16	±4.2
31	Oats (manure), sugar beets, potatoes	68	.....	71	.....	68	.....
30	Oats, sugar beets, potatoes	57	.....	64	.....	49	.....
	Difference in favor of manure	11	±1.6	7	±2.4	19	±2.5
5	Oats (manure), potatoes, sugar beets	[1] 50	.....	[1] 83	.....	.....	.....
34	Oats, potatoes, sugar beets	[1] 50	.....	[1] 81	.....	.....	.....
	Difference in favor of manure	0	±2.0	2	±2.8	.....	.....
61	Oats (manure), sugar beets, alfalfa (3 years), potatoes	64	.....	100	.....	77	.....
60	Oats, sugar beets, alfalfa (3 years), potatoes	61	.....	98	.....	72	.....
	Difference in favor of manure	3	±2.0	2	±3.1	5	±1.5
	Mean difference of rotations 23 and 22, 25 and 24, 31 and 30, and 61 and 60	4	.....	6	.....	15	.....

[1] For the period 1916–32 only.

At the three stations there was an opportunity to observe the influence alfalfa exerted on oat yields in 19 different instances. There are 4 identical combinations at the 3 stations with a mean yield difference from similar rotations of −3 bushels at Belle Fourche, 22 bushels at Huntley, and 20 bushels per acre at Scotts Bluff. The results are recorded in table 17.

The differences for all stations varied from −16 bushels in the 42 and 22 pair at Belle Fourche to 34 bushels per acre in the 60 and 30 pair at Huntley. When the results from the 3 stations are considered separately it is apparent that at the Belle Fourche station there is a definitely significant increase in the yield of oats in only one instance. This is revealed by a comparison of the yields from rotation 48 with those from rotation 28. Consideration should be given to the fact that rotation 28 has a 2-year cycle and the companion crop of oats is spring wheat. This has proved to be an undesirable sequence and has notably depressed the yields of both wheat and oats, chiefly because of weeds. The mean yield of oats in this rotation is 27 bushels per acre, the lowest of any in the series listed in this table. Consequently, it is believed that the weeds in this rotation have been the chief cause of the lower oat yields rather than the gradual exhaustion of the productivity of the soil. Eliminating the 48 and 28 combination and taking a mean of the differences of the remaining 6 combinations, it is found that alfalfa has neither depressed nor increased

oat yields for a 21-year period under the heavy soil conditions existing at this station.

TABLE 17.—*The influence of alfalfa on the mean acre yields of oats at the Belle Fourche, Huntley, and Scotts Bluff Field Stations for the period 1912–32*

Rotation no.	Crop sequence	Belle Fourche		Huntley		Scotts Bluff	
		Acre yield	Standard error	Acre yield	Standard error	Acre yield	Standard error
		Bushels		*Bushels*		*Bushels*	
42	Oats, sugar beets, alfalfa (2 years)	44		92		69	
22	Oats, sugar beets	60		82		46	
	Difference in favor of alfalfa	−16	±2.6	10	±3.7	23	±4.6
44	Oats, alfalfa (2 years), potatoes	60		87		71	
24	Oats, potatoes	63		74		45	
	Difference in favor of alfalfa	6	±4.2	13	±4.4	26	±4.3
46	Oats, alfalfa (2 years), sugar beets			[1] 92			
22	Oats, sugar beets			[1] 83			
	Difference in favor of alfalfa			9	±5.3		
48	Oats, alfalfa (2 years), spring wheat	64				65	
28	Oats, spring wheat	27				36	
	Difference in favor of alfalfa	37	±5.5			29	±3.7
60	Oats, sugar beets, alfalfa (3 years), potatoes	61		98		72	
30	Oats, sugar beets, potatoes	57		64		49	
	Difference in favor of alfalfa	4	±2.6	34	±4.9	23	±4.5
61	Oats (manure), sugar beets, alfalfa (3 years), potatoes	64		100		77	
31	Oats (manure), sugar beets, potatoes	68		71		68	
	Difference in favor of alfalfa	−4	±3.1	29	±5.4	9	±4.0
62	Oats, sugar beets, alfalfa (3 years), corn	51				65	
32	Oats, sugar beets, corn	43				30	
	Difference in favor of alfalfa	8	±2.3			28	±4.9
64	Oats, alfalfa (3 years), potatoes, sugar beets	[1] 72		[1] 88			
34	Oats, potatoes, sugar beets	[1] 50		[1] 81			
	Difference in favor of alfalfa	2	±3.7	7	±4.4		
	Mean difference of rotations 42 and 22, 44 and 24, 60 and 30, and 61 and 31	−3		22		20	

[1] For the period 1916–32 only.

These results indicate that at the Huntley station the inclusion of alfalfa in the cropping program consistently increased oat yields, although in 3 of the 6 rotation comparisons the differences are small and not particularly significant when compared with the standard error.

In all but one instance the differences are substantial and significant in favor of alfalfa at the Scotts Bluff station. Alfalfa did not materially stimulate the yields of oats in rotation 61 as compared with rotation 31. The mean increase in the yield of oats for the other 5 comparisons is 25 bushels per acre, with a relatively low standard error in every instance.

By selecting comparable rotations, those having in them an application of farm manure and the others including alfalfa, it is possible to observe and compare directly the extent that these treatments

have influenced the yields of oats. There are 5 pairs of rotations affording such comparisons, and for the 3 stations 12 differences are available. Table 18 records these results.

TABLE 18.—*The influence of alfalfa as compared with stable manure on the mean acre yields of oats at the Belle Fourche, Huntley, and Scotts Bluff Field Stations for the period 1912–32*

Rotation no.	Crop sequence	Belle Fourche		Huntley		Scotts Bluff	
		Acre yield	Standard error	Acre yield	Standard error	Acre yield	Standard error
		Bushels		*Bushels*		*Bushels*	
42	Oats, sugar beets, alfalfa (2 years)	44		92		09	
23	Oats (manure), sugar beets	63		81		04	
	Difference in favor of alfalfa	−19	±2.8	11	±2.0	5	±2.7
44	Oats, alfalfa (2 years), potatoes	69		87		71	
25	Oats (manure), potatoes	67		91		61	
	Difference in favor of alfalfa	2	±5.0	−4	±3.1	10	±2.5
46	Oats, alfalfa (2 years), sugar beets			[1] 92			
23	Oats (manure), sugar beets			[1] 80			
	Difference in favor of alfalfa			12	±4.2		
60	Oats, sugar beets, alfalfa (3 years), potatoes	61		98		72	
31	Oats (manure), sugar beets, potatoes	68		71		68	
	Difference in favor of alfalfa	−7	±2.8	27	±4.3	4	±3.1
64	Oats, alfalfa (3 years), potatoes, sugar beets	[1] 52		[1] 88			
35	Oats (manure), potatoes, sugar beets	[1] 50		[1] 83			
	Difference in favor of alfalfa	2	±2.6	5	±3.3		
	Mean difference of rotations 42 and 23, 44 and 25, and 60 and 31	−8		11		6	

[1] For the period 1916–32 only.

When the mean differences for the same rotations at the three stations are computed it is found that at Belle Fourche the inclusion of alfalfa in the cropping program, as compared with the manurial treatment, influenced oat yields to the extent of −8 bushels, at Huntley 11 bushels, and at Scotts Bluff 6 bushels per acre. In only 4 instances of the 12 were there significant yield increases which could be attributed to the alfalfa as compared with the manured rotations. At Belle Fourche negative differences occurred in 2 instances, and in those cases where positive increases occurred there is only a 2-bushel difference. The most favorable results as far as alfalfa is concerned occurred at Huntley where significant yield increases are to be noted in 3 of the 5 instances where comparisons are possible. At Scotts Bluff, apparently, alfalfa, as compared with manure, did not stimulate the yields of oats materially, the maximum being only 10 bushels per acre in the 44 and 25 comparison.

INFLUENCE ON SUGAR BEET YIELDS OF PASTURING OTHER CROPS IN ROTATIONS

In the series of rotations herein reported, which include those receiving applications of farm manure as compared with alfalfa, the results indicate that, as far as the yields of sugar beets are concerned,

the manurial treatment is distinctly more effective than alfalfa in maintaining and improving yields, particularly at the Belle Fourche and Huntley stations. When the beet yields in rotations having 2 years of alfalfa are compared with those where alfalfa has been grown 3 years, the favorable effects on the yield of beets are more pronounced. At all three stations, however, the manurial treatment still is distinctly superior to alfalfa, even in the rotations having 3 years of alfalfa, although the position of alfalfa and the manurial treatment in relation to sugar beets should be recognized.

Where alfalfa or sweetclover is grown chiefly for the purpose of stimulating crop yields, some available evidence indicates that if these crops are pastured 1 or more years the yields following such a practice are materially in excess of those obtained where such crops are harvested for hay. At the time these rotation experiments were inaugurated information as to the possibilities of such a procedure was not available. Only a few rotations including pastured crops were incorporated in the series of experiments, and, unfortunately, these were not directly comparable, particularly as to sequences, with any of the other rotations. In 1926 several additional rotations were added to the series, including sweetclover or alfalfa to be pastured. Comparable rotations, unpastured, are a part of this series. Results are available for only 7 years; consequently, not too much credence should be given to the results obtained for this relatively short period.

Table 19 shows the extent that sugar beet yields have been influenced by pasturing in 2 pairs of rotations, 1 pair at Belle Fourche and the other pair at Huntley. All four rotations include 3 years of alfalfa. The comparison available at the Belle Fourche station is between rotations 71 and 60. During 5 of the 6 years of the cycle the crops were the same, but for the sixth year 1 rotation included oats and the other beets. The sequences varied slightly, but it is believed that the differences in yields of beets which occurred may be attributed in a large measure to pasturing both corn and alfalfa. The comparison at Huntley is between rotations 67 and 60. In both rotations the beet crop is 2 years removed from alfalfa. The condensed results are recorded in table 19, which includes the mean yields for the three 7-year periods, the mean yield for the 17 years at Belle Fourche, the mean yield for the 21 years at Huntley, and the standard error.

TABLE 19.—*The influence of pasturing other crops on mean acre yields of sugar beets (tons) at the Belle Fourche and the Huntley Field Stations, 1916–32 and 1918–32*

BELLE FOURCHE

Rotation no.	Crop sequence	1916–18	1919–25	1926–32	17-year mean	Standard error
		Tons	*Tons*	*Tons*	*Tons*	
71	Sugar beets, oats, alfalfa, alfalfa, alfalfa (pastured), corn (harvested with lambs)	[1] 12.0	14.9	13.0	13.9	.....
60	Sugar beets, alfalfa, alfalfa, alfalfa, potatoes, oats	[1] 11.2	11.3	10.5	10.9	.....
	Difference in favor of pasturing	.8	3.6	3.4	3.0	±0.20

[1] For 3-year period only. Other figures are for 7-year periods.

TABLE 19.—*The influence of pasturing other crops on mean acre yields of sugar beets (tons) at the Belle Fourche and the Huntley Field Stations, 1916–32 and 1912–32*—Continued

HUNTLEY

Rotation no.	Crop sequence	1912–18	1919–25	1926–32	21-year mean	Standard error
		Tons	*Tons*	*Tons*	*Tons*	
67	Sugar beets, alfalfa, alfalfa, alfalfa (pastured with hogs), corn (harvested with hogs), flax	13.9	16.2	17.1	15.7	.....
60	Sugar beets, alfalfa, alfalfa, alfalfa, potatoes, oats	10.5	14.0	13.6	12.7	.....
	Difference in favor of pasturing	3.4	2.2	3.5	3.0	±0.54

At Belle Fourche the beet yields from rotation 71 were consistently higher than those harvested from rotation 60 and definitely so for the last two 7-year periods. The mean increase for the 17-year period is 3.0 tons of beets to the acre, or 28 percent, which it is believed may be attributed chiefly to pasturing the alfalfa the third year and harvesting the corn crop with lambs. At the Huntley station the third year of alfalfa and the following corn crop were both harvested with hogs. Here again substantial yield increases occurred when rotations 60 and 67 are compared, ranging from a minimum of 2.2 tons to a maximum of 3.5 tons, and a mean increase for the 21-year period of 3.0 tons per acre, or approximately 24 percent.

It is recognized that the foregoing results indicating the extent that sugar beet yields may be influenced favorably by pasturing are not conclusive. However, they do conform with results obtained with certain other crops when alfalfa was pastured (*1*, *2*) and emphasize the need for further information with respect to the possibilities of the practice.

YIELD DIFFERENCES EXPRESSED AS PERCENTAGES

The mean yields of sugar beets, potatoes, and oats in the various rotations which received applications of farm manure and those which include alfalfa are recorded in the foregoing tables. These results have been compared with similar rotations not so treated and the differences in the yields determined. While these data permit a study of the yields from different cropping systems and the extent that yields have been influenced in tons and bushels, direct comparisons cannot be made by this method. However, such a comparison is made in table 20, in which the yield differences are expressed in percentages and include the results from all three stations. By this method it is possible to present, in terms of percentages, the influence of the manure on the yields of the 3 crops as compared with untreated rotations as well as with those which have 2 and 3 years of alfalfa. Percentage figures are given indicating the extent that yields are influenced when alfalfa is grown for 2 and 3 years as compared with similar rotations not including alfalfa. It is possible also to make 2 yield comparisons with the alfalfa-manure rotation with 1 untreated and another having alfalfa only. The various percentage differences are given in table 20.

TABLE 20.—*Yield increases or decreases expressed in percentages, following applications of stable manure and including alfalfa in the crop rotations at the Belle Fourche, Huntley, and Scotts Bluff Field Stations, 1912–32*

Crops and field stations where grown	Stable manure compared with—			Alfalfa compared with untreated—		Alfalfa 3 years and manure compared with—	
	Untreated	Alfalfa 2 years	Alfalfa 3 years	Alfalfa 2 years	Alfalfa 3 years	Untreated	Alfalfa alone
Sugar beets:	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Belle Fourche	38	60	21	−15	15	74	21
Huntley	53	46	15	6	36	99	15
Scotts Bluff	66	8	24	54	35	79	21
Potatoes:							
Belle Fourche	32	6	39	30	−2	10	9
Huntley	24	10	−21	23	42	70	8
Scotts Bluff	51	−13	−15	80	60	71	7
Oats:							
Belle Fourche	10	15	4	18	8	12	5
Huntley	9	−7	−17	14	30	56	2
Scotts Bluff	38	−11	−6	62	56	57	7

Yield increases of sugar beets as a result of applications of farm manure were substantial in every instance except at Scotts Bluff when compared with 2 years of alfalfa, where the increase is only 8 percent. At the other 2 stations the manurial treatment was distinctly superior to 2 years of alfalfa, showing an increase of 60 percent at Belle Fourche and 46 percent at Huntley. Apparently 3 years of alfalfa had a more favorable effect on the yields of beets than 2 years of alfalfa, but even when these rotations are compared with the manured rotations the latter treatment proves to be distinctly superior in its effect on beet yields. Two years of alfalfa appear to have depressed beet yields at Belle Fourche and not appreciably increased them at Huntley. On the other hand, at Scotts Bluff there is an indicated increase of 54 percent from 2 years of alfalfa. There is a 15-percent increase as a result of 3 years of alfalfa at Belle Fourche and a 36 and 35-percent increase, respectively, at the other 2 stations. The largest percentage increases of beet yields occurred at all 3 stations from a rotation including both alfalfa and manure as compared with those from the corresponding rotation untreated, the range being from 74 percent at Belle Fourche to 99 percent at Huntley. Farm manure in rotation 61 resulted in yield increases of beets ranging from 15 to 24 percent as compared with rotation 60.

In considering the percentage differences with potatoes, the yield increases are less than with sugar beets and also somewhat less consistent. As compared with the untreated rotations manure definitely stimulated potato yields. When the manurial treatment is compared with 2 and 3 years of alfalfa at Belle Fourche the percentage figures are in favor of manure; the results are not consistent at Huntley; while at Scotts Bluff the potato yields were better following alfalfa. Rotations including alfalfa as compared with those untreated returned the largest increases with one exception. By comparing the alfalfa-untreated percentages with those given in the two manure-alfalfa columns it becomes apparent that, with the exception of Belle Fourche, alfalfa had a more favorable influence on the yields of potatoes than applications of stable manure. Grouping the results from the three stations, the most favorable increase in the yield of

potatoes occurred when the alfalfa-manure rotation is compared with the untreated one. These percentages further indicate that when manure is applied to rotation 61 as compared with 60, material increases in the yield of potatoes are not to be expected.

The manurial treatment applied to these rotations increased the yields of oats only slightly at Belle Fourche and Huntley, but it increased the yield materially, 38 percent, at Scotts Bluff. On the other hand, alfalfa appears to have had a more favorable influence on yields of oats both at Huntley and Scotts Bluff, with the manurial treatment slightly superior at Belle Fourche. When the 2- and 3-year alfalfa rotations are compared with the rotations not including this crop, the percentages from all 3 stations are in favor of alfalfa. As occurred with both sugar beets and potatoes, oat yields responded most favorably to the alfalfa-manure treatment when compared with a rotation untreated. Percentage differences in favor of the manure in an alfalfa rotation, although slight, are consistent.

In the foregoing pages, which have been confined to the discussion of the influence of farm manure and alfalfa on the yields of sugar beets, potatoes, and oats, consideration has been given only to the difference in yields as influenced by these two treatments under varying conditions. Notably at Scotts Bluff the quality of the potatoes was adversely affected by scab in the shorter rotations not including alfalfa but receiving applications of manure. On the other hand, even in the shorter rotations, such as 40 and 44, but which include alfalfa, the potatoes were notably free from the scab disease.

In all instances applications of farm manure stimulated the yields of sugar beets. However, there is evidence to indicate that as sugar-beet yields are increased their sucrose percentages decrease somewhat.[3] At Scotts Bluff, where extremely heavy applications of farm manure were made on land to be planted to sugar beets, the sucrose content of the beets was unfavorably influenced as compared with lighter applications of manure and the lower yields of beets resulting therefrom. At present there is no evidence to indicate that the same result would not occur where beet yields were materially increased by including alfalfa in the cropping program.

SUMMARY

The 21-year results of experiments with farm manure and alfalfa on subsequent crop yields were obtained at the Belle Fourche (S. Dak.), Huntley (Mont.), and Scotts Bluff (Nebr.) Field Stations. These stations are located in the northern part of the Great Plains. The crops involved are sugar beets, potatoes, and oats.

The climate is semiarid and does not differ materially at the three locations. The soils at the three stations range from a heavy clay or gumbo at Belle Fourche to a friable, fine sandy loam at Scotts Bluff. The soil conditions at Huntley are about intermediate.

The rotations from which results are recorded were selected from a relatively extensive series inaugurated in 1912 as a part of the investigational program at the three stations.

There are nine pairs of rotations which include alfalfa as compared with those having the same crops and sequences but without alfalfa.

[3] NUCKOLS, S. B. THE RESIDUAL EFFECTS OF MANURIAL TREATMENT UPON THE QUALITY OF SUGAR BEETS. [In manuscript.]

Five pairs of rotations received applications of farm manure as compared with similar simple rotations. In six instances the manurial treatment is compared with similar rotations but including alfalfa.

In presenting the data for the 21 years, the mean yields by 7-year periods are given first. In each instance mean yields from sugar beets, potatoes, or oats are compared, and the increase or decrease which may be attributed to the treatments is determined.

At all three stations applications of farm manure increased the yields of sugar beets materially in every instance, the maximum increase amounting to 11.3 tons per acre.

The increased yields of sugar beets as a result of including alfalfa in the cropping program were not consistent. At Scotts Bluff increased yields of beets as a result of alfalfa occurred consistently. At the other two stations 2 years of alfalfa have increased the yields of beets in only a few instances.

The effect of applications of farm manure as compared with alfalfa on the yields of beets is given in table 3. In every instance during the last 7-year period the manurial treatment proved superior to alfalfa, the yield increases ranging from a minimum of 1.5 to a maximum of 11.1 tons per acre.

Applications of farm manure resulted in increasing the yields of potatoes at all three stations, although the increases were not so pronounced as in the case of sugar beets. The manurial treatment has not increased the yields of potatoes in an alfalfa rotation.

When the potato yields from similar rotations are compared with the one including alfalfa and the others not having this crop, it is apparent that alfalfa favorably influenced the yields of potatoes at Scotts Bluff and at Huntley. Consistent results were not obtained at Belle Fourche where the soil conditions are less favorable for potato production.

At Belle Fourche in 3 out of 4 rotations larger yields of potatoes resulted from the manurial treatment than occurred following alfalfa. The results at the other two stations were less consistent, although it is evident that the manurial treatment sustained potato yields better than alfalfa.

During the first two 7-year periods applications of farm manure did not increase the yields of oats materially in a large majority of instances at the 3 stations. Increases in the yields of oats which may be attributed to manure occurred at the 3 locations for the last 7-year period in all but 1 instance.

The inclusion of alfalfa in the cropping program stimulated the yields of oats in every instance at Huntley and Scotts Bluff and in all but one instance at Belle Fourche during the last 7-year period. Less consistent results occurred for the earlier periods.

The merits of farm manure and alfalfa are compared. At Belle Fourche the manurial treatment developed the best results in a majority of instances. On the other hand, at Huntley and Scotts Bluff alfalfa has produced the best results. The results of the different treatments are summarized for the 21-year period and the standard error is computed.

Significant increases in the yields of sugar beets attributed to applications of farm manure occurred in every instance, ranging from a mean of 3.6 tons at Belle Fourche to a maximum of 6.4 tons per acre at Scotts Bluff. Yield increases of beets in the alfalfa rotations,

compared with those not having alfalfa, ranged from a mean of 0.6 ton at Belle Fourche to a maximum of 4.1 tons per acre at Scotts Bluff. The mean superiority of the manured rotations as compared with those having alfalfa amounted to 3.5 tons at Belle Fourche, 3.4 tons at Huntley, and 1.9 tons per acre at Scotts Bluff.

Applications of farm manure resulted in increases in the yield of potatoes in most instances, the mean increases at the different stations ranging from 50 bushels at Belle Fourche to 67 bushels per acre at Scotts Bluff. It was found that alfalfa definitely stimulated potato yields at Huntley and Scotts Bluff but not consistently at Belle Fourche. When the effectiveness of both manure and alfalfa are compared in similar rotations, the manurial treatment appears to have been slightly superior at Belle Fourche, whereas at Scotts Bluff alfalfa produced somewhat better results.

Significant mean increases in the yields of oats as a result of the manurial treatment did not occur at either Belle Fourche or Huntley. However, the application of manure resulted in a material increase in the yields of oats in the three rotations not having alfalfa at Scotts Bluff. When oat yields from alfalfa rotations are compared with those not including that crop, it is found that alfalfa definitely stimulated oat yields at Huntley, whereas the results from the different rotations at Belle Fourche were not consistent. When oat yields from manured rotations are compared with those from rotations including alfalfa, the mean of the differences indicates that the manurial treatment was somewhat superior at Belle Fourche, whereas at Huntley and Scotts Bluff slightly better yields resulted from including alfalfa in the rotation.

In a number of instances the results obtained with sugar beets at Belle Fourche and Huntley indicate that alfalfa did not materially stimulate yields. Two comparisons are available as to the effect of pasturing other crops on the yields of sugar beets as compared with similar rotations not so treated. The results indicate that pasturing materially stimulates the yields of beets.

To afford a more direct comparison of the effect of the different treatments on the yields of sugar beets, potatoes, and oats, table 20 is included which expresses the yield differences in percentages.

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