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EFFECT OF ALFALFA ON THE SUBSEQUENT YIELDS OF IRRIGATED FIELD CROPS.

By C. S. Scofield,
Agriculturist in Charge, Office of Western Irrigation Agriculture.

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AIM OF THE EXPERIMENTS.

It has long been recognized that the growing of alfalfa has a beneficial effect upon the producing capacity of irrigated lands; in other words, crops grown on land following alfalfa give larger yields than those following nonleguminous crops. In the series of experiments here reported it is aimed to show the extent of this beneficial effect as observed with three common field crops in several different rotations at three different locations in the northern Great Plains.

These experiments were conducted by the Bureau of Plant Industry at the following places: (1) The Scottsbluff Field Station,[1] located on the North Platte Reclamation Project, near Mitchell, Nebr.; (2) the Belle Fourche Field Station, located on the Belle Fourche Reclamation Project, near Newell, S. Dak.; and (3) the Huntley Field Station,[2] located on the Huntley Reclamation Project, near Huntley, Mont. These stations are so situated as to be representative of conditions on much of the irrigated land in the northern Great Plains, and it is believed that the results secured are generally applicable to that region.[3]

[1] The work of this field station is conducted and supported cooperatively by the United States Department of Agriculture and the Nebraska Agricultural Experiment Station.

[2] The work of this field station is conducted and supported cooperatively by the United States Department of Agriculture and the Montana Agricultural Experiment Station.

[3] For a brief description of the agricultural and soil conditions of this region, see Scofield, C. S., Effect of farm manure in stimulating the yields of irrigated field crops. *In* Jour. Agr. Research, v. 15, No. 9, pp. 493-503. 1918.

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DESCRIPTION OF THE EXPERIMENTS.

These experiments are a part of an extensive series of rotations conducted under irrigation at the three stations specified. The experiments were started with the crop season of 1912 and have been continued without modification. The field plats, which include one-fourth of an acre each, are laid out in series. The series are separated by 40-foot roads, and the plats in the series are separated by 5-foot alleys. The plats at Scottsbluff are 132 feet long by 82.5 feet wide; those at Belle Fourche are 264 feet long by 41.25 feet wide, and those at Huntley are 227 feet long by 48 feet wide.

The present bulletin deals with the effect produced by growing alfalfa for one, two, or three years on plats which are later used for two or three years for other crops and then are reseeded to alfalfa. The alfalfa crops are cut for hay, and at the end of the alfalfa period the land is plowed soon after the last cutting, so that only the stubble is plowed under. The results are based on seven pairs of rotations, the two members of each pair differing from each other only in that one member includes either two years or three years of alfalfa, while the other does not. Each rotation occupies as many plats as there are years in the cycle, so that each crop is represented each year. The crops and sequences involved in the 14 rotations are as follows:

Rotation 20: Potatoes, sugar beets.
Rotation 40: Alfalfa, alfalfa, potatoes, sugar beets.
Rotation 22: Oats, sugar beets.
Rotation 42: Alfalfa, alfalfa, oats, sugar beets.
Rotation 24: Potatoes, oats.
Rotation 44: Alfalfa, alfalfa, potatoes, oats.
Rotation 28: Wheat, oats.
Rotation 48: Alfalfa, alfalfa, wheat, oats.
Rotation 30: Potatoes, oats, sugar beets.
Rotation 60: Alfalfa, alfalfa, alfalfa, potatoes, oats, sugar beets.
Rotation 31: Potatoes, oats, sugar beets (manured).
Rotation 61: Alfalfa, alfalfa, alfalfa, potatoes, oats, sugar beets (manured).
Rotation 32: Corn, oats, sugar beets.
Rotation 62: Alfalfa, alfalfa, alfalfa, corn, oats, sugar beets.

It will be noted from the list of rotations that the comparisons to determine the effect of the alfalfa are made between 2-year and 4-year rotations and between 3-year and 6-year rotations. In the first set of comparisons a 2-year period of alfalfa is used and in the second set a 3-year period.

As these rotation experiments were started in 1912, in each case on land that had not previously grown alfalfa, there was no effect to be observed until 1913, and the crops grown that year following alfalfa were from plats that had been in alfalfa only one season. The first full effect of the alfalfa in the rotation was obtained in the 4-year rotations in 1914 and in the 6-year rotations in 1915, and then only in the case of crops which immediately succeed alfalfa in the rotation.

In the above list of the seven rotations which include alfalfa, that crop was followed by potatoes in four cases and by oats, wheat, and corn in the other three. The second-year effect of alfalfa is shown in two cases on sugar beets and in five cases on oats. In the three 6-year rotations, sugar beets are grown the third year following the alfalfa and presumably, therefore, derive the least benefit from that crop.

The cultural operations used with these rotations have been only those demanded by good farming. With respect to any one crop, the same variety has been used in all rotations at each station each year. The same varieties have not been used at the different stations, nor has the same variety been used for all years at the same station. It has been the aim to use one of the best of the locally adapted varieties in each case.

In the rotations where alfalfa follows sugar beets, the alfalfa has been seeded in the spring following the beet crop, and consequently it has done little more than get well established the first year. Where the alfalfa follows oats it has been customary to seed it in the fall in the oat stubble, and in general this has resulted in a good stand and nearly a full crop the following season. At the close of the alfalfa period in these rotations the alfalfa sod has been plowed immediately after the last cutting. This first plowing or "crowning," as it is called, is done only 3 or 4 inches deep, in order to cut the roots close to the surface and kill the plants. After the inverted sod has dried out well it is disked, and the land is then plowed to a depth of 8 or 9 inches.

The field work of these rotation experiments has been under the direction of the farm superintendent at each station and under the immediate supervision of a scientific assistant, who is charged with performing or directing the cultural operations, the irrigation, and the harvesting, and with taking the field notes and reporting the results each year.[1]

RESULTS OF THE EXPERIMENTS.

IRISH POTATOES.

There are four pairs of rotations at each station in which the members of the pairs differ from each other only in that one includes a period of alfalfa and the other does not. In two of these cases,

[1] The following is the personnel concerned with the field work of these rotation experiments: At Scottsbluff, Mr. Fritz Knorr was superintendent from 1910 to the end of 1916. Mr. James A. Holden was in charge of the irrigated rotations from the spring of 1912 until the end of 1916, when he succeeded Mr. Knorr as farm superintendent. Mr. David W. Jones supervised the irrigated rotation work during 1917 and the early part of 1918, when he entered the military service; during the remainder of the season Mr. Holden directed the work. At Belle Fourche, Mr. Beyer Aune has been superintendent since 1909. He has kept in close touch with the irrigated rotation work, being assisted at different times by Mr. John B. Wentz, Mr. N. L. Mattice, Mr. George T. Ratliffe, and Mr. Oscar R. Mathews. At Huntley Mr. Dan Hansen has been superintendent since 1910. The irrigated rotations were under the supervision of Mr. John M. Spain during 1912, Mr. John W. Knorr during 1914, and Mr. Edward G. Noble from 1915 until the summer of 1918, when Mr. Noble entered the military service. Mr. Hansen directed the work in 1913 and during the latter part of 1918.

rotations 40 and 44, the alfalfa period covers two years and in rotations 60 and 61 it covers three years. In the above-enumerated rotations the 1913 potato crops followed only one year of alfalfa. In 1914 they followed two years of alfalfa, which is the normal course for the first two rotations, 40 and 44, while for rotations 60 and 61 the normal course of three years of alfalfa was first reached for the crop of 1915.

Table I shows the yields of potatoes for the four pairs of rotations at each of the three stations. These yields, given in bushels per acre, are for the total crop, including small and diseased potatoes. The annual difference in yield between the crops following alfalfa and the check plats are also shown in the table, together with the mean annual yield of the crop for each rotation and the mean of the annual differences in yield. With each of the means the probable error is given.[1]

The results given in Table I show that in nine cases out of twelve the mean of the annual differences in yield was in favor of the crops following alfalfa. But in only six of the nine cases is this mean difference significant; that is, more than three times the probable error. In the other six cases the mean is less than three times the probable error and is not regarded as significant.

It has been customary in connection with these experiments to sort the potatoes in the field at the time of digging. This sorting has been done by means of a wire screen with 2-inch meshes. The smaller potatoes that pass through this screen are classed as unmarketable, while those passing over the screen are marketable. It has been observed that at Scottsbluff the percentage of marketable potatoes has been significantly larger from the plats following alfalfa than from the check plats. This has not been true, however, at Belle Fourche or at Huntley.

It is clear from the facts set forth in Table I that the beneficial effect of alfalfa on subsequent yields of potatoes has been much more marked and consistent at Scottsbluff than at the other two stations. This may be due to the fact that the soil at Scottsbluff is a light sandy loam, while at both the other stations the soil is a heavy clay loam. The essential facts concerning these yields for each of the three stations are summarized in the following paragraphs.

At Scottsbluff the yield of potatoes, large and small, for the 48 plat years has averaged 236 bushels per acre, with a mean annual difference resulting from alfalfa of 100 ± 7. The yield of marketable

[1] The probable error of the mean as used in these tables is obtained by Merriman's formula 36, which is stated as follows: $r\ o\ p = \frac{0.8453\,v.}{n\sqrt{n-1}}$ In other words, the probable error of the mean is obtained by multiplying the sum of the departure from the mean by the quotient of $n\sqrt{n-1}$ into 0.4853, where n equals the number of yields involved. (Merriman, Mansfield. Method of Least Squares, ed. 8, p. 223. New York, London, 1913.)

potatoes from the same plats excepting 1918, when this classification was not made, has averaged 192 bushels per acre, with a mean annual difference in favor of those following alfalfa of 101 ± 7. Again omitting the crop of 1918, the percentage of the total yield classed as marketable is 76, while the mean annual difference in percentage marketable in favor of those following alfalfa is 12 ± 1.3.

TABLE I.—*Effect of alfalfa on the yields of Irish potatoes at the Scottsbluff, Belle Fourche, and Huntley Field Stations, for the 6-year period from 1913 to 1918, inclusive.*

Station and rotation No.	Yield of potatoes per acre (bushels).						
	1913	1914	1915	1916	1917	1918	Mean.
Scottsbluff:							
20 (no alfalfa)	398	146	88	142	131	87	165±29
40 (following alfalfa)	403	280	206	285	273	179	271±20
Difference	+ 5	+134	+118	+143	+142	+92	+106±14
24 (no alfalfa)	235	146	109	217	134	150	165±15
44 (following alfalfa)	402	319	228	308	290	227	296±18
Difference	+167	+173	+119	+ 91	+156	+ 77	+131±13
30 (no alfalfa)	329	216	146	226	167	79	194±24
60 (following alfalfa)	322	272	231	319	281	238	277±11
Difference	− 7	+ 56	+ 85	+ 93	+114	+159	+ 83±15
31 (no alfalfa)	353	243	175	244	211	81	218±23
61 (following alfalfa)	380	299	220	306	346	249	300±17
Difference	+ 27	+ 56	+ 45	+ 62	+135	+168	+ 82±17
Belle Fourche:							
20 (no alfalfa)	128	86	102	157	133	167	129± 9
40 (following alfalfa)	88	96	94	129	124	203	122±11
Difference	− 40	+ 10	− 8	− 28	− 9	+ 36	− 7± 7
24 (no alfalfa)	109	112	111	151	120	191	132±10
44 (following alfalfa)	177	127	144	149	170	153	153± 5
Difference	+ 68	+ 15	+ 33	− 2	+ 50	− 38	+ 21±11
30 (no alfalfa)	74	68	59	166	139	168	112±17
60 (following alfalfa)	97	105	105	119	108	170	117± 7
Difference	+ 23	+ 37	+ 46	− 47	− 31	+ 2	+ 5±11
31 (no alfalfa)	90	140	137	188	205	231	165±16
61 (following alfalfa)	139	112	115	124	130	165	131± 5
Difference	+ 49	− 28	− 22	− 64	− 75	− 66	− 34±13
Huntley:							
20 (no alfalfa)	200	179	350	228	241	390	265±20
40 (following alfalfa)	250	156	350	247	224	445	279±30
Difference	+ 50	− 23	0	+ 19	− 17	+ 55	+ 14±10
24 (no alfalfa)	316	171	273	236	229	315	257±17
44 (following alfalfa)	113	195	190	166	182	373	203±21
Difference	−203	+ 24	− 83	− 70	− 47	+ 58	− 54±25
30 (no alfalfa)	188	156	228	224	175	286	209±14
60 (following alfalfa)	285	293	397	292	238	345	308±16
Difference	+ 97	+137	+169	+ 68	+ 63	+ 59	+ 99±14
31 (no alfalfa)	160	140	273	212	91	324	200±26
61 (following alfalfa)	277	184	420	402	297	474	343±34
Difference	+117	+ 44	+147	+190	+206	+150	+143±15.5

At Belle Fourche the yield of potatoes, large and small, for the 48 plat years has averaged 135 bushels per acre, while the mean annual difference resulting from the growing of alfalfa has been a decrease of 4 ± 6. The yield of marketable potatoes from the same plats has averaged 107 bushels per acre, with a mean annual decrease for the plats following alfalfa of 4 ± 5.6. The percentage of the total yield classed as marketable for the 48 plats is 81, with a mean annual difference in favor of the plats following alfalfa of 0.5 ± 2.2. These results indicate that at Belle Fourche there has not been, so far, any beneficial effect from alfalfa on subsequent yields of potatoes.

At Huntley the total yield of potatoes for the 48 plat years has averaged 258 bushels per acre, while the mean annual difference in favor of the plats following alfalfa is 50 ± 12.6. The yield of marketable potatoes from the same plats has averaged 241 bushels per acre, with a mean annual difference in favor of the plats following alfalfa of 55 ± 11.4. The percentage of the total crop classed as marketable is 93, with the difference in favor of the plats following alfalfa of 1 ± 0.55. Thus, the results from the Huntley station indicate that the beneficial effect of alfalfa on subsequent potato crops, though fairly large, is, when judged by the size of the probable error, barely significant.

In an earlier paper, the effects of farm manure on the crop yields in certain of these irrigated rotations was reported,[1] and it seems proper to present here a comparison between the effects of periodical applications of farm manure and the use of alfalfa in the rotation. Such a comparison of results appears to be justified, because the two tests were made in the same fields and the same set of plats were used as checks in both cases. The experiments reported for the test of farm manure covered the 6-year period from 1912 to 1917, while those of alfalfa covered the 6-year period from 1913 to 1918. There were, however, only three rotation pairs for the potato experiments with manure, while there were four pairs with alfalfa. Also, in the manure experiments the manure was applied immediately preceding the potato crop in two of the three cases and to the sugar-beet crop, which preceded the potatoes, in the third case. In the alfalfa experiments the potato crop followed the alfalfa in all four cases.

The comparative features of the two experiments are summarized in Table II.

The results brought together in Table II show clearly that on the lighter soil of the Scottsbluff station both manure and alfalfa have a beneficial effect on the yield of potatoes. The manure has resulted in an increased total yield of the treated plats over that of the check

[1] Scofield, C. S. Loc. cit.

plats of 40 bushels per acre, while the alfalfa has increased the yield by 100 bushels per acre over that of the check plats. At Belle Fourche and at Huntley the beneficial effects of manure have been at least significant. The alfalfa has not produced increased yields at Belle Fourche, though it has done so at Huntley.

TABLE II.—*Comparison of the effect of farm manure and of alfalfa on subsequent yields of Irish potatoes in crop rotations under irrigation at the Scottsbluff, Belle Fourche, and Huntley Field Stations.*

Factors compared.	Yield of potatoes per acre.					
	Scottsbluff.		Belle Fourche.		Huntley.	
	Manure.	Alfalfa.	Manure.	Alfalfa.	Manure.	Alfalfa.
Total crop:						
Yield (mean of check and treated plats).....bushels..	208	236	131	135	239	258
Mean annual difference.....do....	40±7	100±7	34±6.4	−4±6	26±8.3	50±12.6
Marketable potatoes:						
Yield.....do....	150	192	105	107	221	241
Mean annual difference in yield.do....	46±7	101±7	36±6.3	−4±5.6	24±8.5	55±11.4
Percentage.....	72	76	80	81	92	93
Mean annual difference in percentage..	8±1.5	12±1.3	7±1.9	.5±2.2	.....	1±.55

OATS.

The effect of alfalfa on the subsequent yield of oats is shown in Table III for six pairs of rotations at Scottsbluff and Belle Fourche and for four pairs at Huntley. The oats crop follows directly after alfalfa in only one rotation (No. 42) at each station. In all the other rotations the oats occur as the second crop after alfalfa, being preceded by potatoes in three cases (Nos. 44, 60, and 61), by wheat in one case (No. 48), and by corn in one (No. 62). Because of this position in the rotation the oats did not come on plats that had been in alfalfa until 1914 except in the case of rotation No. 42. Thus, 16 comparisons are made in Table III, of which 12 show increases in the mean yield of the crops following alfalfa and 4 show decreases. But if we accept as a test of significance of the mean that it shall be at least three times as large as its probable error, then only 5 of the 16 comparisons show definite benefits from the alfalfa, and in one case, (rotation No. 42, at Belle Fourche) there is a consistent reduction in yield following alfalfa.

While these results do not show a strikingly beneficial effect from the use of alfalfa in the rotation, it is to be observed that these oat crops have been grown on soil that was virgin at the beginning of the experiment and of relatively high productivity, as shown by the mean yields of all the plats included in the experiment. It has been noted also in connection with these experiments that the plant growth has been more vigorous on the plats of oats following alfalfa, as is shown in the yields of straw. These notes, together with the facts concerning the grain yields for each of the three stations, are summarized below.

TABLE III.—*Effect of alfalfa on the yields of oats at the Scottsbluff, Belle Fourche, and Huntley Field Stations during the 6-year period from 1913 to 1918, inclusive.*

Station and rotation No.	Yield of oats per acre (bushels).						
	1913	1914	1915	1916	1917	1918	Means.
Scottsbluff:							
22 (no alfalfa)	90	76	16	49	75	53	60±8
42 (following alfalfa) 1 year	101	95	16	55	79	71	70±8
Difference	+ 11	+ 19	0	+ 6	+ 4	+ 18	+10±2
24 (no alfalfa)	.....	69	19	56	65	50	52±6
44 (following alfalfa) 2 years	.....	95	20	62	69	72	64±6
Difference	.....	+ 26	+ 1	+ 6	+ 4	+ 22	+12±4
28 (no alfalfa)	.....	65	9	33	53	44	41±7
48 (following alfalfa) 2 years	.....	83	22	41	61	59	53+7
Difference	.....	+ 18	+ 13	+ 8	+ 8	+ 15	+12±1.5
30 (no alfalfa)	.....	79	16	64	65	69	59±7
60 (following alfalfa) 2 years	.....	84	18	56	74	77	62±8
Difference	.....	+ 5	+ 2	− 8	+ 9	+ 8	+ 3±2
31 (no alfalfa)	.....	86	20	71	88	80	69±8
61 (following alfalfa) 2 years	.....	83	19	56	76	90	65±9
Difference	.....	− 3	− 1	− 15	− 12	+ 10	− 4±3
32 (no alfalfa)	.....	51	10	68	61	60	50±7
62 (following alfalfa) 2 years	.....	70	12	48	65	79	55±8
Difference	.....	+ 19	+ 2	− 20	+ 4	+ 19	+ 5±5
Belle Fourche:							
22 (no alfalfa)	45	77	99	57	71	87	73±6
42 (following alfalfa) 1 year	26	61	75	36	35	48	47±5
Difference	− 19	− 16	− 24	− 21	− 36	− 39	−26±3
24 (no alfalfa)	.....	74	112	58	73	90	81±7
44 (following alfalfa) 2 years	.....	110	116	58	72	83	88±9
Difference	.....	+ 36	+ 4	0	− 1	− 7	+ 7±5
28 (no alfalfa)	.....	26	50	27	40	36	36±3
48 (following alfalfa) 2 years	.....	105	118	58	69	86	87±7
Difference	.....	+ 79	+ 68	+ 31	+ 29	+ 50	+51±7
30 (no alfalfa)	.....	93	107	56	66	70	78±7
60 (following alfalfa) 2 years	.....	95	109	50	52	78	77±9
Difference	.....	+ 2	+ 2	− 6	− 14	+ 8	− 1±3
31 (no alfalfa)	.....	90	104	71	76	81	84±4
61 (following alfalfa) 2 years	.....	100	114	83	49	81	85±7
Difference	.....	+ 10	+ 10	+ 12	− 27	0	+ 1±5
32 (no alfalfa)	.....	92	68	62	41	54	64±6
62 (following alfalfa) 2 years	.....	104	80	64	45	67	72±7
Difference	.....	+ 12	+ 12	+ 2	+ 4	+ 13	+ 8±2
Huntley:							
22 (no alfalfa)	97	109	79	94	81	99	93±3
42 (following alfalfa) 1 year	103	84	73	91	89	103	90±3
Difference	+ 6	− 25	− 6	− 3	+ 8	+ 4	− 3±3
24 (no alfalfa)	.....	103	81	72	68	93	83±5
44 (following alfalfa) 2 years	.....	105	77	83	62	93	84±5
Difference	.....	+ 2	− 4	+ 11	− 6	0	+ 1±2
30 (no alfalfa)	.....	87	104	47	46	80	73±9
60 (following alfalfa) 2 years	.....	108	82	102	87	127	101±6
Difference	.....	+ 21	− 22	+ 55	+ 41	+ 47	+28±10
31 (no alfalfa)	.....	94	103	77	50	86	82±6
61 (following alfalfa) 2 years	.....	103	76	105	111	119	103±4
Difference	.....	+ 9	− 27	+ 28	+ 61	+ 33	+21±10

At Scottsbluff the yield of oats, grain, for the 62 plat years has averaged 58 bushels per acre, with a mean annual difference in favor of those following alfalfa of 6 ± 1.3. The yield of straw from these same plats, omitting the crop of 1915, which was injured by hail and cut with a mower, has averaged 1.28 tons per acre, with a mean annual difference in favor of the plats following alfalfa of 0.30 ± 0.05. Thus, while the yield of grain following alfalfa was increased by 10 per cent of the mean yield of all plats, the yield of straw was increased by 23 per cent.

At Belle Fourche the yield of grain for the 62 plat years has averaged 72 bushels per acre, with a mean annual difference in favor of those following alfalfa of 5 ± 3. The yield of straw from these same plats has averaged 1.24 tons per acre, with a mean annual difference in favor of the plats following alfalfa of 0.31 ± 0.06. Thus, the yield of grain following alfalfa has been increased by 7 per cent, while the yield of straw has been increased 25 per cent.

At Huntley the yield of grain for the 42 plat years has averaged 88 bushels per acre, with a mean annual difference in favor of the plats following alfalfa of 11 ± 3.7. The yield of straw from these same plats has averaged 1.51 tons per acre, with a mean annual difference in favor of the plats following alfalfa of 0.55 ± 0.05. Thus, while the increase in the yield of grain has been 12.5 per cent, the increase in the yield of straw has been 36 per cent.

SUGAR BEETS.

The effect of alfalfa on the yield of sugar beets is shown in Table IV. Five pairs of rotations are reported for Scottsbluff and Belle Fourche and four pairs for Huntley. Two of the rotations at each station cover four years, the sugar-beet crop of 1914 being the first to come on plats that had been in alfalfa. The normal course of the rotation was not in effect in these cases until 1915. In the other rotations the first alfalfa effect reached the beet crop only in 1915, and the full effect of three years of alfalfa was not obtained until the crop of 1917.

Coming, as it does, in the second or third year after the alfalfa, the sugar-beet crop can not be expected to show the benefits of alfalfa in the rotation that are shown by the potatoes and oats. Yet in the 14 comparisons of mean yields shown in Table IV, 5 of the means show significant differences in favor of the alfalfa rotations; 1 shows a significant difference against alfalfa, and 8 show differences that are not significant.

If we consider only the comparisons in which the full course of alfalfa has been in effect, i. e., the yields for 1917 and 1918 for the 6-year rotations, we have 40 annual comparisons, of which 24 show increased yields of 1 ton or more for the beets following alfalfa, while 8 show decreases of 1 ton or more, and 8 show differences of less than 1 ton per acre.

TABLE IV.—*Effect of alfalfa on the yields of sugar beets at the Scottsbluff, Belle Fourche, and Huntley Field Stations, 1914 to 1918, inclusive.*

Station and rotation No.	Yield of sugar beets per acre (tons).					
	1914	1915	1916	1917	1918	Means.
Scottsbluff:						
20 (no alfalfa)	14.5	10.6	5.8	13.0	15.3	11.8±1.2
40 (following alfalfa) 2d year	21.2	16.3	10.4	17.7	21.8	17.5±1.4
Difference	+6.7	+5.7	+4.6	+4.7	+6.5	+5.7± .3
22 (no alfalfa)	14.2	12.0	7.3	11.1	14.3	11.8± .7
42 (following alfalfa) 2d year	20.7	16.3	7.3	14.5	21.9	16.1±1.8
Difference	+6.5	+4.3	0	+3.4	+7.6	+4.3± .9
30 (no alfalfa)	.....	10.2	9.8	9.1	10.6	9.9± .2
60 (following alfalfa) 3d year	.....	12.5	7.3	15.3	16.0	12.8±1.4
Difference	.....	+2.3	−2.5	+6.2	+5.4	+2.9±1.4
31 (no alfalfa)	.....	15.6	17.1	16.0	20.2	17.2± .7
61 (following alfalfa) 3d year	.....	15.3	11.9	19.5	23.3	17.5±1.9
Difference	.....	−.3	−5.2	+3.5	+3.1	+.3±1.4
32 (no alfalfa)	.....	10.1	8.8	10.8	8.9	9.6± .4
62 (following alfalfa) 3d year	.....	13.3	6.8	15.4	16.5	13.0±1.5
Difference	.....	+3.2	−2.0	+4.6	+7.6	+3.4±1.3
Belle Fourche:						
20 (no alfalfa)	11.3	12.2	9.7	15.3	10.9	11.9± .6
40 (following alfalfa) 2d year	12.8	11.0	8.8	14.1	11.0	11.5± .6
Difference	+1.5	−1.2	−.9	−1.2	+.1	−.4± .4
22 (no alfalfa)	12.3	9.1	8.1	12.7	8.6	10.2± .8
42 (following alfalfa) 2d year	11.1	7.0	4.2	10.0	8.9	8.2± .9
Difference	−1.2	−2.1	−3.9	−2.7	+.3	−2.0± .5
30 (no alfalfa)	.....	7.3	4.6	7.4	7.3	6.6± .5
60 (following alfalfa) 3d year	.....	9.4	7.2	12.7	13.7	10.7±1.2
Difference	.....	+2.1	+2.6	+5.3	+6.4	+4.1± .9
31 (no alfalfa)	.....	13.2	8.2	15.3	12.2	12.2±1.0
61 (following alfalfa) 3d year	.....	10.9	10.4	15.7	13.8	12.7±1.0
Difference	.....	−2.3	+2.2	+.4	+1.6	+.5± .7
32 (no alfalfa)	.....	6.8	4.0	7.6	6.0	6.1± .7
62 (following alfalfa) 3d year	.....	8.3	4.8	8.5	9.9	7.9± .7
Difference	.....	+1.5	+.8	+.9	+3.9	+1.8± .5
Huntley:						
20 (no alfalfa)	15.1	8.3	15.3	9.6	14.6	12.6±1.2
40 (following alfalfa) 2d year	13.9	15.4	10.4	8.4	16.2	12.9±1.2
Difference	−1.2	+7.1	−4.9	−1.2	+1.6	+.3±1.4
22 (no alfalfa)	10.4	6.8	11.1	11.3	10.2	10.0± .5
42 (following alfalfa) 2d year	9.3	7.6	11.4	5.9	13.1	9.5± .9
Difference	−1.1	+.8	+.3	−5.4	+2.9	−.5± .9
30 (no alfalfa)	.....	4.8	6.7	6.7	8.4	6.7± .4
60 (following alfalfa) 3d year	.....	12.9	7.4	8.3	14.2	10.7±1.6
Difference	.....	+8.1	+.7	+1.6	+5.8	+4.0±1.4
31 (no alfalfa)	.....	9.1	10.0	9.6	10.6	9.8± .2
61 (following alfalfa) 3d year	.....	8.7	15.6	13.0	14.7	13.0±1.0
Difference	.....	−.4	+5.6	+3.4	+4.1	+3.2± .9

In addition to recording the yield of beets from these rotation plats, it has been customary also to determine the average size of the beets by counting and weighing the product of several represent-

ative rows, to record the percentage of sugar in the beets as reported by the local sugar factory upon the samples from each plat, and to determine the proportion of the weight of the tops to the combined weight of beets and tops. This last determination is important not only as showing something of the vigor of growth of the sugar beets, but also as indicating the quantity of feed available as a by-product of the beet crop.

The facts for each of the three stations regarding the effect of alfalfa in stimulating the yield of subsequent crops of sugar beets, as shown in Table IV, and also as to its effect on the size of beets, the percentage of sugar in the beets, and the percentage of tops are summarized below.

At Scottsbluff the yield of beets from the 44 plat years averaged 13.8 tons per acre, while the mean annual difference in favor of those following alfalfa (second and third year) was 3.4 ± 0.5. The size of beets from the same plats averaged 1.53 pounds, with a mean annual difference in favor of those following alfalfa of 0.39 ± 0.032. The sugar content of the beets for the 44 plat years averaged 17 per cent, with a mean annual difference against the plats following alfalfa of 0.5 ± 0.15. The proportion of the weight of tops to the combined weight of beets and tops for the 44 plat years is 27 per cent, with a mean annual difference in favor of the beets following alfalfa of 2.3 ± 0.6.

At Belle Fourche the yield of beets for the 44 plat years averaged 9.9 tons per acre, with a mean annual difference in favor of the plats following alfalfa (second and third year) of 0.64 ± 0.36. The size of the beets from the same plats averaged 0.78 pound, with a mean annual difference in favor of the plats following alfalfa of 0.08 ± 0.035. The percentage of sugar in the beets averaged 19.7 per cent, while the mean annual difference in favor of the plats following alfalfa is 0.5 ± 0.19. The records as to percentage of tops are incomplete.

At Huntley the yield of beets for the 36 plat years averaged 10.7 tons per acre, with a mean annual difference in favor of the plats following alfalfa of 1.5 ± 0.6. The size of beets from the same plats averaged 0.96 pounds, with a mean annual difference in favor of those following alfalfa of 0.17 ± 0.05. The sugar in the beets averaged 17 per cent, with a mean annual difference against the plats following alfalfa of 1.3 ± 0.22. The proportion of the weight of tops to the combined weight of beets and tops, omitting 1918, when the records were not made, has averaged 38 per cent, with a mean annual difference in favor of the plats following alfalfa of 8 ± 1.8.

It is possible to make a comparison between the effect of alfalfa on the subsequent yield of beets and the effect of the application of farm manure at the rate of 12 tons per acre, as was done with the potato crop. The chief difference in the two comparisons is that

where manure was used it was applied directly preceding the beet crop in three of the four cases, while in the alfalfa rotations one or two other crops occur between the alfalfa and the beet crops. There were four rotation pairs in the manure experiments previously described,[1] covering a 6-year period, 1912 to 1917. A summary of those results, together with the results given in the preceding paragraphs, is presented in Table V. These comparisons show that the period of alfalfa in the rotation has been nearly as beneficial as the periodical applications of farm manure, even though the position of the beet crop in the alfalfa rotations has not been so favorable as in the manured rotations. It is also to be remarked that while both manure and alfalfa have increased the yield of the beets, the size of beets, and the vigor of growth, as expressed in the larger proportion of tops, there has not been a corresponding increase in the percentage of sugar in the beets.

TABLE V.—*Comparison of the effect of farm manure and of alfalfa on subsequent yields of sugar beets in irrigated-crop rotations at the Scottsbluff, Belle Fourche, and Huntley Field Stations.*

Factors compared.	Mean yields per acre.					
	Scottsbluff.		Belle Fourche.		Huntley.	
	Manure.	Alfalfa.	Manure.	Alfalfa.	Manure.	Alfalfa.
Yield of treated and untreated plats.....tons..	15.3	13.8	10.7	9.9	11.3	10.7
Annual difference.....do....	+4.3±.28	+3.4±.5	+1.9±.36	+.64±.36	+2.6±.33	+1.5±.6
Size of beets.....pounds..	1.55	1.53	.84	.78	.92	.96
Annual difference in size. do....	+.32±.044	+.39±.032	+.08±.035	+.08±.035	+.21±.034	+.17±.05
Sugar in beets.....per cent..	16.5	17.0	19.6	19.7	16.8	17.0
Annual difference.....do....	−.12±.20	+.5±.15	+.3±.22	+.5±.19	+.16±.17	−1.3±.22
Yield of tops.....do....	26	27	.....	.....	32	38
Annual difference.....	+2.7±.6	+2.3±.6	.....	.....	+3.2±1.12	+8.0±1.8

SUMMARY.

The effect of a period of two or three years of alfalfa in a rotation on the subsequent yields of Irish potatoes, oats, and sugar beets grown under irrigation has been tested for six years at three different stations in the northern Great Plains. Comparison is made between the yields of these crops when grown in the same sequence but without alfalfa. A further comparison is made in the case of potatoes and sugar beets as to the relative effect of a period of alfalfa in the rotation and the application of farm manure at the rate of 12 tons per acre once during the period of the rotation.

At Scottsbluff, Nebr., where the soil is light sandy loam, the effect of alfalfa has been to increase the yield of potatoes about 100 bushels per acre, to increase the proportion of marketable potatoes about 12 per cent, to increase the yield of oats about 6 bushels per acre, and to increase the yield of sugar beets 3.4 tons per acre.

[1] Scofield, C. S. Loc. cit.

At Belle Fourche, S. Dak., where the soil is heavy clay loam rich in organic matter, there has been no beneficial effect from alfalfa on the subsequent potato crop, and the effect on oats and sugar beets, while apparently beneficial, has been too slight to be regarded as significant.

At Huntley, Mont., on a very productive clay-loam soil, the effect of alfalfa has been to increase the yield of potatoes about 50 bushels per acre, without, however, increasing the proportion of marketable potatoes, which has been relatively high on all plats. The alfalfa has apparently increased the yield of oats about 11 bushels per acre and the yield of sugar beets about 1.5 tons per acre.

A comparison of the results from the use of alfalfa in the rotation with those from the use of farm manure shows that with potatoes at Scottsbluff the alfalfa is distinctly more beneficial than farm manure, although the latter gives excellent returns. With the other crops and at the other stations the differences between the effects are less striking, and in general the farm manure has given better results.

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