The Effect of Alfalfa in a Rotation on Yield and Quality of Sugar Beets[1]

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The value of alfalfa in irrigated rotations has been studied in several of the western states (2, 3, 4, 5)[3]. Gardner and Robertson (1) reported the results of an eight-year rotation with alfalfa and a five-year rotation without alfalfa in Colorado after the first 16 years of the experiment. The results of their study indicated that the major effect of alfalfa on yields of succeeding crops grown on the Fort Collins loam was due to an increase in available soil nitrogen. Other effects of alfalfa, if any, were of minor importance. This paper is a report of the influence of alfalfa on growth of sugar beets in the same experiment after an additional 8 years' results.

Procedures

To study the effect of alfalfa in a rotation, an experiment consisting of two rotations was conducted on the Colorado State University Agronomy Farm on Fort Collins loam (1). One rotation included alfalfa for three years followed by corn, sugar beets, wheat, sugar beets and barley as a companion crop for alfalfa. The second rotation omitted alfalfa but other crops in the sequence were the same. In the alfalfa rotation the third cutting of the three-year-old stand was plowed under in the fall.

The experiment was initiated in 1935 following corn. Prior to this the experimental area was in small grain preceded by 8 years of a grass and legume sod. The original plots were one-nineteenth of an acre in size. They were later reduced to one-quarter the original size by different fertilizer treatments. Two replications of each treatment were used.

The fertility level at the beginning of the experiment was high, but after cropping without fertilizer for 7 years the fertility of the soil was reduced to a relatively low status. At this time the plots were split and phosphate fertilizer was applied to the

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[3] Numbers in parentheses refer to literature cited.

north half of each plot when planted to sugar beets. The phosphate treatment was continued for the remaining years of the experiment. Phosphate was applied at the rate of 18.8 pounds of P per acre (43 lb P_2O_5) from 1942 through 1948, and 37.5 pounds P per acre (86 lb P_2O_5) from 1949 through 1959. In 1950 the plots were split again, but in the opposite direction. Nitrogen was applied to the east half of all plots at acre rates of 66 pounds N in 1950, 33 pounds in 1951, 66 pounds in 1955, 54 pounds in 1956, 72 pounds in 1957, 54 pounds in 1958 and 82 pounds in 1959. After the second split, there were four fertilizer treatments in each rotation, namely, check, P, N and N + P. The check (no fertilizer) treatment was continued for 24 years, the P treatment for 17 years, and the N and N + P treatments for 7 years.

Results

Rotation Effects without Fertilizer

Sugar beet yields for the two rotations without commercial fertilizer are shown in Figure 1. The data are plotted as 4-year averages for both beet crops (after corn and after wheat). The field was initially at a high fertility level and produced 18 to 20 tons of beets per acre in the first year of the experiment. Based upon yields during the first 4 years, the residual fertility level was higher for the 5-year rotation than for the 8-year rotation.

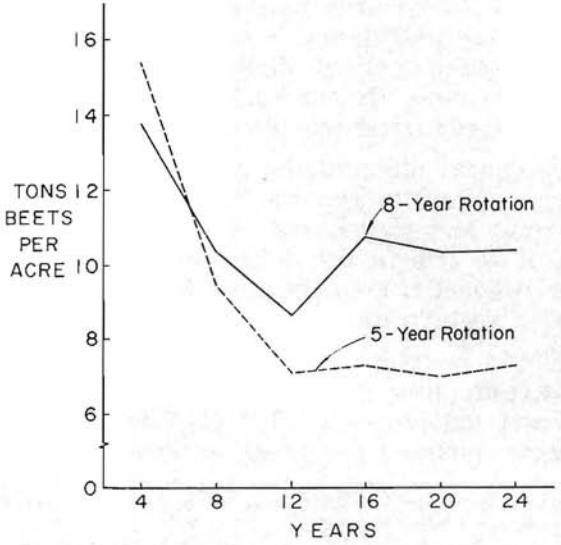

Figure 1.—Twenty-four years of sugar beet yields in an 8-year (alfalfa) and a 5-year rotation without fertilizer.

Beet yields decreased rapidly for both rotations as cropping was continued without fertilization. By the sixth year of the experiment the 8-year rotation with alfalfa was outyielding the 5-year (non-legume) rotation. During the last 12 years of the experiment there was a relatively uniform yield for each crop sequence with the alfalfa rotation outyielding the 5-year rotation by about three tons of beets per acre. Within each rotation, yields were about the same for beets following either corn or wheat, although a higher level of production was maintained where alfalfa was inserted in the rotation. Yield levels were low for both rotations, indicating that alfalfa alone was not sufficient to maintain a high level of production.

The average sucrose percentage for each 4-year period for the two rotations without fertilizer is given in Figure 2. The sucrose content of beets from both rotations increased with continued cropping. Most of the increase in sugar content over the 24-year period was probably the result of decreasing available soil nitrogen as cropping continued without application of fertilizer, although some increase may be attributed to improved genetic material. Except for the first 4-year period, sucrose percentage was always lower in beets grown in the alfalfa rotation. This was caused apparently by the additional soil nitrogen supplied from alfalfa residues.

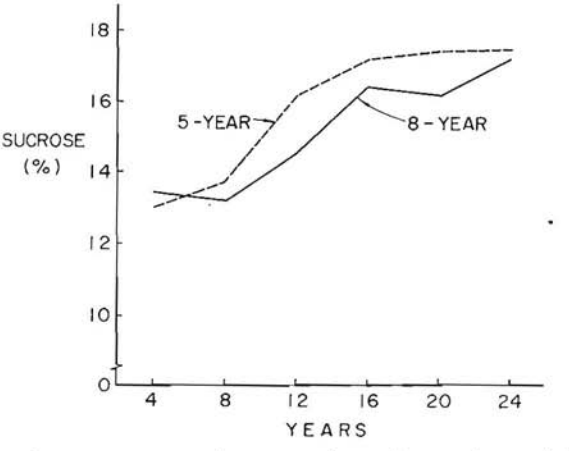

Figure 2.—Sucrose percent for sugar beets in an 8-year (alfalfa) and a 5-year rotation for a 24-year period.

Sugar production was similar to root yields. Sucrose yields decreased initially, then remained relatively constant for the last 12 years at about 1.7 and 1.2 tons sugar per acre for the 8-year

and 5-year rotations, respectively. As with root yields, sugar production was not as high as normally expected for the area.

Influence of Phosphate Fertilization

After conducting the two rotations for 7 years, phosphate fertilizer was applied whenever the plots were planted to beets. The average results for the last 16 years (1944-1959) are given in Table 1. Root yields and sucrose production both were greater for the 8-year rotation, with or without phosphate fertilization, but the advantage of the 8-year over the 5-year rotation was greater where beets followed corn. The rotations had the opposite influence on sucrose percentage and the average was about 0.8% higher for beets grown in the 5-year rotation.

Table 1.—Influence of phosphate fertilization on yield of sugar beets, sucrose percentage and sucrose in 8- and 5-year crop rotations, 16-year average, 1944-1959.

	Beets after corn			Beets after wheat		
	8-year rotation	5-year rotation	Significance for rotations	8-year rotation	5-year rotation	Significance for rotations
			No fertilizer			
Roots (T/A)	10.50	7.20	**	9.70	7.20	**
Sucrose (%)	15.80	17.00	**	16.60	17.00	*
Sucrose (T/A)	1.66	1.22	**	1.61	1.22	**
			Phosphated[1]			
Roots (T/A)	13.20	8.40	**	11.90	8.80	**
Sucrose (%)	16.00	16.80	**	16.20	16.90	**
Sucrose (T/A)	2.11	1.41	**	1.93	1.49	**

* Significant at 5% level.
** Significant at 1% level.
[1] 18.8 lb P (43 lb P_2O_5) 1944 through 1948, and 37.5 lb P (86 lb P_2O_5) per acre rate from 1949 through 1959.

The trend in yield of beets in the two rotations during the 16 years after applying phosphate is shown in Figure 3. The results are for beets after corn averaged for 4-year periods. The initial point gives the yield for the previous 4-year period without phosphate. The curves show that the application of phosphate after cropping without fertilizer resulted in a general increase in yield for the alfalfa rotation during the following 16 years. The yield of beets in the 5-year rotation continued to decline but at a slower rate than where no phosphorus was applied (Figure 1). Statistical analysis of the data for the 16 years shown in Figure 3 revealed a significant difference between the regression lines representing the two rotations. Similar trends were obtained for beets following wheat, but the response to phosphorus in the 8-year rotation was less than for beets after corn. Sugar production per acre followed a trend similar to root yields.

The results show that phosphorus deficiency was one of the causes for poor yields in both rotations for the 16-year period (Table 1). There was a larger response to phosphate fertilizer

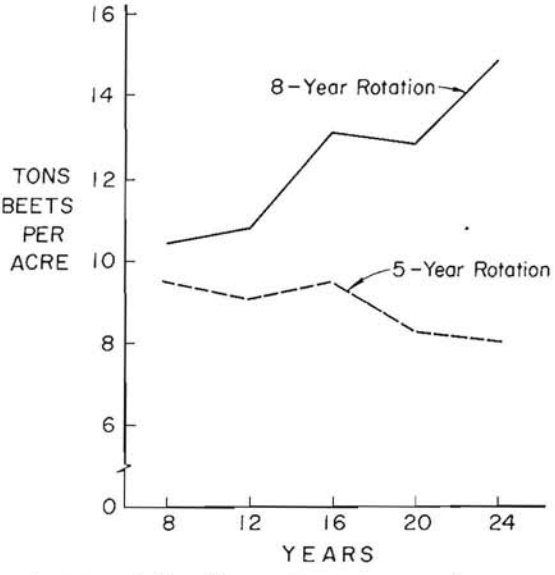

Figure 3.—Average yields of sugar beets grown after corn in an 8-year (alfalfa) and a 5-year rotation for sixteen years.

in the alfalfa rotation because of the higher level of available nitrogen from alfalfa residues. In the 5-year rotation nitrogen deficiency continued to be the principal factor limiting crop growth.

Although phosphate deficiency is reported to have a detrimental influence on sucrose content, it was not observed in this experiment. The data in Table 1 show that the application of phosphate fertilizer had little effect on sucrose percentages.

Influence of Nitrogen and Phosphate Fertilization

During the last 10 years of the experiment when the plots were split, nitrogen fertilizer was applied for 7 years. The dates and rates of application are described in the procedures. With the previous split for phosphate, this gave the 4 fertilizer treatments, check (no fertilizer), P, N and N + P. The yield of roots and sugar for the 4 fertilizer treatments were averaged for the 7 years that nitrogen was applied and are presented in Table 2. Evaluation of either root yields or sucrose production gives the same conclusions.

Highest yields of roots and sugar for the experiment were obtained with the nitrogen-phosphorus combination for both

Table 2.—Yield of beets and sugar in 8- and 5-year rotations as influenced by fertilizer treatment, 7-year average.

Fertilizer treatment	Beets after corn			Beets after wheat		
	8-year rotation	5-year rotation	Significance for rotations	8-year rotation	5-year rotation	Significance for rotations
			Tons roots per acre			
Ck	11.6	7.5	**	10.5	7.7	*
P	15.5	8.2	**	13.3	9.3	**
N	11.5	10.6	N.S.	11.3	10.9	N.S.
N + P	15.4	14.4	N.S.	16.5	15.9	N.S.
			Tons sugar per acre			
Ck	2.08	1.32	**	1.81	1.37	*
P	2.65	1.45	**	2.31	1.62	**
N	1.92	1.86	N.S.	1.81	1.94	N.S.
N + P	2.53	2.50	N.S.	2.80	2.81	N.S.

P — Rate of 37.5 lb P (86 lb P_2O_5) each time planted to beets.
N — Average rate of 61 lb N per acre for the 7 years.
* — Significant at 5% level.
** — Significant at 1% level.

beet crops in both rotations and with phosphate alone for beets after corn in the 8-year rotation. Maximum yields with the 8-year rotation were about one ton per acre more than the average for the local area during the same years.

In the 8-year rotation where beets followed wheat, the application of phosphate produced about 82% of the yield obtained with the nitrogen-phosphorus combination. Phosphate alone for the 5-year rotation averaged about a ton response for the two beet crops. Nitrogen alone produced 67 to 75% of the nitrogen-phosphorus combination for both beet crops in each rotation. The results show the need for phosphate fertilizer on both rotations. Nitrogen from alfalfa residues was adequate in the 8-year rotation where beets followed corn, but additional fertilizer nitrogen was required for beets after wheat in the 8-year rotation and for both beet crops in the 5-year rotation.

Influence of Alfalfa on Sugar Beets

The data indicate that the principal influence of alfalfa in the rotation on the yield of sugar beets grown in this soil was to increase available soil nitrogen. Root yields of the no-fertilizer treatment for beets after corn and after wheat in the 5-year rotation were essentially the same (Tables 1 and 2), while the same comparison for the 8-year rotation shows a higher yield for beets after corn. This undoubtedly reflects a higher residual soil nitrogen supply from the alfalfa two years after plowing it down (beets after corn) than four years after plowing (beets after wheat). The addition of nitrogen alone did not greatly influence yield on the 8-year rotation but caused marked increases for the rotation without alfalfa.

With continued cropping the soil became deficient in phosphorus for both rotations, but when phosphorus was applied, maximum yields were produced in the 8-year rotation where beets followed corn. The average application of 61 lb N per acre to the phosphate treatment increased sugar production 1.12 tons per acre over phosphate alone for the two beet crops in the 5-year rotation. In the 8-year rotation the application of nitrogen gave a response over phosphate alone of 0.5 tons of sugar per acre where beets followed wheat but no additional response was obtained where beets followed corn. If a linear response to nitrogen is assumed, the use of alfalfa in the rotation would result in a saving of 103 lb fertilizer nitrogen for the two beet crops. In Western Colorado, Schumaker, et al. (5) estimated that alfalfa contributed the equivalent of 100 lb fertilizer N for the beet crop following corn and grown 2 years after alfalfa. Other crops in the rotation also would benefit from residual nitrogen from alfalfa, and in a complete evaluation of alfalfa all crops in the rotation must be considered. In addition to fertility effects, alfalfa may help to control weeds and certain soil borne diseases (3, 5).

Alfalfa in the 8-year rotation reduced the sucrose percentage in the roots because of the additional nitrogen it supplied. The reduction in sucrose caused by alfalfa was, however, more than over-balanced by an increase in root yield where the available soil phosphate was kept at a high level and where fertilizer nitrogen was not applied until beets followed wheat.

In addition to the influence on soil fertility, alfalfa in the rotation affected some physical properties of the soil. Measurements obtained during the last years of the study showed that water infiltration rates were two to three times greater on the 8-year rotation plots than on those of the 5-year rotation when compared on the same crops in each case. Although initial infiltration rates were not obtained, it is assumed that this property decreased over the years where alfalfa was not in the rotation but remained more or less constant when alfalfa was included. Surface soil bulk density and the water stability of soil aggregates were not sufficiently influenced by the two rotations to show a difference.

Summary

1. Sugar beets were grown twice in an 8-year rotation with 3 years alfalfa, corn, barley and wheat and in a 5-year rotation with the same crops except for alfalfa. The results were evaluated to determine the influence of alfalfa on yield and quality of sugar beets.

2. The use of alfalfa in a rotation maintained sugar beets at a higher level of production, but without phosphate fertilization production levels were not economically sound.

3. The combination of nitrogen and phosphate was required to maintain maximum yields of both beet crops in the 5-year rotation. In the 8-year rotation, phosphate was required for both beet crops and additional fertilizer nitrogen was required where beets followed wheat (four years after the alfalfa crop). No fertilizer nitrogen was required to obtain maximum yields where beets followed corn (two years after the alfalfa).

4. The principal benefit of alfalfa for sugar beets in the experiment was to increase available soil nitrogen. Alfalfa reduced the nitrogen fertilizer requirement 103 lb per acre for the two beet crops.

5. Water infiltration rates were greater for the alfalfa rotation at the end of the study period.

6. The sugar percentage was lowered one-half to one percent where alfalfa was included in the rotation. Any decrease in sugar content was generally more than compensated by an increase in root and sugar yield.

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