Sugar Beet Production in Michigan as Affected by Crop Sequence and Fertility Levels[1]

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The original field layout for this experiment was described by Cook, *et al.* in 1945 (1)[3]. This is the fourth successive five year summary of sugar beet yields from the Ferden Farm rotation experiment (2,6,7). The yields that are in this report are almost double those produced during the first five years in this experiment.

The higher production level is considered to be related to changes that have been made in the experiment, and to a refined appreciation of the conditions which affect sugar beet growth, as well as to a better understanding of methods and tools that can be used to create a suitable environment for sugar beets.

The purpose of this paper is to discuss changes that have been made in crop sequence and management of the experiment, to discuss the effect of the changes and treatments upon sugar beet yields, and to report yields and observations from a continuous sugar beet experiment and a beet-bean strip crop rotation experiment.

Characteristics of the Soil

The soil upon which these experiments are located is a relatively young humic gley. As such this soil was developed under a naturally poor drainage situation. The soil is relatively high in organic matter and therefore dark colored. The soil is classed as a Sims sandy clay loam. It contains 25 to 28% clay and 50 to 58% sand. The field is tile drained every four rods and is bordered by open ditches on three sides.

The structure of the soil is not as stable as desired (8). Because of this, poor aeration at times is evident, especially during wet seasons (4). Periodically, the general outline and shape of the beet roots suggests a soil that has relatively poor structure.

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[3] Numbers in parentheses refer to literature cited.

Tillage Methods

The minimum tillage principle was put into effect in 1951 (3). On the sugar beet plots, this involves moldboard plowing in late October or early November. Plowing depth averages approximately 10 inches. No other tillage is practiced in the fall. In the spring, a harrow is used immediately prior to planting the sugar beets. The drill that has been used on these experiments has spring-loaded press wheels. The planting time fertilizer is placed one inch to the side and two inches below the seed.

Systems of Farming

Seven systems of farming are evaluated in one experiment. The original crop sequence plan included a legume sod crop for hay in five of the seven systems (1). By 1951, it was evident that clover-timothy had a less desirable effect than alfalfa-brome upon the yield of other crops in the rotation, (7). Therefore, in this one rotation, alfalfa-brome was substituted for the clover-timothy crop.

During the course of the research, marked changes occurred in the sugar beet growing area of Michigan. The number of farms having livestock decreased rapidly while the proportion of cash crop farms increased.

By 1958, it seemed desirable to alter some of the rotations so that the systems of farming would realistically evaluate that which might occur as a result of using more intense cash crop systems. In addition, soybeans, a relatively new crop in the Saginaw Valley, is proving to be a valuable one which fits well with sugar beet production.

The systems of farming have been numbered to facilitate discussion. The crops and the sequence that have been grown since 1958, with the exception that is noted, in each of the rotations are as follows:

Rotation 1: alfalfa-brome, alfalfa-brome, beans[4], sugar beets, barley
Rotation 2: sweet clover (oats), sugar beets, corn (GM), beans, wheat
Rotation 3: beans, sugar beets, corn (GM), soybeans, wheat (GM)
Rotation 4: alfalfa-brome, corn, sugar beets, beans, wheat
Rotation 5: sweet clover, oats, beans, sugar beets, soybeans, wheat
Rotation 6: beans, wheat, corn, sugar beets, barley
Rotation 7: beans, wheat (GM), soybeans, sugar beets, corn (GM)

[4] Changed from corn to beans in 1962.

In these studies, the word beans refers to the navy beans or dry white pea beans. Barley in Rotations 1 and 6 is a spring-planted crop, decreasing in importance in the sugar beet growing area. Sweet clover appears in Rotations 2 and 5 and is harvested for seed. Spring oats in Rotations 2 and 5 are planted as a winter cover crop in August on the sweet clover areas. The "GM" refers to a mixture of equal parts of alfalfa, mammoth, June, and alsike clover which is used as a green manure crop.

Each of the rotations is evaluated on the basis of two fertility levels. When the experiment was initiated in 1940, 200 pounds of 2-16-8 was used for sugar beets on the low fertility side. This represented the rate used by the average sugar beet grower at that time. Five hundred pounds of the same fertilizer was used on the high fertility side. By 1951, it was evident that more than 500 pounds of fertilizer might economically be feasible. Therefore, the rates used on the low side (200 pounds) were changed to 1000 pounds. Thus, the previous low became the new high.

Another change was made in 1962 because there was a lack of a definite crop yield response between the high and low fertility plots. In addition, soil tests did not reflect a great change in value from the use of the higher fertilizer rates. The rate on the high fertility side was doubled, bringing the amount to 2,000 pounds of 2-16-8 used on sugar beets. During this time, commercial fertilizer became more concentrated so that 5-20-10 is now used instead of 2-16-8. In other words, now 1,600 pounds of 5-20-10 is used which supplies the same phosphate and potash as 2,000 pounds of 2-16-8.

In regard to the use of supplementary nitrogen, each of the plots is subdivided so that one half of each plot is treated with an extra 40 pounds at thinning time. Ammonium nitrate has been used most frequently although in some instances urea was the source of the supplemental nitrogen.

Plot Design

Basically, the experiment has a split, split plot design (5). Each crop in each rotation is grown each year. The treatments are replicated 4 times. Each rotation is split and data are collected from 2 fertility levels. The fertility levels are subdivided, and ½ of each plot receives supplementary nitrogen. In other words, the entire experiment contains 560 plots, of which 132 are devoted to sugar beets each year. Planting is done with a 6-row commercial planter. Harvesting is accomplished mechanically with a modified one row machine.

Results and Discussion

In addition to treatments, weather and timeliness of operations associated with weather affect the yield of crops (5). The data in Table 1 summarize the seasonal and annual precipitation. The long time average for the Ferden farm is approximately 30 inches. Therefore, the sugar beet yields that are reported represent those produced with only 60 to 70% normal precipitation during three of five years.

Table 1.—Seasonal and annual precipitation on the Ferden Farm for 1959 through 1963.

	Inches of precipitation				
	Year				
	1959	1960	1961	1962	1963
April	3.48	2.62	4.67	0.95	1.49
May	3.43	2.76	1.48	2.89	2.62
June	2.64	4.18	4.19	3.58	2.26
July	4.06	0.96	4.25	1.77	3.59
August	1.81	3.33	6.93	2.43	2.63
September	2.53	1.77	3.58	1.86	1.11
October	3.53	1.24	1.91	1.92	0.74
Total for season	21.48	16.86	27.01	15.40	14.44
Total for year	29.89	23.43	34.79	20.16	20.02

While the yield data that are reported were analyzed statistically, the analysis of variance data are not included in this summary. This was to simplify the tables and to expedite discussion of the results. The only instance where treatments did not cause a statistically significant difference in yield at the 5% level occurred where supplemental nitrogen was used in 1963. In general, any differences in rotations greater than 9% are significant. The same figures for levels of fertility and nitrogen are 6 and 8% respectively.

The yields of sugar beets produced without supplemental nitrogen and with 400 pounds per acre of 5-20-10 fertilizer are shown in Table 2. The highest yields were produced during those two years with average or more than normal rainfall.

The highest average yield was produced in Rotation 5. In this rotation, which contains sweet clover, the beets follow beans. This historically has been a good sequence of crops.

Where alfalfa precedes corn, the yield of sugar beets after corn (Rotation 4) was approximately the same as after beans (Rotation 1).

The range in yield from one year to another was as great in Rotation 5 as in any of the rotations. Most of the yield increase reflected in the final average occurred during 1959 and in 1961, which were the wettest years. This suggests that the

Table 2.—Sugar beet yields as affected by seven systems of crop sequence. (Low fertility level - no supplementary nitrogen.)

Rotation no.	Crop sequence*	Tons of sugar beets per acre						
		Year						
		1959	1960	1961	1962	1963	Range	Mean
1	A, A, Be, SB, Ba	21.2	13.9	17.6	13.3	16.8	7.9	16.6
2	Sw[1], SB, C[2], Be, W	19.3	15.5	18.0	13.9	11.2	8.1	15.6
3	Be, SB, C[2], S, W[1]	19.4	14.6	20.4	11.5	12.9	8.9	15.8
4	A, C, SB, Be, W	20.2	16.2	18.0	13.4	16.6	6.8	16.9
5	Sw[1], Be, SB, S, W	21.9	16.0	24.0	16.2	15.2	8.8	18.7
6	Be, W, C, SB, Ba	16.7	16.2	14.7	11.3	15.0	5.4	15.8
7	Be, W[2], S, SB, C[2]	17.3	14.6	18.4	13.9	14.8	4.5	15.8
	Mean	19.4	15.3	18.7	13.4	14.6		
	L. S. D.	1.8	1.4	1.6	3.2	1.6		

*A = alfalfa brome hay, Be = beans, SB = sugar beets, Ba = barley, Sw = sweet clover, C = corn, W = winter wheat, S = soybeans.
[1] Oat cover crop seeded after sweet clover.
[2] A mixture of small seeded legumes planted in the crop for green manure purposes.

opportunity for high yields with adequate moisture is greater in this rotation than in some of the others.

Rotations 6 and 7 historically have been relatively low yielding rotations. The range in yields in these rotations from year to year was much lower than in any of the other systems. As will be shown, nitrogen problems are more evident in these rotations. Erickson and Van Doren demonstrated that soil structure problems as measured by oxygen diffusion rates developed under these two systems, especially during wet years (4).

The lowest average yields occurred in Rotation 2, the other rotation that contained sweet clover. The low average yields reflects strongly the low yield of only 11.2 tons per acre produced in 1963. The effect of two exceedingly dry seasons in succession probably accounts for this situation. Drought may have been more severe because two to three tons per acre of dry matter as sweet clover straw was plowed the fall before beets were planted.

As might be expected, the response from the use of 40 pounds of supplemental nitrogen sidedressed to the beets at thinning time varied from one year to another. The data in Table 3 show the increase or apparent yield decrease associated with the use of supplemental nitrogen in the various rotations on the low fertility plots. The greatest average yield increase occurred in Rotations 3 and 6 although the increase was very inconsistent from one year to the next. The nitrogen was least effective in Rotations 1 and 5. These are the two highest yielding rotations.

The data in Table 4 show the yearly effects of using more than 400 pounds of 5-20-10 fertilizer on the sugar beets in each of the rotations. In interpreting these data, one should keep

Table 3.—Yearly changes in yield of sugar beets as affected by the use of 40 pounds of supplemental nitrogen in seven systems of crop sequence. (Low fertility level - with supplementary nitrogen.)

Rotation no.	Crop sequence*	Change in yield - tons per acre					
		Year					
		1959	1960	1961	1962	1963	Mean
1	A, A, Be, SB, Ba	—0.1	+0.4	+0.5	+0.3	—1.1	+0.0
2	Sw[1], SB, C[2], Be, W	—0.1	—0.9	+2.2	+1.5	+0.6	+0.7
3	Be, SB, C[2], S, W[1]	+1.4	+0.9	+0.6	+2.6	+2.2	+1.5
4	A, C, SB, Be, W	+1.2	—0.7	+2.5	+1.1	+0.2	+0.9
5	Sw[1], Be, SB, S, W	—0.7	+0.8	+0.3	+1.0	+0.3	+0.3
6	Be, W, C, SB, Ba	+2.3	—1.0	+4.8	+3.4	—0.8	+1.7
7	Be, W[2], S, SB, C[2]	+2.9	+0.8	—0.4	+1.7	—0.7	+0.9
	Mean	+1.0	+0.0	+1.5	+1.7	+0.1	
	L. S. D.	0.5	0.5	0.4	0.4	N.S.	

*A = alfalfa brome hay, Be = beans, SB = sugar beets, Ba = barley, Sw = sweet clover, C = corn, W = winter wheat, S = soybeans.
[1] Oat cover crop seeded after sweet clover.
[2] A mixture of small seeded legumes planted in the crop for green manure purposes.

Table 4.—Yearly changes in yield of sugar beets as affected by the use of extra fertilizer in seven systems of farming. (High fertility level - no supplemental nitrogen.)

Rotation no.	Crop sequence*	Change in yield - tons per acre					
		Year					
		1959	1960	1961	1962	1963	Mean
1	A, A, Be, SB, Ba	+1.8	+1.5	+2.6	+3.4	+0.2	+1.9
2	Sw[1], SB, C[2], Be, W	+2.1	—0.6	+1.0	+2.1	+5.9	+2.1
3	Be, SB, C[2], S, W[1]	+1.4	+2.4	+2.6	+4.7	+3.3	+2.9
4	A, C, SB, Be, W	—0.2	—0.3	+1.1	—2.2	+2.1	+0.1
5	Sw[1], Be, SB, S, W	+0.6	—0.4	+0.1	+1.6	+2.9	+1.0
6	Be, W, C, SB, Ba	+0.3	—3.0	—0.7	+2.8	+1.5	+0.2
7	Be, W[2], S, SB, C[2]	+2.5	+1.6	+2.0	+1.8	+2.7	+2.1
	Mean	+1.2	+0.17	+1.2	+2.0	+2.7	
	L. S. D.	1.5	0.6	0.4	0.6	0.8	

*A = alfalfa brome hay, Be = beans, SB = sugar beets, Ba = barley, Sw = sweet clover, C = corn, W = winter wheat, S = soybeans.
[1] Oat cover crop seeded after sweet clover.
[2] A mixture of small seeded legumes planted in the crop for green manure purposes.

in mind that in 1959, 1960, and 1961, the rate of fertilizer used, 800 pounds of 5-20-10, was twice that used on the low fertility plots and that in 1962 and 1963 the rates used, 1,600 pounds of 5-20-10, was equal to four times that used on the low fertility plots.

The average increase in yield from the use of 1,600 pounds was greater than the increase in yield from the 800 pound rate. This occurred despite the fact that 1962 and 1963 were exceptionally dry years, the driest of the five year period.

The amount of increase in yield varied with the rotation. One of the lowest average increases was obtained in the cash crop rotation which had no green manure or cover crops (Rotation 6). This might be expected in this situation where soil

aeration may be a limiting factor as was suggested by Erickson and Van Doren (4).

The average yield increase obtained in Rotation 4 was also insignificant amounting to only one-tenth of a ton. An explanation for this situation is not readily apparent.

The data shown in Table 5 indicate the yearly effect of sidedressing the sugar beets with 40 pounds of nitrogen on the high fertility plots. The difference in average response on all rotations from year to year was not great, being equal to only five-tenths of a ton per acre. The average response in Rotation 6 was greatest, being equal to 2.7 tons. The increase in yield was not as large in this rotation in 1962 and 1963 because in these years more planting time fertilizer was used which necessarily means more nitrogen was used. The extra nitrogen used in 1962 and 1963 in the planting time fertilizer was equal to 40 pounds, the same amount as was used as a sidedressing.

The data in Table 6 are the sugar beet yields that were produced in each of the rotations with the high fertilizer rate and with the use of 40 pounds of sidedressed nitrogen.

The highest average yields, 20.9 tons per acre, were produced in Rotation 5, the rotation in which beets followed beans which were preceded by sweet clover. The lowest yields were produced in Rotation 6, the cash crop rotation without green manures or cover crops.

The greatest range in yield from one year to another was also obtained in Rotation 5 which suggests that with adequate moisture the opportunity for satisfactory yields is greatest in this rotation. The range in yields in Rotation 6 and 3 was approximately one half of those obtained in Rotation 5. This suggests that some factor other than rotation, planting time, or fertilizer, is limiting the plants' growth.

Continuous Sugar Beets

Because sugar beets are a high value cash crop, it would be desirable to grow the crop year after year. This, however, is not practical because disease or pest problems frequently develop. To determine specifically the kind of problems that develop, a continuous sugar beet plot was established in 1959. The yields that were obtained are 26.0, 16.5, 14.8, 13.0, and 17.4 tons per acre respectively for the years 1959 through 1963.

The continuous decrease in yield for each of the seasons up to 1963 suggests why continuous sugar beets is not practical. It is not immediately evident why the yields were down because there were no clear-cut symptoms of pest or disease damage except in 1961 when leaf blight (*Cercospora beticola*) was severe.

Table 5.—Yearly changes in yield of sugar beets as affected by the use of extra nitrogen in seven systems of crop sequence. (High fertility level - with supplementary nitrogen.)

Rotation no.	Crop sequence*	Change in yield - tons per acre					
		Year					
		1959	1960	1961	1962	1963	Mean
1	A, A, Be, SB, Ba	—0.2	+0.8	+0.5	+0.6	+2.7	+0.9
2	Sw[1], SB, C[2], Be, W	—0.1	+0.3	+1.6	+0.8	+2.3	+1.0
3	Be, SB, C[2], S, W[1]	+0.1	+0.1	+0.1	+1.8	+1.1	+0.6
4	A, C, SB, Be, W	+2.4	+0.8	+1.1	+0.7	+0.4	+1.1
5	Sw[1], Be, SB, S, W	+1.3	+2.7	+1.7	+0.6	+0.3	+1.3
6	Be, W, C, SB, Ba	+3.1	+3.1	+4.4	+2.4	+0.5	+2.7
7	Be, W[2], S, SB, C[2]	+0.7	+0.1	+1.4	+1.0	+0.1	+0.7
	Mean	+1.0	+1.1	+1.5	+1.1	+1.1	
	L. S. D.	0.48	0.51	0.46	0.38		

*A = alfalfa brome hay, Be = beans, SB = sugar beets, Ba = barley, Sw = sweet clover, C = corn, W = winter wheat, S = soybeans.
[1] Oat cover crop seeded after sweet clover.
[2] A mixture of small seeded legumes planted in the crop for green manure purposes.

Table 6.—Sugar beet yields as affected by seven systems of crop sequence. (High fertility level - with supplementary nitrogen.)

Rotation no.	Crop sequence*	Tons of sugar beets per acre						
		Year						
		1959	1960	1961	1962	1963	Range	Mean
1	A, A, Be, SB, Ba	22.8	16.2	20.7	17.3	19.7	6.6	19.3
2	Sw[1], SB, C[2], Be, W	21.3	15.2	20.6	16.8	19.4	6.1	18.7
3	Be, SB, C[2], S, W[1]	20.9	17.7	22.3	18.0	17.3	3.8	19.1
4	A, C, SB, Be, W	22.4	16.7	21.0	16.5	18.7	5.9	19.1
5	Sw[1], Be, SB, S, W	23.8	18.3	25.8	18.4	18.4	7.4	20.9
6	Be, W, C, SB, Ba	20.1	16.3	18.8	16.5	17.0	3.8	17.7
7	Be, W[2], S, SB, C[2]	20.5	16.3	21.8	16.7	17.6	4.2	18.6
	Mean	21.7	16.6	21.6	17.2	18.4	5.4	19.1
	L. S. D.	1.8	1.4	1.6	3.2	1.6		

*A = alfalfa brome hay, Be = beans, SB = sugar beets, Ba = barley, Sw = sweet clover, C = corn, W = winter wheat, S = soybeans.
[1] Oat cover crop seeded after sweet clover.
[2] A mixture of small seeded legumes planted in the crop for green manure purposes.

The disease was not evident on other experiments in the same field where beets were grown in rotation with other crops.

Sugar Beet - Bean Strip Cropping

Four-year average yields where sugar beets and beans were grown in alternate strips are shown in Table 7. In this experiment, each strip was six rows wide. The rows ran east and west.

The rows of sugar beets adjacent to the beans averaged 21.1 tons per acre while the inside rows averaged only 17.0 tons. The picture was different with the beans. Border rows yielded six bushels per acre less than did those not bordering beets. The practice might still be worthwhile though, because four tons of beets are worth considerably more than six bushels of beans.

Table 7.—The effect of a beet-bean strip cropping plan upon yields.

Year	Beets - tons/acre		Beans - bu/acre	
	Inside rows	Outside rows	Inside rows	Outside rows
1960	17.0	24.4	28.1	18.9
1961	16.3	20.4	36.4	32.1
1962	17.2	19.0	27.2	20.2
1963	17.3	20.7	40.3	36.8
Mean	17.0	21.1	33.0	27.0
% increase		24.1		
% decrease				18.1

Summary

The data in this paper represent the fourth successive five-year summary of the sugar beet yields produced in the Ferden farm rotation experiment. This replicated field experiment is located in the Saginaw Valley region of Michigan and involves seven systems of farming, two fertility levels and the use of supplementary nitrogen applied as a sidedressing.

On the basis of the data shown in this paper, the following statements can be made:

1) The yields of sugar beets after corn were approximately the same as after beans, providing the corn was preceded by alfalfa.

2) The lowest sugar beet yields were produced in a cash crop rotation that did not include a green manure or cover crop immediately previous to the sugar beets.

3) Preceding sugar beets with sweet clover resulted in yields approximately two tons per acre less than with a bean crop between the sweet clover and the sugar beets.

4) The highest average of sugar beet yields was produced in Rotation 5 where sugar beets followed beans which were preceded by sweet clover.

5) The use of more than 400 pounds of 5-20-10 fertilizer did not consistently increase sugar beet yields to levels above those produced with this rate.

6) The greatest yield response from the use of sidedressed nitrogen was produced in the rotation that had no green manure or cover crop.

7) The use of an extra 40 pounds of sidedressed nitrogen caused increases in yield ranging from 0 to 1.7 tons per acre on the low fertility plots. This was less than on the high fertility plots, despite the fact that the high fertility plots received significantly more nitrogen in the planting time fertilizer.

8) The use of an extra 40 pounds of sidedressed nitrogen caused increases in yield ranging from 0.5 to 2.7 tons per acre on the high fertility plots.

9) The yields of sugar beets were increased, but bean yields were decreased when alternate strips of six rows of beans and six rows of beets were planted in an east and west direction, side by side.

10) Growing sugar beets year after year on the same land may not be desirable because leaf blight caused a reduction in yield one year out of four.

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