Sugar Beets in Seven Michigan Systems of Crop Rotation[1]

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At a meeting' of the sugar beet research committee, composed of representatives of beet sugar companies, the Farmers and Manufacturers Beet Sugar Association, and the Michigan Experiment Station, held at Michigan State College in 1939, attention became centered on the lack of experimental results pertaining to crop rotation and sequence. Such questions as "What crop should sugar beets follow in the rotation?", "Are legumes essential in the sugar beet rotation, and if so, what legume is most desirable?", and "What proportion of the rotation period should be allotted to the production of soil building legumes?" could not be definitely answered because of a lack of experimental evidence. To obtain such evidence the Ferden rotation and crop sequence experiment was started in the spring of 1940.

It is the object of this paper to explain the field lay-out and to present in full detail the results obtained with sugar beets. Other crop results are considered in so far as it is believed they might appreciably affect the over all program of the sugar beet farmer. Results of 1940 are not considered because it required that year to get the rotations started. There are also some errors in the 1941 results arising from getting the rotations under way. Not until 1942 did beets actually follow 2 years of alfalfa, and it was in 1942 that sugar beets in rotation 7 were first grown on land where swectelover had been plowed under.

Field Layout and Plans

This experiment is being conducted on the Ferden farm in Saginaw County, 4 miles south of Chesaning. The soil contains from 25 to 28 per cent clay and 50 to 58 *per cent* stand. It is classified as Brookston sandy clay loam. The field is tiled but the structure is such that it drains rather slowly. There is a very gentle slope which allows some surface drainage.

Seven 5-year rotations arc being studied. They are as follows:

1. Barley, alfalfa, alfalfa, corn, sugar beets.

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2. Barley, alfalfa, alfalfa, sugar beets, corn.
3. Barley, alfalfa, alfalfa, beans, sugar beets.
4. Barley, oats, alfalfa, corn, sugar beets.
5. Barley, oats, clover-timothy, corn, sugar beets.
6. Barley, beans, wheat, corn, sugar beets.
7. Barley, sweetclover, beans, wheat, sweet clover, corn, sugar beefs. The sweetclover is seeded with barley and is plowed under the next spring for beans and is seeded in the spring on wheat to be plowed under the next spring for corn.

The plots are arranged in a split plot randomized block design. Treatments are replicated four times and all crops appear each year. Barley and sugar beets occur in all rotations. Corn appears in all but one of the rotations.

The field outline for block 1 is shown in figure 1. Each individual crop plot is 28 by 90 feet. The rotations were arranged at random in each block, with each rotation occupying five plots in each of the four blocks. The five plots provide for each of the five crops in the rotation, except, of course, that in rotations 1, 2, and 3 alfalfa occupies two plots out of the five. There arc 140 plots in the entire experiment, 5 by 4 for each rotation, with 7 rotations. Each plot is then further divided into two 14 by 90 feet sub-plots. One sub-plot receives 2-16-8 fertilizer at the rate of 1,000 pounds per acre in 5 years while the other receives 400 pounds of the same fertilizer during the rotation period. In both cases one-half the fertilizer is applied for sugar beets and the other one-half for grain, all for barley in rotations 1, 2, and 3 and divided between the two grain crops in the other rotations. When the experiment was started, a flip of a coin determined which sub-plot was to receive the high fertilizer treatment.

To facilitate tractor and team work on the plots, it was decided at the outset that crops would not be placed entirely at random in the five plots within a rotation but would be grouped as much as possible so all of one series (A, B, O, D, or E) would grow a common crop within each block. Thus it was decided, by chance, that in block 1 barley should come in series B in all rotations (see figure 1) and that corn should come in series A and sugar beets in scries C. Of coarse in rotation 2 the position of corn and sugar beets had to be reversed and in rotation 3 beans replaced corn. This variation offered no difficulty, however, because the land for all three crops can be fitted at the same time. With this arrangement, the plowing and fitting of three series in each block can be across the plots with all seven plots being worked simultaneously.

The other two crops in each rotation were placed, in the order of occurrence, in the other two series, D and E in figure 1. Because these other crops vary in the different rotations, it is necessary to work the plots individually.

Figure J.—Field outline of block 1 of the Ferden rotation experiment showing the crops as they occurred on each plot during the 5 years under discussion.

	Series A	Series B	Series C	Series D	Series E (28' ← 90' →)
45	Sugar beets	Barley	Corn	Alfalfa	Alfalfa
41 H	Corn	Alfalfa	Barley	Sugar beets	Alfalfa
42—	Barley 2	Alfalfa	Alfalfa	Corn	Sugar beets
43 L	Alfalfa	Sugar beets	Alfalfa	Barley	Corn
44	Alfalfa	Corn	Sugar beets	Alfalfa	Barley
45	Corn 7	Barley (sw cl)	Sugar beets	Wheat (sw cl)	Beans
41 H	Sugar beets	Beans	Barley (sw cl)	Corn	Wheat (sw cl)
42—	Barley (sw cl)	Wheat (sw cl)	Beans	Sugar beets	Corn
43 L	Beans	Corn	Wheat (sw cl)	Barley (sw cl)	Sugar beets
44	Wheat (sw cl)	Sugar beets	Corn	Beans	Barley (sw cl)
45	Corn	Barley	Sugar beets	Alfalfa	Oats
41 L	Sugar Beets	Oats	Barley	Corn	Alfalfa
42—	Barley 4	Alfalfa	Oats	Sugar beets	Corn
43 H	Oats 4	Corn	Alfalfa	Barley	Sugar beets
44	Alfalfa	Sugar beets	Corn	Oats	Barley
45	Corn	Barley	Sugar beets	Wheat	Beans
41 L	Sugar beets	Beans	Barley	Corn	Wheat
42—	Barley 6	Wheat	Beans	Sugar beets	Corn
43 H	Beans	Corn	Wheat	Barley	Sugar beets
44	Wheat	Sugar beets	Corn	Beans	Barley
45	Corn 5	Barley	Sugar beets	Clover-timothy	Oats
41 H	Sugar beets	Oats	Barley	Corn	Clover-timothy
42—	Barley	Clover-timothy	Oats	Sugar beets	Corn
42 L	Oats	Corn	Clover-timothy	Barley	Sugar beets
44	Clover-timothy	Sugar beets	Corn	Oats	Barley
45	Corn	Barley	Sugar beets	Alfalfa	Alfalfa
41 H	Sugar beets	Alfalfa	Barley	Corn	Alfalfa
42—	Barley	Alfalfa	Alfalfa	Sugar beets	Corn
43 L	Alfalfa 1	Corn	Alfalfa	Barley	Sugar beets
44	Alfalfa	Sugar beets	Corn	Alfalfa	Barley
45	Beans	Barley	Sugar beets	Alfalfa	Alfalfa
41 L	Sugar beets	Alfalfa	Barley	Beans	Alfalfa
42—	Barley	Alfalfa	Alfalfa	Sugar beets	Beans
43 H	Alfalfa 3	Beans	Alfalfa	Barley	Sugar beets
44	Alfalfa	Sugar beets	Beans	Alfalfa	Barley

Notes—"H" and "L" refer to high (1,000 pounds in 5 years) and low (400 pounds in 5 years) application of 22-16-8 fertilizer, respectively. The numerals in column A are rotation numbers corresponding with those given in the text. All plots are 90 feet east and west and 28 feet north and south. Alleys are 28 feet wide.

The use of manure and the disposition of crop residues are regulated according to the systems of farming which might be practiced with the different rotations. In rotations 1, 2, and 3, manure at the rate of 10 tons per acre is applied for corn or beans. In rotations like 4 and 5, with only 20 per cent of the land in hay production,

the farmer could not feed so many cattle so the manure application is 7 tons per acre. No manure is applied in rotations 6 and 7 because under such farming systems livestock would not be raised.

Corn stover is left on all the plots. Grain and bean straw and sugar beet tops are returned to the plots in rotations 6 and 7.

Barley in rotations 1, 2, and 3 and oats in rotation 4 serve as nurse crops for alfalfa. A red clover and timothy mixture is seeded with oats in rotation 5. Sweetclover is seeded with both grain crops in rotation 7 and is plowed under for beans and corn.

Plowing has been done in the spring and in only one direction. Thus dead and back furrows have been avoided. Oats and wheat have been planted after barley and beans, respectively, without plowing. All other plots have been plowed for each crop. Normal tillage methods have been followed. The 14-foot width of the sub-plots is right for one round of a grain drill (11 disk), four rows of corn, six of sugar beets, and six of beans.

With some variations because of seasonal and other unavoidable circumstances the harvest areas have been the entire plot in the case of grain, the center two rows of corn, and the center four rows of sugar beets and beans.

Experimental Results

The sugar beet yields obtained in this experiment are shown year by year in table 1. The results have varied markedly with seasonal conditions and they illustrate *very* nicely the need for many years results before definite conclusions may be drawn. There are, however, some noticeable trends already showing up.

The year 1941 was very good for sugar beets on this farm. The mechanical condition of the soil was good at planting time and weather was favorable throughout the season. Yields were high on all plots and were significantly higher on the plots in rotation 2 than on any other plots. The statistical analysis of the results showed that it required 2.75 tons of beets for a significant difference that year so there were no differences caused by rotation except that, caused by rotation 2, where beets followed alfalfa.

During the late summer and fall the beets on rotation 2 looked much better than on any other plots. The tops were larger and of a much darker green. Green tissue tests made October 7 on the leaf petioles showed those on rotation 2 to be very high in nitrate nitrogen, while blank tests were obtained on all other plots. The correlation between color and test was very consistent. Apparently the beets were taking nitrogen from the decomposed alfalfa.

Table 1.—The effect of rotation at two fertility levels < the yields of sugar beets over a 5-year period.

Rotation	Tons per acre						
	1941	1942	1943	1944	1945	5-year mean	Rotation 5-year mean
IH	15.20	11.20	5.90	12.85	6.65	10.34	
							9.51
1L	14.73	8.98	4.81	10.88	3.78	8.68	
211	20.80	12.30	4.23	12.73	4.34	10.88	
							10.02
2L	19.68	10.48	3.00	11.28	1.37	9.16	
3H	16.78	10.78	6.24	13.28	7.12	10.24	
							9.63
3L.	15.60	8.70	5.83	10.73	4.12	9,02	
4H	16.50	11.30	5.67	11.68	7.07	10.45	
							9.52
4L	15.63	9.53	4.11	9.48	4.22	8.59	
5H	16.43	10.33	5.25	31.88	6.29	10.04	
							9.32
5L	15.40	8.75	4.00	10.45	3.80	8.60	
OH	16.13	9.85	4.82	10.85	6.53	9.64	
							8.79
OL	15.48	8.40	3.43	S.3S	3.9S	7.93	
711	16.13	11.78	3.98	11.80	6.12	10.08	
							9.39
7L	15.70	10.53	3.62	9.55	4.05	8.69	
Diff. req. for sig. between rotuliom Average of LI anil L,	2.75	2.37	1.41	1.42	1.16	0.81	0.81
Diff. req. for sig. between levels in any one rotation							

It seems desirable at this point to mention some supporting work done that same season on a similar soil in Tuscola county. The experiment is one designed to compare the effects of stable manure and sweetclover on various crops. The crop in 1941 was sugar beets. Tissue tests made on the green leaf petioles on September 19 sliowed without exception that beets growing where sweetclover had been plowed under that spring were well supplied with nitrate nitrogen. Where sweetclover had not been plowed under, the plants tested very low. Beets growing on manured plots gave intermediate tests. Apparently the beets were obtaining nitrogen from the decomposed sweetclover residues.

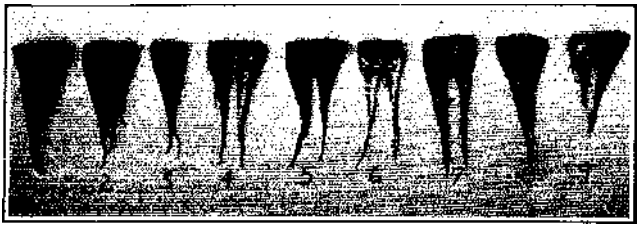

Figure 2.—Sugar beets grown in the greenhouse, comparing alfalfa with ammonium nitrate as a source of nitrogen.

1. No fertilizer—26,000 pounds green alfalfa per acre.
2. 2-16-8, 1,000 pounds—green alfalfa 26,000 pounds per acre.
3. 2-16-8, 1,000 pounds per acre.
4. 2-16-8, 1,000 pounds—NH_4NO_3, 900 pounds per acre.
5. 2-16-8, 1,000 pounds—NH_4NO_3, 600 pounds per acre.
6. 2-16-8, 1,000 pounds—NH_4NO_3, 300 pounds per acre.
7. 2-16-8, 1,000 pounds—NH_4NO_3, 600 pounds per acre in two applications of 300 pounds each.
8. 2-16-8, 1,000 pounds—NH_4NO_3, 900 pounds per acre in three applications of 300 pounds each.
9. 2-16-8, 1,000 pounds—NH_4NO_3, 900 pounds per acre in three applications of 300 pounds each.

Sugar beets require large quantities of nitrogen which may be very largely furnished by the nitrogen released from decomposing alfalfa. This has been shown by experiments performed in the greenhouse. Figure 2 shows the results obtained in an experiment performed in 2-gallon pots of soil taken from the Ferden farm. Each pair of beets represents the average of eight beets grown in four pots. The treatments are listed in the caption under figure 2. All treatments except No. 1 included 1,000 pounds per acre of 2-16-8 fertilizer. Treatments 1 and 2 included 106 grams of green chopped alfalfa per pot. This was considered to be about twice the weight, on an area basis, of an average crop of alfalfa in the field. Treatments 4 through 9 included NH_4NO_3 in different amounts in addition to the 2-16-8 fertilizer. Treatment 3 supplied only the 2-16-8 fertilizer at the rate of 1,000 pounds per acre. That it was insufficient is shown by the small size of the beets. Treatment 2 was just about equal to number 4. In other words 13 tons of green alfalfa, containing about 75 per cent water, had an effect about equal on the growth of the beets to 900 pounds of NH_4NO_3.

There are some indications that green manure, sweetclover, alfalfa, or grass is even better than stable manure in furnishing nitrogen for young sugar beet plants. This was shown on the Horst farm where sweetclover green manure proved better than manure and has been

shown to be true in pot cultures in the greenhouse. A comparison between alfalfa, manure, and grass is shown in figure 3. These materials were incorporated with soil from the Ferden plots at the rate of 10 tons fresh material per acre. The manure was fresh horse manure taken from a stable. The alfalfa was in the early blossom stage and the grass was lawn clippings. The beets growing on the pots which received manure alone, fertilizer alone, or both manure and fertilizer were very light green in color. They showed very pronounced signs of nitrogen starvation. The beets growing where grass or alfalfa had been mixed in the" soil were larger and were very dark green, not deficient in nitrogen. In figure 3, the second pot from the left and the last one at the right show what a difference in growth resulted from the alfalfa green manure.

The results obtained in 1942 were quite similar to those of 1941. Again as shown in table 1, the highest yields were obtained on rotation 2, where beets followed alfalfa. The differences, however, were not as great as in 1941. The analysis showed that a difference of 2.37 tons was required before one could be sure the difference was not due to chance. The average yield of the high and low fertility plots in rotation 2 was 11.39 tons and in rotation 6, 9.13 tons or a difference of 2.26 tons, just slightly less than the value necessary to indicate significance.

In 1942, as in 1941, the color of the leaves in the fall and tests made on the green eptioles indicated that the beets on rotation 2 were getting sufficient nitrogen while those on all other rotations were deficient in nitrogen.

As a check on this alfalfa-nitrogen relationship a tour of the principal sugar beet counties was made on August 21-22, 1942. Stops were made wherever beets looked unusually green and healthy or unusually yellow. Tissue tests were made to confirm the fact that the dark green or yellow color was due to the presence or lack of sufficient

Figure 3.—Sugar beets grown on Brookston sandy clay loam from the Ferden plots. Treated as indicated. The 2-16-8 was applied at the rate of 1,000 pounds per acre and the grass, manure, and alfalfa at the rate of 10 tons fresh material in each case.

nitrogen. Invariably it was found that the beets having the best color and highest nitrate content were those which followed alfalfa or which were only 1 year away from an alfalfa crop. The most yellow field observed on that tour was on good soil where oats had been combined the year before. The oats had been a good crop and the straw was plowed under for the beets. The farmer could not remember that alfalfa had ever been grown on the field.

By analyzing the results from 1941 and 1942 together, it was possible to take out the variance due to years and the interaction variance between rotations and years. The result showed that rotations had caused highly significant differences in yield.

The season of 1948 was very poor for sugar beets on the Ferden farm. The spring was levy wel and the soil on the plots was badly puddled when the heels were planted about a month later than is considered seasonal. The plants developed slowly and yields were about one-half as large as in the 1942 season.

Weather conditions during 1945 were vary similar 1o those during 1948. The two seasons differed in that in 1945 the planting date was much earlier and the soil at. planting time was in fairly good condition. Rainfall immediately after planting, however, and for most of the growing season, was far above normal. It is safe to conclude that aeration was poor in that soil during much of the growing season.

A comparison now of the yields obtained during the 2 years 1943 and 1945, table 1, shows much in common. During both years rotation 2 slipped badly, producing yields lower than did any other rotation. In 1945 the average of the two yields was 2.86 tons, with the other six rotations yielding, as an average, from 5.05 to 5.65 tons. The difference is highly significant.

In 1944, another good season, legumes in the rotation caused significant increases in sugar beet yields. Beets in rotation 6 yielded significantly less than did those in rotations 1, 2, 3, and 5. Apparently better results were obtained from 2 years of alfalfa and from clover and timothy than from 1 year of alfalfa or from sweetclover. The beets in rotation 2, however, did not yield more than did those in rotations 1 and 3.

The variance caused by the interaction of rotations and years was highly significant when the first 3 years results were combined. Significance due to rotations, however, disappeared. This was because the behavior of beets in rotation 2 was exactly the reverse of what it was during the first 2 years. When the results for 1944 were combined with those for the first 3 years, the analysis showed that significant differences between rotations again resulted. Considering the 4-year averages of both high and low fertility plots, the beets

in rotation 2 yielded significantly more than did those in all other rotations except No. 3. The difference in yield between plots in rotations 2 and 3 was not significant. The average yield obtained from rotation 6, where there is no legume, was lower than from all other rotations but the differences were significant only in the case of 6 as compared to 2 or 3.

When the results for the 5 years were combined, some definite trends in the mean yields were apparent, although the statistical analysis shows that the differences are not large enough to be significant. It is seen in the last column in table 1 that when the yields from the high and low fertility plots are averaged the yield from rotation 2 is 1.23 tons higher than that from rotation 6, where no soil building legume has been grown, *in* fact the yield from rotation 2 is still above all other yields despite 2 adverse years, 1943 and 1945, for that rotation. It is interesting that the average yield from rotation 4 where there is only 1 year of alfalfa, is almost identical to that from rotation 1, with 2 years of alfalfa.

It is also interesting that whereas the yields from rotation 3, where beans replace corn, were below those from rotation 1 during the first 2 years the reverse was true during the last 3 years, and the 5-year average is slightly in favor of rotation 3. From the 5-year average, the effect of sweetclover seems about equal to that of red clover and slightly inferior to that of alfalfa.

The question arises, "Why did the yields of beets in rotation 2 fall so low during such years as 1943 and 1945, seasons of unusually high spring and early summer rainfall?" With the information at hand it is impossible to answer this question. The Ferden soil puddles easily if worked wiiile too wet or if it is saturated for any considerable period. Under the poorly aerated conditions which exist during such periods, it is possible that some type of decomposition injurious to sugar beets may take place where the fresh alfalfa has recently been turned under. Further investigations are necessary, however, before such a conclusion can be definitely drawn.

Stand has been a problem in rotation 2 throughout the experiment. Each year the stands have been thinner than in any other rotation. The greater yields obtained on plots in that rotation during 1941 and 1942 were inspite of relatively poor stands. It is believed that the poor stands have been due to the mechanical difficulties of fitting a seed bed after alfalfa rather than to the effect of the alfalfa on disease. The plots have been relatively free of black root.

Levels of Fertility

Sugar beets are very responsive to commercial fertilizer. This has been shown by many experiments performed on a number of soil types in several of the principal sugar beet counties. At the beginning

of the Perden experiment it was thought that the different cropping systems might have a different effect on sugar beets under different levels of plant food availability. Accordingly each plot was divided into two sub-plots, one to receive fertilizer at the rate of 400 pounds in 5 years and the other to receive 1,000 pounds during the same period.

Sugar beet yields have been significantly higher every year on the side of the plot which received the heavier application of fertilizer. The statistical analysis showed that after the first year a significant interaction existed between years and levels of fertilizer which continued through the fifth year and in the grouping of 5 years. This means that the beets did not respond the same each year to the two different levels of fertilizer. For instance the differences in yield due to *the* increased amount of fertilizer were larger in 1942 than in 1941 and were largest in 1945.

It was thought at the beginning of the experiment that in some cropping systems sugar beets might need more fertilizer than in others. In that case the differences between the yields resulting from the 1,000 pound application and the 400 pound application (one-half on the beets in each case) would have been greater in some rotations than in others. This was not true as was shown in the statistical analysis by a non-significant interaction between levels and rotations. Apparently the response of the beets to the fertilizer was the same in all the seven rotations.

Sucrose Content

A discussion of any agronomic practices pertaining to sugar beets would not be complete without a consideration of sucrose content. Except for the year 1943, the sucrose content of the beets on all plots was determined each year, at harvest time. During 1941 and 1942 the beets grown on rotation 2 were lower in percentage of sucrose than were those from any other rotation. As shown by the data presented in table 2 the difference in 1941 was highly significant but was not significant in 1942. It seems doubtful if this higher sucrose content was actually due to the alfalfa which preceded the sugar beets, because the relationship did not hold in 1944 and 1945. • In 1941 and 1942 the yields were greater on the plots in rotation 2. This was in spite of poorer stands. That means that the average weight of beets was greater on the rotation 2 plots. It is generally recognized that larger beets are lower in sucrose than arc smaller beets.

Table 2.—The effect of rotation on the sucrose content of sugar beets.

Rotation	Percent sucrose			
	1941	1942	1944	1945
1	16.8	16.3	17.2	16.7
2	16.0	15.5	17.2	16.6
3	17.0	16.1	17.5	16.3
4	16.8	16.1	17.2	16.9
5	17.1	15.9	17.2	17.0
6	16.8	16.7	17.5	17.0
7	16.7	16.3	18.0	17.5
Significance (rotations)	**	...	...	*
Difference required for significance between rotations	0.7			

In 1944 and .1945 the highest sucrose percentages were obtained on beets grown in rotation 7, where sweetclovor was turned under as green manure in the spring of 1943 and .1944 respectively. The difference was significant in 1945. It was also found in 1945 that the percentages of sucrose were lower in beets grown in the three rotations which include 2 years of alfalfa than in the other four rotations. This would again indicate that possibly alfalfa does tend to lower sucrose jjercentages.

The sucrose content of the sugar beets on the Ferden plots was not significantly different on the plots which received the larger as compared to the smaller applications of fertilizer.

Other Crops

Michigan sugar beet growers are interested in several other cash crops. Most important among these are corn, white beans, and wheat. It is necessary then that these crops be considered before deciding on a suitable rotation for sugar beets. It would not of course be wise to sacrifice, by carrying out some practice favorable to sugar beets, more on other crops than was gained on the beets.

Corn

Six of the rotations in this study include corn. The results presented in table 3 show that corn yields have been very significantly affected by the legumes in the rotation. Considering the results year by year the data show that in 1942, 1944, and 1945 the differences in yield caused by rotations were highly significant. This is also true of the 5-year averages. The highest average yields were obtained where alfalfa occurred in the rotation, while the lowest yields occurred in rotation 6 where no soil building legume is grown. It is interesting to note that 1 year of alfalfa in the rotation (rotation 4) was as good

Table 3.—The effect of rotation at two levels of fertilizer application on the yearly and 5-year average yields of corn.

Rotation	Bushels per acre						
	1941	1942	1943	1944	1945	Mean	Rotation Mean
1H	45.7	72.8	30.5	35.2	39.9	44.8	44.7
1L	47.0	71.4	27.5	36.8	39.9	44.6	
2H	35.4	70.0	25.6	32.5	34.8	39.7	39.1
2L	35.6	63.8	26.9	31.3	34.5	38.4	
4H	47.9	69.2	30.2	34.6	47.3	45.8	45.5
4L	48.3	68.9	29.9	36.3	42.1	45.1	
5H	46.6	66.4	22.9	33.1	34.6	40.7	42.3
5L	47.0	69.3	22.8	36.2	43.7	43.8	
6H	45.5	47.0	20.1	28.5	27.7	33.8	33.1
6L	41.4	51.2	17.3	27.6	24.4	32.4	
7H	45.5	70.4	22.5	29.0	34.9	40.5	39.5
7L	45.1	65.0	23.6	29.0	29.4	38.4	
Significance (rotations)		**		**	**		**
Difference required for significance between rotations	11.6	10.8	7.6	3.6	4.6		3.5

as 2. In fact the yield of corn obtained in rotation 4 averaged slightly higher than that obtained in rotation 2 where alfalfa has been grown for 2 years out of 5. In this respect the corn and sugar beet yields agree.

Compare now the corn yields from rotation 2 with those from rotation 1, where exactly the same crops are grown but where the order of corn and sugar beets are reversed. Where corn has followed sugar beets the average yield for 5 years has been significantly less than where corn has followed alfalfa. In other words what has been gained by growing sugar beets directly after alfalfa has been at least partly lost on the corn crop.

Judging from the results obtained with corn in this experiment, sweetclover is greatly inferior to alfalfa as a soil building crop. The average yield of 39.5 bushels obtained in rotation 7 is significantly less than that obtained from either of the alfalfa rotations where corn

immediately followed the alfalfa crop. That sweetclover was beneficial, however, is shown by the fact that corn in rotation 7 significantly outyielded corn in rotation 6, where no legume is grown.

Red clover and timothy seemed slightly inferior to alfalfa but the difference between the yields of corn caused by the two soil building crops was too small to be significant.

White Beams and Wheat

White beans are grown in the rotation with sugar beets on many Michigan farms. As has already been shown sugar beets do well after beans. Since beans are a rather high value cash crop, it is important that one consider the effect of other crops on bean yields. The crop is included in rotations 3, 6, and 7 so it is possible to determine the effect of two soil building legumes, alfalfa and sweetclover.

As shown by the results presented in table 4, the highest yields have occurred in rotation 3, where beans have followed alfalfa. The average yield for the rotation, averaging the yields from the high and low fertilized plots, over a period of 5 years is 16,5 bushels per acre as compared to a yield of 13.7 bushels where no soil building legume has been grown. In rotation 7 the crops grown are exactly the same as in rotation 6 except that sweetclover is grown twice in the rotation for green manure. It is seeded in barley and is plowed under the following spring for beans. The data show that the effect of the sweetclover on the beans has been about half as great as the effect of alfalfa, an average increase of 1.5 bushels of beans for the sweetelover green manure as compared to an increase of 2.8 bushels as a result of the alfalfa in rotation 3.

Table 4.—The effect of rotation at two levels of fertilizer application on the yearly and 5-year average yields of white beans.

	Bushels per acre						
Rotation	1941	1942	1043	1944	1945	Mean	Rotation Mean
3H	22.0	20.6	16.5	4.0	19.0	16.6	16.5
3L	20.0	20.1	17.3	5.3	18.S	16.3	
6H	22.0	13.7	13.6	6.5	14.8	14.1	13.7
6L	20.0	13.6	11.5	5.6	15.1	13.2	
7H	24.5	15.0	14.2	4.1	16.3	14.8	15.2
7L	26.6	16.7	12.2	6.1	16.5	15.6	

Wheat follows beans in rotation 6 and 7. That the sweetclover which was plowed under for beans in rotation 7 increased the yield of wheat is shown by the data recorded in table 5. The average yield increase over the 5-year period was 3.6 bushels per acre. Thus it is seen that from one sweetclover manure crop is obtained 1.5 bushels of beans and 3.6 bushels of wheat. The money spent for 10 pounds of sweetclover seed was indeed very well invested.

Table 5.—The effect of rotation at two levels of fertilizer application on the yearly and 5-year average yields of wheat.

	Bushels per acre						
Rotation	1941	1942	1943	1944	1945	Mean	Rotation Mean
6H	28.0	30.1	18.8	29.4	33.4	28.0	27.0
6L	26.6	26.7	16.7	25.3	34.9	26.0	
7H	30.7	42.5	19.2	30.9	35.5	31.8	30.6
7L	27.5	38.8	19.3	26.7	34.3	29.3	

Levels of Fertility

Fertilizers were not applied directly for corn and beans. One might expect, however, some residual effect from fertilizer applied for the grain and sugar beet crops. The data, reported in tables 3 and 4 show that such was not the case. The statistical analysis of the corn yields shows that the variance due to levels of fertilizer was very small. The 120 corn yields in all rotations, from the plots which received the heavy applications of fertilizer averaged 40.9 bushels per acre as compared to a yield of 40.4 bushels from the plots which received the lower quantity of fertilizer. The difference is within the range of experimental error.

Wheat has been fertilized directly at the time of planting. During the 3 years 1941, 1942, and 1944 the yields were definitely higher on the more heavily fertilized plots, but during the years 1943 and 1945 there was no increase in yield as a result of the larger application. Tn spite of this, however, the 5-year averages still show about 2 bushels of wheat in favor of the higher application. If the increase is really significant it was profitable as the extra 150 pounds of 2-16-8 fertilizer costs less than the value of 2 bushels of wheat.

Summary

A crop rotation and sequence experiment designed especially to determine the effects of other crops on sugar beets was started in 1940 on Brookston sandy clay loam on the Ferden farm in Saginaw County, Michigan. Seven rotations, all including sugar beets, are being studied. Plots are replicated four times, and all crops appear each year. The plots are arranged in a split-plot, randomized block

design with each rotation conducted at two fertility levels. The plot size and arrangement is such that all tillage, planting, and harvesting can be done with standard farm machinery.

During the 5 years 1941 to 1945 inclusive, some very interesting observations and yield results have been obtained from the sugar beets grown on the plots. During 2 of the 5 years the highest yields occurred in rotation 2, where beets follow alfalfa. In 1944 the yields of beets from rotation 2 were about equal to those from rotations 1 and 3, where beets follow corn and beans, respectively. Weather conditions during these 3 years were fairly good for beets in the Ferden area. During the other 2 years, 1943 and 1945, seasons of heavy spring and summer rainfall, yields were generally low and those from rotation 2 were lower than those from the rotations where beets followed corn or beans.

Considering the 5-year averages, the lowest yields have occurred in rotation 6, where no soil building legume has been grown. Alfalfa in the rotation has caused higher yields than has sweetclover. One year of alfalfa in a 5-year rotation has given as good results as 2 years. Red clover and sweetclover have proven to be about equal in their effects on sugar beet yields.

Sugar beet yields have been significantly higher where the fertilizer applications have been at the rate of 1,000 pounds in 5 years than where the rate of application has been 400 pounds. The response to the heavier fertilizer application has not varied among the different rotations but has varied from year to year.

Very significant differences have shown up in the yields of corn obtained in the different cropping systems. Where no soil building legume has been grown, corn yields have been about 12 bushels below those obtained where the rotation included alfalfa and where corn followed directly after the alfalfa. One year of alfalfa has been as good as 2 in the rotation.

Where sugar beets followed the alfalfa and corn followed the sugar beets, corn yields have been about 6 bushels below those obtained where corn followed the alfalfa immediately.

Red clover has been slightly inferior to alfalfa, in so far as effect on corn yields is concerned, and sweetclover has been the poorest of the three legumes.

Bean yields have been increased by soil building legumes in the rotation. Alfalfa has given better results than sweetclover.

Wheat yields have been increased by the plowing under of sweetclover green manure in the rotation.

The heavier applications of fertilizer have increased wheat yields, as compared to yields obtained from plots where the lesser quantity of fertilizer has been applied, but have not affected corn or bean yields.