Sugar Beet Production in Michigan as Affected by Cropping Sequence and Fertility Level[1]

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The concept of cropping systems that evolved from early research on cropping sequence and rotations is changing. Improved technology has minimized the values previously placed on several rotational effects. The use of legume sod crops, once thought of as necessary to lasting crop production, has been reduced in importance owing to increased supplies of low-cost commercial nitrogen. Disease resistant crop varieties and improved pesticides have decreased the need of rotational control of some soil-borne pathogens. Mechanization has reduced the necessity of labor distribution afforded by rotations and increased the economy in specialization. The net effect of these developments is to lessen the need of producing soil building sod crops, particularly on the more productive soils. In lieu of these facts, it is important to have an evaluation of the effects of less sod and more intensive cropping systems on the subsequent production of specific crops. Data evaluating the effect of various cropping systems on the production of sugar beets in Michigan is presented in this report.

Experimental Methods

An experiment was initiated in 1941, to study the effects of seven different cropping sequences on the production of sugar beets. In 1951, another experiment adjacent to the older experiment involving six new sequences was established. The soil type was predominantly a Sims clay loam with associated minor types of the same soil management group. The two experiments, while being in the immediate vicinity of one another, will be discussed as separate studies owing to the differences in length of time established and in previous management history. The experiment was originated to answer certain questions regarding differential cropping sequence in the production of sugar beets. Of particular interest was the effects that legumes might have on the sugar beet yields. Accordingly, alfalfa and the clovers are important rotational constituents in the study.

The experiment was designed so that all crops in any one rotation appear each year. The plots are divided into high and low fertility sub-plots and are replicated four times. A more detailed description of the plot layout and design established

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in 1941 are published (1)[3]. The plot layout and design of the new rotations, established in 1951, are similar to these.

In 1951, after 10 years of operation, changes were made in some of the experimental treatments. From 1941 to 1950, one sub-plot of each rotational plot had received 400 pounds of 2-16-8 fertilizer per rotation (five years) and the other sub-plot received 1000 pounds. One-half of the fertilizer was applied to sugar beets and the remainder divided among the row and grain crops in the rotation. In 1951, the treatments on the sub-plot receiving the 400 pounds of fertilizer per rotation was changed to 2000 pounds of 4-16-8. The new rotations had a fertilizer program similar to this changed program for the old rotations. The sub-plots were further divided into two sub-plots, one of which received supplemental nitrogen on all cash crops. Alfalfa-brome hay was substituted for clover-timothy hay in rotation 5 listed below because clover-timothy is not a recommended forage for this area in Michigan, and crop yields were shown to be lower than where alfalfa-brome was used.

The rotations included in both experiments are as follows:

1. Alfalfa-brome hay, alfalfa-brome hay, corn, sugar beets, barley.
2. Alfalfa-brome hay, alfalfa-brome hay, sugar beets, corn, barley.
3. Alfalfa-brome hay, alfalfa-brome hay, white pea beans, sugar beets, barley.
4. Alfalfa-brome hay, corn, sugar beets, barley, oats.
5. Alfalfa-brome hay, alfalfa-brome (plowed down), sugar beets, corn, barley[4].
6. White pea beans, wheat, corn, sugar beets, barley.
7. White pea beans, wheat (green manure[5]), corn, (sweet clover), sugar beets, barley (green manure[5]).
8. Alfalfa-brome hay, alfalfa-brome hay, corn, sugar beets, barley.
9. Alfalfa-brome hay, alfalfa-brome (plowed down), corn, (sweet clover), sugar beets, barley[4].
10. Alfalfa-brome hay, alfalfa-brome (plowed down), sugar beets, corn (sweet clover), barley[4].
11. Alfalfa-brome hay, corn (sweet clover), sugar beets, oats (green manure[5]), barley[4].
12. White pea beans, wheat, sweet clover (plowed down), sugar beets, barley (green manure[5]).
13. White pea beans, wheat, sweet clover seed, sugar beets, barley (green manure[5])[4].

[3] Numbers in parentheses refer to literature cited.
[4] Rotations 5 and 8-13 were started in 1951, the rest started in 1941.
[5] Green manure refers to a mixture of equal parts of mammoth, June, alsike and sweet clovers seeded at a rate of 12 pounds/ac.

Experimental Results

Old Rotations

The weather during the last seven years varied greatly between years. The wettest year of the entire 17-year study occurred in 1957, and the dryest year in 1955. The yields of the old rotations for these two years, as shown in Table 1, are likewise contrasting with the highest yields of the entire study occurring in 1955, and the lowest yield of the last seven years in 1957. Generally, the yields of beets from 1951 to 1957 were approximately two tons per acre higher than during the previous 10 years. This comparison can be made only at the low level of fertilization where fertilizer rate was constant over the entire period. The average yield for each rotation for the entire 17-year period can likewise be made only at the low level of fertilization for the

Table 1.—The Yield of Sugar Beets as Affected by Cropping System and Fertilizer Application.

Rotation and Level	Tons per Acre 1951	1952	1953	1954	1955	1956	1957	Mean	Rotation Mean	Yield Increase With N	1941-1957 Mean
1 H	13.6	12.2	15.2	17.9	21.1	10.8	8.6	14.2	13.6	0.0	
1 L	12.9	12.0	14.4	15.0	20.3	10.0	6.3	13.0			11.7
2 H	14.3	11.9	13.4	14.6	20.0	10.7	7.2	13.2	12.9	—0.6	
2 L	14.7	12.0	11.9	12.8	18.7	11.1	6.8	12.6			11.5
3 H	15.4	13.9	16.2	16.8	22.3	12.0	9.9	15.2	14.4	—0.4	
3 L	14.6	11.7	13.6	15.6	21.3	11.0	6.7	13.5			12.3
4 H	11.1	12.7	16.4	15.9	22.9	10.3	8.2	13.9	13.6	0.4	
4 L	12.7	13.1	15.3	14.0	20.8	10.6	6.7	13.3			12.0
5 H	8.5	11.0	14.2	8.6	22.0	9.5	9.5	11.9	11.6	0.1	
5 L	8.3	11.3	13.5	8.8	20.5	8.8	7.9	11.3			
6 H	9.0	11.9	14.0	15.0	20.4	10.0	7.2	12.5	12.0	0.9	
6 L	9.4	11.3	13.3	13.0	19.3	8.5	6.2	11.6			10.5
7 H	9.6	13.1	14.3	15.8	22.0	10.8	84	13.4	13.2	0.7	
7 L	10.8	12.8	14.6	13.3	21.1	10.2	7.3	12.9			11.6
L.S.D. 5% between rotations at each level	1.7	1.8	1.4	1.4	1.9	1.6	1.6	0.5	0.5		0.4
L.S.D. 5% within rotations	1.0	1.3	1.3	1.0	1.3	.8	.9	0.3		0.5	

same reason. The average yields for all periods fall into a rather consistent pattern with little interaction between periods and rotations. The general results and conclusions of earlier progress reports (6) (3) are still valid in regard to crop sequence effect.

During the last seven years, the following results have occurred:

1. The highest average beet yields have been obtained where beets have followed white pea beans in rotations with two years of alfalfa-brome hay preceding the beans (rotation 3).

2. The beet yields where corn, instead of beans, has been the intervening crop between the alfalfa and sugar beets (rotation 1, 4) have averaged 0.8 ton less.

3. The lowest beet yields occurred where beets followed second year alfalfa-brome hay that had not been harvested the second year (rotation 5). Where the alfalfa-brome was harvested as hay (rotation 2) the beet yields averaged 1.3 tons more than where it was plowed down, but these yields were still 0.7 ton under those obtained from beets in alfalfa rotations with an intervening corn crop.

4. Beets grown after corn that had been seeded to a green manure crop (rotation 7), have yielded 0.4 ton below those obtained from beets after corn in the alfalfa rotations 1 and 4. Nitrogen sidedressing increased the beet yields in rotation 7 to where they were equal to 1 and 4.

5. Beets after corn without green manure of alfalfa (rotation 6) have yielded 0.8 of a ton less than where green manure was seeded. Forty pounds of nitrogen sidedressed to these beets increased the yield nearly equivalent to that where a green manure crop appeared in the rotation.

6. Nitrogen sidedressing on beets in rotations having an alfalfa sod within two years of beet planting has not produced a significant yield increase and has produced a decrease in yield where alfalfa has immediately preceded beets. Yield decreases with nitrogen sidedressing occurred in 1955, with high summer temperatures prevailing. Response of sugar beets to nitrogen sidedressing has previously been shown to be negatively correlated with summer temperature (2).

7. Beets from plots fertilized with 1000 pounds of 4-16-8 per acre have produced yields averaging nearly one ton more than from those receiving 500 pounds. If the last five years are considered, allowing the two years previous as time to reach equilibrium with the new fertilizer rate, then beets from plots at the higher fertilizer rate have averaged 1.3 tons more than those from plots at the lower rate.

Sucrose

The average sucrose percentage of the last seven years did not vary greatly from that previously found. The 1951-1957 averages, as shown in Table 2, compares with the average of the entire period covered by sucrose analysis (1946-1957). Fertilizer level has not had any effect on sucrose analysis and percentages shown are the average over both levels.

Sucrose percentage has been highest in beets produced in non-legume rotations (rotation 6 and 7), and lowest in beets grown after alfalfa (rotations 2 and 5). Beets grown after corn (rotations 1 and 4) or beans (rotation 3) in rotations with alfalfa had sucrose percentages intermediate between the extremes.

Table 2.—The Average Percent Sucrose and Gross Sugar Produced as Affected by Cropping System and Nitrogen Sidedressing.

Rotation	% Sucrose		Pounds Gross Sugar/Acre at the High Fertilizer Level (1951-1957)		
	1951-1957	1946-1957		With Addition N	Net Change
1	17.9	17.9	5084	4970	—114
2	17.2	17.2	4540	4233	—307
3	18 0	18.0	5472	5209	—263
4	18.3	18.2	5088	5119	+31
5	17.2		4094	4032	—62
6	18.7	18.6	4676	4904	+228
7	18.4	18.4	4932	5076	+144
L.S.D. 5% between rotation means	0.4	0.4			

The values in Table 2 of gross sugar produced show nearly the same differences between rotations as the yield data with the highest yield of sugar produced occurring in rotations with beets following beans and the lowest yield with beets after alfalfa. Nitrogen sidedressing has not shown any consistent interaction with rotations on sucrose percentage, but has produced an average decrease of 0.4 percent in sucrose over all rotations. The increase in yield attributed to nitrogen in rotations 4, 6 and 7 more than offsets this reduction in sugar percent and the gross sugar produced was increased. In the other systems, the gross sugar was reduced by nitrogen sidedressing.

Yearly Variability

The variability of both yield of sugar beets and percent sucrose was greater between years than between treatments within years. The average beet yield and sucrose percentage over all rotations in the older experiment, the number of days between planting and harvest, and modifying climatological data for the last seven years are given in Table 3. The yearly variability of beet yields has been attributed, at least in part, to early summer precipitation (5). The average yields from 1945 to 1957 show a highly significant correlation coefficient of r = — .826 with total precipitation occurring in April, May, June, and July. The two years of high sucrose percentage, 1952 and 1953 have in common the weather conditions of an average early summer precipitation and a dry season prior to harvest. The only year of high sucrose percentages prior to this was in 1946, with an average sucrose content of 19.5%. The year, 1946, as 1952 and 1953, was characterized by average early summer precipitation (10.0 inches) and low precipitation prior to harvest (1.7 inches).

Table 3.—The Average Beet Yield and Percent Sucrose, Growing Season, and Climatological Data Over All Rotations in the Older Experiment for 1951-1957.

	Year						
	1951	1952	1953	1954	1955	1956	1957
Avg. yield, tons/acre	12.5	12.3	14.1	14.0	20.3	10.4	8.0
Avg. sucrose percent	16.6	20.2	21.3	15.8	17.9	17.3	16.4
No. of days from planting to harvest	165	174	165	174	185	138	162
Precipitation, inches April, May, June, July	9.9	9.5	11.5	10.5	7.8	19.9	21.6
30 days prior to harvest	4.9	0.4	1 6	3.5	3.1	0.5	2.7
Temperature, No. of days with Maximums over 90°, June and July	8	22	11	12	31	3	6
Minimums under 32°, 30 days prior to harvest	9	15	4	9	5	5	4

The temperature data do not correlate as well as precipitation with the best yields and sucrose percentages, although high temperature appears to be associated with a dry climate and, conversely, a low temperature with wet climate. Temperature effects are important, however, in affecting response to beets to nitrogen sidedressing as shown previously (2).

New Rotations

The yields of sugar beets in the new rotations have averaged higher the last seven years than in the old rotations. This is shown by comparing rotations 1 and 8 on the two areas. The new rotations were established on an adjacent area, of similar soil type, to the old rotations, but the two areas are not comparable. It is believed that previous historical differences in ownership and management are responsible, in part, for the difference. The yield data for the new rotations are given in Table 4.

Table 4.—The Yield of Sugar Beets as Affected by Cropping System and Fertilizer Application.

Rotation and Level	Tons per Acre 1951	1952	1953	1954	1955	1956	1957	Mean	Rotation Mean	Yield Increase with N
8 H	14.7	13.7	17.9	19.1	20.2	13.1	14.1	16.1	15.5	.2
8 L	14.3	12.4	16.4	18.1	18.4	12.8	12.1	14.9		
9 H	14.9	14.2	16.0	18.4	22.0	11.6	12.0	15.6	15.1	.5
9 L	14.9	12.8	14.1	18.4	20.8	12.0	9.8	14.7		
10 H	15.6	16.7	14.6	16.1	19.6	12.8	14.3	15.7	15.3	—.6
10 L	14.8	16.8	14.6	16.9	18.8	11.1	12.0	15.0		
11 H	15.1	13.7	15.0	17.1	21.1	14.3	13.6	15.7	15.5	.4
11 L	15.3	13.3	14.5	17.4	21.0	13.2	11.7	15.2		
12 H	16.7	17.1	15.2	17.1	21.8	12.9	17.5	16.9	16.5	.0
12 L	16.1	16.1	14.4	17.1	21.2	13.1	14.7	16.1		
13 H	15.7	16.9	13.4	17.8	19.3	12.8	14.4	15.8	15.4	.0
13 L	15.2	15.8	12.8	17.3	20.1	12.4	12.3	15.1		
L.S.D. 5% between rotations at each level	1.9	2.3	1.4	2.6	2.7	1.9	2.0	0.6	0.6	
L.S.D. 5% within rotations	1.8	1.0	0.9	2.0	1.6	1.3	1.5	0.4		0.7

The yield difference between rotation 12, where sugar beets followed sweet clover plowed down in full blossom in August and seeded to an oats cover crop, and the other systems is significant. The plowing down of sweet clover has been shown to give benefits to beet yields only when immediately preceding the sugar beets in sequence (4).

The beneficial effects of plowed down sweet clover are mostly dissipated after one year. Plowing down sweet clover ahead of sugar beets has averaged over a ton more than where the sweet clover is harvested for seed. As occurred in the older experiment, planting sugar beets after alfalfa resulted in the lowest yield.

Nitrogen sidedressing has increased yields slightly where beets follow corn and produced a decrease in yield where beets follow alfalfa. The fertilizer response has been of the same magnitude as in the older experiment.

Table 5.—The Average Percent Sucrose and Gross Sugar Produced as Affected by Cropping System and Nitrogen Sidedressing.

		Pounds Gross Sugar/Acre at the High Fertilizer Level		
Rotation	% Sucrose		With Additional N	Net Change
8	18.4	5925	5835	—90
9	18.7	5834	5860	+26
10	17.9	5621	5255	—366
11	18.8	5903	5893	—10
12	19.0	6422	6253	—169
13	19.0	6004	5846	—158
L.S.D. 5% between rotation means	0.2			

Sucrose percentages for beets grown in these rotations are shown in Table 5. The fertilizer rate has not been significant in affecting sucrose percent and the percentages given are of an average over both levels. Sugar beets after a year of sweet clover (rotations 12, 13) averaged the highest percent sucrose and except for the first year, had the highest yearly percent. This high percent sucrose, coupled with the high yield, particularly where the sweet clover was plowed down, places this rotation first in quantity of gross sugar produced. The lowest yield of gross sugar occurred where sugar beets followed alfalfa.

Nitrogen sidedressing, on the average, decreased sucrose percentage to about the same extent as occurred in the old experiment, 0.5%. The decrease in sucrose percent was not compensated for by a sufficient yield increase, so that, in general less sugar has been produced where additional nitrogen fertilizer was used. A substantial loss in yield of sugar was noted where nitrogen was applied to beets following alfalfa.

Summary

Two cropping system experiments, one established in 1941 and the other in 1951, and comprising 12 different cropping systems have been carried out in Michigan. One of these rotations is common to both experiments. The effects of rotation on yield and sugar content of sugar beets have been studied, together with the interaction of these systems with two fertilizer rates and supplemental nitrogen.

The data may be summarized as follows:

In cropping systems with alfalfa sod, on soils similar to that involved in these experiments:

1. Sugar beets should not follow alfalfa in rotation, owing to the possibility of a depression in both yield of roots and percent sucrose.

2. Sugar beets should be planted after an intervening crop of white pea beans or corn following the alfalfa with the best sequence, beets after beans.

3. The cropping system of 20 percent is as effective in producing high yields as one with 40 percent sod.

4. A nitrogen sidedressing should not be used on sugar beets, if beets are planted two years or less after a good alfalfa sod is turned under.

In cropping systems without alfalfa:

1. Highest yields of sugar beets are obtained where they follow a sweet clover crop. The best yields of beets occurred where spring seeded sweet clover is plowed down at full blossom the year before sugar beets are planted.

2. Sweet clover harvested for seed the year before beets are planted diminishes the yield benefit from that occurring from plowing it down, but results will still be as good as in alfalfa systems where beets follow corn.

3. Sweet clover seeded in corn ahead of beets does not benefit yields as much as results from having sweet clover come to maturity as previously described, but it will benefit yields sufficiently to pay for the seeding.

4. Nitrogen sidedressing increases yield of beets where sweet clover seedings were not made the year before sugar beets and also where seedings were made in corn. Sugar beets planted after corn with the seeding and with the nitrogen sidedressing, yield just as well as in alfalfa rotations with beets following corn.

In all cropping systems:

1. The difference in yield between the beets produced at the high fertilizer rate (1000 pounds/acre of 4-16-8) and the low rate (500 pounds/acre of 4-16-8) is marginal (1.0 - 1.3 tons/acre) in respect to profitable use of fertilizer at today's market value. The most effective rate is probably between the two rates used and will vary according to the varying price of beets and fertilizer.

2. Alfalfa sod is not necessary to have high beet yields. Assiduous use of sweet clover and nitrogen fertilizer eliminates the necessity of alfalfa sod as a soil conditioner on these soils.

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