STATION BULLETIN 514—1975

Effect Of Six 4-Year Rotations On Yield, Quality, And Monetary Return Of Sugarbeets In The Red River Valley (1971–74)

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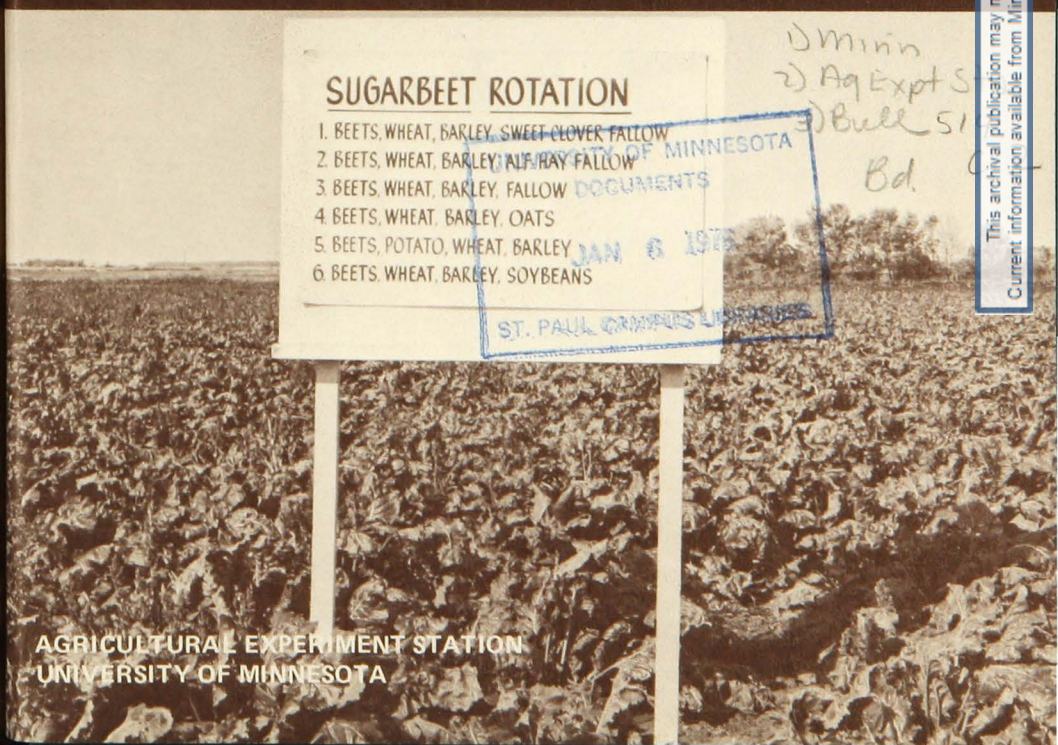

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ON THE COVER: The sign on this test plot shows the six 4-year rotations used in the study reported in this publication. The emphasis of the research reported here is on the effect of commercial nitrogen fertilizer on the yield and quality of sugarbeets. **OPPOSITE PAGE:** Sugarbeet production is a major agricultural enterprise in the Red River Valley in northwestern Minnesota.

Effect Of Six 4-Year Rotations On Yield, Quality, And Monetary Return Of Sugarbeets In The Red River Valley (1971-74)

By Olaf C. Soine*

This study began in spring 1967 at the Northwest Experiment Station, Crookston. The first 4-year results have already been published (3).[1] The emphasis during the second 4-year period has been on the effect of commercial nitrogen fertilizer on the yield and quality of sugarbeets. Since most beet growers in the Red River Valley are no longer using a "land fallow system," they are changing their fertilizer practices, using more nitrogen fertilizers. The new procedure processors use for testing each grower's sugarbeets for sugar and impurities has placed still more emphasis on accurate nitrogen fertilization.

MATERIALS AND METHODS

The same experimental procedure was followed during the second 4-year period, with the exception of the nitrogen fertilization of beets. Nitrogen was broadcast on one-half of the plots and incorporated into the soil before the beets were planted. The rate was calculated by determining the amount of soil nitrate-nitrogen in the 0- to 24-inch soil depth and by adding ammonium nitrate, if needed, to equal a total of 150 pounds nitrogen per acre. This rate was lowered to 125 pounds per acre both in 1973 and 1974 because the higher nitrogen rate tended to increase processing impurities in beets.

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[1] Numbers in parentheses refer to literature cited.

These rotations were studied:

1.	Sugarbeets	wheat	barley	black fallow
2.	Sugarbeets	wheat	barley	mixed legume fallow
3.	Sugarbeets	wheat	barley	alfalfa fallow
4.	Sugarbeets	potato	wheat	barley
5.	Sugarbeets	wheat	barley	soybeans
6.	Sugarbeets	wheat	barley	oats

The plots in Rotation 1 were kept black the 4th year. The legume in Rotation 2 was a mixture of alfalfa and sweet clover; it was plowed under in late June, and the land was fallowed the remainder of the year. The first crop of alfalfa in Rotation 3 was cut for hay about June 25; the stubble was immediately plowed, and the land was fallowed for the remainder of the year. Rotations 4, 5, and 6 were regular 4-year rotations with no fallow.

Cropping and fertilization plan

Recommended crop varieties and cultural practices were used. Each crop in each rotation was planted in the spring, except the alfalfa and sweet clover which were planted the previous year. Since the plots were 33 feet wide and 45 feet long, commercial-sized field machinery could be used for all operations.

The crop rotation sequence established in 1967 was continued in the second 4-year study. Fertilizer applications made in addition to the nitrogen treatments described earlier are summarized in table 1.

Table 1. Fertilizer application rates used in sugarbeet rotation studies, 1971-74

Sugarbeets: 250 lbs. 0-46-0 per acre broadcast previous fall
Wheat, barley, oats: 150 lbs. 30-15-0 drill applied
Soybeans (22-inch rows): 100 lbs. 30-15-0 row application
Potato (40-inch rows): 400 lbs. 20-15-20 row application

RESULTS AND DISCUSSIONS

Soil nitrate-nitrogen

Soil samples were taken late in the fall from plots that were scheduled for beets the coming year. They were analyzed for nitrate-nitrogen in the 0- to 24-inch depth. The 1970-73 average data are given in table 2. The black fallow and plowing under of a leguminous crop (mixed legume fallow) resulted in large accumulations of soil nitrate-nitrogen. Removing the first crop of alfalfa and immediately plowing under the stubble (alfalfa fallow) did not accumulate as much nitrate-nitrogen. Soil samples from the three nonfallow rotations were similar to each other; all were considerably lower in nitrate-nitrogen than were soil samples from fallow rotations.

Soil samples (0- to 24-inches) were taken again from the beet plots after the crop was removed and analyzed for nitrate-nitrogen. The 1971-74 averages (table 2) show that, at the end of the growing season, only small differences existed between rotations in the amount of nitrate-nitrogen remaining in the soil.

Table 2. Average pounds per acre of nitrate-nitrogen (No_3-N) in 0- to 24-inch soil depth in late fall before beets and the amount remaining after sugarbeet harvest the following fall

Rotation[1]	1970-73 Fall sampling before beets	1971-74 Fall sampling after beets
	NO_3-N (lbs/A)	
1. Black fallow	162	25
2. Mixed legume fallow	168	44
3. Alfalfa fallow	133	42
4. Barley	43	29
5. Soybeans	50	39
6. Oats	39	28

[1] Sugarbeets follow these crops.

Each year, an average of 1.62 tons per acre (dry matter) of plant material was added to the soil on Rotation 2. Each year on Rotation 3, an average of 1.65 tons per acre of alfalfa hay (having 14.5 percent moisture) was removed, and the stubble was plowed under.

Crop yields

Average yields for all crops for the 4-year period are shown in table 3. Average yields of hard red spring wheat (Era) varied from 46.9 bushels on Rotation 6 to 57.5 bushels on Rotation 4. The low yield on Rotation 6 may be due to soil-depleting cropping. Malting barley (Larker) yields were similar on all rotations and showed no consistent differences. Oat (Lodi) yields were considerably lower than those for the 1967-70 period. Potato (Norland) yields were normal and averaged 72 bushels per acre higher in 1971-74 than were the 1967-70 results. Soybean yields were good for this northern area.

Table 3. Average acre yields for all crops in sugarbeet rotation studies, 1971-74

	No N	Added N			
	T/A		Bushels/acre	Bushels/acre	Bushels/acre
	Beets		Wheat	Barley	Black fallow
1.	17.8	17.7	51.2	63.5	0
	Beets		Wheat	Barley	Legume fallow
2.	17.5	17.7	53.5	57.0	1.55 T/A
	Beets		Wheat	Barley	Alfalfa fallow
3.	17.6	17.9	55.3	64.0	1.74 T/A
	Beets		Potato	Wheat	Barley
4.	14.1	17.4	338 bu.	57.5	62.8
	Beets		Wheat	Barley	Soybeans
5.	14.5	17.2	50.1	60.1	29.3
	Beets		Wheat	Barley	Oats
6.	14.0	17.4	46.9	60.8	86.1

The health and vigor of the sugarbeets in this large field are obvious. Modern agricultural practices are required for a good stand like this.

Sugarbeet root yields

Table 4 shows the root yield, the percentage of sugar, and the recoverable sugar for the 4-year period. Since the rotations were replicated three times and the amounts of soil nitrate-nitrogen in the 0- and 24-inch depth varied betwen plots, variable amounts of nitrogen fertilizer were added to the beet plots. Approximately 85-100 pounds of ammonium nitrate were added to the nonfallow beet plots. From 20 to 30 pounds were added to the beet plots in the legume and alfalfa rotations when a poor stand of legumes occurred.

Root yields from three fallow-no nitrogen rotations were similar and averaged approximately 3.5 tons per acre higher than those from the nonfallow plots for the 4-year average. With the addition of nitrogen fertilizer, beet yields from the three nonfallow Rotations 4, 5, and 6, were comparable to those on the fallow rotations. Beets following alfalfa fallow with added nitrogen had the highest yields, and those following soybeans had the lowest.

Table 4. Average root yields, the percentage of sugar, and the recoverable sugar with and without added nitrogen, 1971-74

Rotation	Yield		Sugar		Recoverable sugar	
Beets following	No N	Added N	No N	Added N	No N	Added N
	. . . T/A . . .		. . . . . %		. . . lbs/A . . .	
1. Black fallow	17.8	17.6	15.84	15.83	5220	5158
2. Mix. leg. fallow	17.5	17.7	15.16	15.28	4816	4900
3. Alf. fallow	17.6	17.9	15.46	15.33	4977	5001
4. Barley	14.1	17.4	15.82	15.30	4168	4839
5. Soybeans	14.5	17.2	15.69	15.82	4240	5037
6. Oats	14.0	17.4	15.99	15.66	4204	5038
LSD 5%	2.2	NS	NS	NS	636	NS

In the 1967-70 trials, 100 pounds of 6-42-0 were drill-applied for beets, and no other nitrogen fertilizer was added. Beets following black fallow (1967-70) had the highest average yield of 18 tons per acre, while beets following oats averaged 16 tons per acre, a significant difference. There were no other significant yield differences in the first trials.

In the 1971-74 trials with no nitrogen added, the differences in root yields between the fallow and nonfallow plots ranged from 2 to 3.5 tons per acre lower than those from the same plots in the 1967-70 trial. This shows that, after 8 years of continuous cropping with no nitrogen added, soil fertility has declined. However if continuous black fallowing is practiced, it will tend to lower all crop yields.

Percentage of sugar

Sugar content in beets varies from year to year and may be affected by excessive nitrogen, cultural practices, and weather conditions. There were no significant differences in percentage of sugar between any of the rotations or nitrogen treatments. When averages are compared, beets following mixed legume fallow in Rotation 2 (no added nitrogen) had the lowest percentage of sugar, and those following oats and black fallow had the highest. With added nitrogen, percentage of sugar in beets following barley and oats rotations decreased about 0.25 percent in sugar. The nitrogen added to beet plots on the three fallow rotations had only a minor effect on percentage of sugar.

Over all rotations, the 1971-74 results averaged 1.2 to 1.5 percent higher sugar than did the 1969-70 trials. Beets from the three fallow rotations, with or without nitrogen, averaged 1.6 percent higher in sugar content than did the same rotations in the first trial.

Recoverable sugar

This is the total amount of sugar the factory can process from beets. The 1971-74 data are given in table 4. Beets following black fallow with or without nitrogen contained the highest amounts of recoverable sugar. They averaged approximately 1,000 pounds more than did beets from the nonfallow rotations when no additional nitrogen was applied. This difference was partly due to the higher yield of beets following black fallow. Plowing under the mixed legume on Rotation 2 seemed to increase impurities and resulted in a lower amount of recoverable sugar.

There was little difference between the three nonfallow rotations. The addition of nitrogen increased root yields, which resulted in more recoverable sugar from beets following the three nonfallow rotations. Beets following barley in Rotation 3 (with added nitrogen) had the lowest recoverable sugar. This soil depletion rotation, with two cultivated and two grain crops, may explain these results.

The 1971-74 recoverable sugar from beets on all rotations averaged 800 pounds more than those from the 1967-70 trials. The lower root yields and percentage of sugar during the first trial were the contributing factors in this difference. No significant differences occurred between the rotations during the 1971-74 trial when nitrogen was added.

Impurity index

Table 5 gives the impurity index and amino-nitrogen content of sugarbeet brie for 1971-74 with and without added nitrogen. Impurities were much higher in 1974 because of the short growing season, and these higher values increased the 1971-74 averages. Beets following the three fallow rotations had the highest values. Beets following the mixed legume fallow had the highest, and those following the soil-depleting oat rotation had the lowest impurity index. These indices for the 1967-70 trial were considerably higher than those for the 1971-74 trial.

Table 5. Impurity index and amino-nitrogen content of sugarbeet brie with and without added nitrogen, 1971-74

Rotation	Impurity Index*		Amino-Nitrogen	
Beets following	No N	Added N	No N	Added N
	ppm**			
1. Black fallow	521	517	333	327
2. Mixed legume fallow	615	634	411	435
3. Alfalfa fallow	562	595	382	432
4. Barley	463	605	272	373
5. Soybeans	466	504	263	234
6. Oats	410	498	212	299
LSD 5%	92	72	82	62

* Impurity Index $= \frac{3.5\ Na + 2.5\ K + 9.5\ amino\text{-}N}{Percent\ Sugar}$

By American Crystal Sugar Company.

** Parts per million.

Amino-nitrogen

Continuous fallowing hastens both the organic matter breakdown and the accumulation of nitrogenous material in the soil, which results in higher sugarbeet amino-nitrogen content. Continuous cropping without nitrogen lowers this nitrogenous material. Consequently, beets grown on the nonfallow rotations had the lowest amount of amino-nitrogen. Adding nitrogen fertilizer increased the amino-nitrogen content of beets (table 5) following the three nonfallow rotations compared to those of the fallow rotations. The amino-nitrogen values for the 1967-70 (3) and 1971-74 trials were similar.

Sodium and potassium

The average amount of sodium and potassium in the sugarbeet brie samples is given in table 6 for the 1971-74 trial. Beets after the fallow rotations (no nitrogen added) had a higher sodium content than those following the nonfallow rotations. The addition of nitrogen increased the sodium content of beets on the mixed legume and alfalfa fallow rotations. No differences existed in potassium results between rotations and nitrogen treatments.

Large-scale, modern equipment is used by most sugarbeet farmers in the Red River Valley to assure rapid harvest at the optimum time.

Table 6. Amount of sodium and potassium in sugarbeet brie with and without added nitrogen, 1971-74 averages

Rotation	Na		K	
Beets following	No N	Added N	No N	Added N
	ppm			
Black fallow	520	480	1319	1370
Mixed legume fallow	620	647	1335	1341
Alfalfa fallow	560	573	1267	1241
Barley	378	531	1370	1397
Soybeans	333	474	1411	1283
Oats	321	456	1338	1363
LSD 5%	138	110	NS	NS

In the 1967-70 trial (3), sodium and potassium values were higher than those in the 1971-74 trial.

Cost of production and spendable income

Farm custom rates for North Dakota and Minnesota (1, 2) were used to calculate costs of production and income following the same procedure used in the 1967-70 report. Costs and prices varied greatly during this 4-year period, but the data in table 7 average out these differences. Land rental increased from $20 to $30 and taxes increased $5 to $5.50 an acre during the 1971-74 period.

The net spendable income includes land rental; if the grower owns his land, it is not an "out-of-pocket" expense. If a grower rents land, this would be a direct cost. Sugarbeets "with added nitrogen" were used in table 7 because growing beets without proper nitrogen fertilization is not a recommended practice. By adding the average spendable income in each rotation, an average annual figure is obtained for the four crops. Since the last payment for the 1974 sugarbeet crop in this area is made approximately Sept. 30, 1975, an estimated sugar price of $45 per ton was used for the 1974 crop.

Table 7. Average net spendable income per acre for the six 4-year sugarbeet rotations with added nitrogen, 1971-74

					Total 4 crop/acre
1.	Beets	Wheat	Barley	Bl. fallow	
	$349	$132	$66	−$16	$531
2.	Beets	Wheat	Barley	Mix. leg. fallow	
	$344	$119	$54	−$21	$496
3.	Beets	Wheat	Barley	Alf. fallow	
	$338	$134	$65	$24	$561
4.	Beets	Potato	Wheat	Barley	
	$324	$361	$141	$66	$892
5.	Beets	Wheat	Barley	Soybeans	
	$327	$111	$61	$102	$601
6.	Beets	Wheat	Barley	Oats	
	$335	$110	$64	$37	$546

Fallowing land can store more soil moisture and available plant food, which may increase yields and income. During the past 4 years, the beet crop from the three fallow rotations averaged $15 per acre higher net income than those following the nonfallow rotations. However, considering the net income from all four crops, the nonfallow rotations produced the highest returns. Rotation 4—beets, potatoes, wheat, barley—had the highest net spendable income. Prices and potato yields were good for the 1971-74 period, and income was comparable to sugarbeets. Alfalfa hay at $45 per ton helped offset the cost of fallowing in Rotation 3. Without nitrogen fertilization, net spendable income from beets from the three nonfallow rotations would have been reduced approximately $57 per acre.

SUMMARY

The continued effect of six different 4-year rotations on root yield, percentage of sugar, quality, recoverable sugar, and monetary return of sugarbeets was studied over an 8-year period. The first 4-year study (1967-70) has been published (3). The three fallow rotations stored up large amounts of soil nitrate-nitrogen in the 0- to 24-inch depth, but after the beet crop removal, all six rotations had approximately the same amount left in the soil.

Beet root yields from land cropped each year with no added nitrogen were significantly lower than those grown on fallowed land. With adequate nitrogen fertilization, no significant differences occurred among six rotations over the 4-year period.

There were no significant differences in sugar content of beets from the six rotations with or without added nitrogen. However, with rates of 125 to 150 pounds per acre of total nitrogen, no detrimental nitrogen effects would be expected.

Sugarbeets following black and alfalfa fallow had significantly more recoverable sugar than those from the nonfallow and mixed legume rotations without nitrogen. No significant differences occurred when nitrogen was added.

Fallowing and plowing under leguminous crop materials increased impurities in sugarbeets more than did regular cropping. However, adding nitrogen fertilizer increased the impurities on the nonfallow rotations.

Amino-nitrogen content in beets was increased more by fallowing practices than by regular cropping. Adding nitrogen fertilizer also increased this parameter.

The sodium content of sugarbeets was significantly increased by fallowing land. Adding nitrogen fertilizer to the nonfallow plots also increased the sodium content.

The amount of potassium in sugarbeet brie was not significantly affected by any treatment. Both sodium and potassium values were considerably lower during 1971-74 than during the 1969-70 period.

Of the three fallow rotations, sugarbeets grown on mixed legume fallow had the lowest percentage of sugar, and the highest impurity index, amino-nitrogen, and sodium content, as well as the lowest recoverable sugar.

Results from both trials indicate that fallowing land does not increase net income from beets or total 4-year income. The 8-year trial has shown that proper fertilization, especially of nitrogen, is essential for profitable sugarbeet production in the Red River Valley.

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