Fertilizer Studies with Sugar Beets in South Central Montana[1]

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The average sugar beet yield in Yellowstone and Big Horn counties in Montana over a period of years has been about 12 to 13 tons per acre. In contrast, some of the better farmers have averaged nearly 20 tons per acre and yields of more than 30 tons per acre have been obtained. It is well known that high sugar beet yields are the result of a combination of many management factors. It was thought, however, that soil fertility may be one of the most important factors in determining sugar beet yields in these areas. Accordingly, this study was begun.

Table 1.—Fertilizer and Manure Treatments Used **in the 1950 and 1951 Experiments.**

	Treatment per acre			
No.	**Lbs.** N	**Lbs. P_2O_5**[1]	**Lbs. K_2O**	**Tons Manure**
i	0	0	0	0
2	80	0	0	**0**
3	0	80	0	**0**
4	80	80	0	**0**
5	40	80	0	0
6	160	80	0	**0**
7	80	160	80	0
8	80	80	0	0
9	80	80	0	15
10	0	80	0	15
11	0	0	0	**15**

[1] **In** 1950 treatments, 3, 4, 5, 6 and 8 received 160 pounds P2O5 and treatment 7 received) pounds P2O5.

This report is concerned with (1) the effect of nitrogen, phosphorus, potassium and manure upon the yield and sugar content of sugar beets, and (2) the relation of the response to the soil chemical properties.

Experimental Methods

Thirteen fertilizer and manure experiments were conducted cooperatively with farmers on the Huntley Reclamation Project and in the vicinity of Hardin, Montana, during 1950 and 1951.

The fertilizer and manure treatments are given in Table 1. The eight fertilizer treatments occurred at all thirteen locations, whereas the manure treatments were included at two locations. The treaments include tests for N, P, K, manure, along with N x P interaction, and manure x fertilizer interaction. Ammonium nitrate, double superphosphate (43 percent) and 60 percent muriate of potash were used as fertilizer sources. All of the P, K and 10 pounds per acre of N were banded 3 inches to the side and 3 to 4 inches below the surface or 3 to 4 inches directly below the seed at planting time in the eight 1950 experiments. The remaining N was side-

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Table 2.—Chemical Properties of the Soils from 13 Fertilizer Experiments.

Soil No.	Soil Type	Organic Matter %	Total N %	Nitrifiable N PPM	PH	Exchange-able K M.E/100g.	Exchange-able Na M.E/100g.	Exchange Capacity M.E/100g.	Equivalent Conductivity $KX10^{6}$	CO_2 Sol. P PPM
MO 1	Laurel clay loam	2.18	0.14	27.4	7.4	1.79	0.81	22.9	0.96	0.7
MO 2	Havre fine sandy loam	1.73	0.09	35.4	7.6	1.18	0.70	13.9	1.24	8.3
MO 3	Harlem silt loam	2.05	0.12	41.1	7.4	1.37	0.56	23.0	1.08	5.2
MO 4	Laurel clay loam	2.16	0.13	37.7	7.5	1.04	0.54	28.3	1.78	16.6
MO 5	Manvel silty clay loam	1.79	0.12	32.2	7.6	1.45	1.63	31.7	1.38	1.0
MO 6	Billings silty clay	2.36	0.16	35.2	7.6	1.66	2.33	33.2	2.41	0.8
MO 7	Manvel clay loam	1.60	0.12	31.6	7.7	1.03	1.61	23.6	1.72	1.8
MO 8	Manvel clay loam	1.61	0.11	30.6	7.7	0.82	0.90	21.0	1.28	1.2
MO 9	Havre fine sandy loam	1.92	0.10	30.3	7.8	1.33	0.21	14.3	0.80	7.5
MO10	Laurel clay loam	2.10	0.10	41.2	7.8	1.12	1.56	28.1	0.80	0.5
MO11	Havre fine sandy loam	1.79	0.10	46.4	7.7	0.91	1.62	20.4	3.09	0.5
MO12	Billings clay	2.66	0.16	49.6	7.7	1.55	1.33	30.2	1.40	0.4
MO13	Manvel silty clay loam	1.78	0.11	40.4	7.8	1.53	0.98	20.5	1.01	2.4

Table 3.—Effect of Nitrogen, Phosphorus and Potassium on the Yield of Sugar Beets in 13 Experiments in South Central Montana during 1950 and 1951.

Fertilizer Treatment	1950 Experiments								1951 Experiments				
	MO1	MO2	MO3	MO4	MO5	MO6	MO7	MO8	MO9	MO10	MO11	MO12	MO13
1	10.0	14.6	14.4	11.0	17.5	16.6	14.6	13.1	19.6	12.6	14.5	13.2	11.9
2	10.0	16.5	16.9	14.1	18.1	17.4	16.5	13.8	21.4	16.4	15.0	16.1	13.5
3	15.1	14.7	14.3	12.2	16.2	17.4	14.9	13.1	19.6	14.5	15.6	13.0	10.7
4	14.7	15.6	16.7	15.3	19.2	18.0	16.8	14.3	22.3	17.8	16.5	15.1	13.9
5	16.4	15.9	16.2	13.5	20.6	18.0	16.6	14.3	22.4	15.6	16.7	15.7	13.6
6	15.8	16.0	17.7	14.8	18.3	17.2	17.1	14.2	22.5	16.9	15.8	17.6	14.0
7	15.4	17.7	17.1	14.5	18.2	17.6	16.5	14.1	22.2	17.2	17.6	15.6	13.2
8	15.8	18.1	17.0	14.8	19.8	18.7	16.9	14.3	22.2	17.1	17.9	16.2	14.4
LSD (.05)	2.1	1.3	2.1	1.7	2.1	1.2	1.5	0.8	2.2	2.0	2.2	2.4	1.3
LSD (.01)	2.8	1.8	....	2.3	2.8	....	....	1.0	....	2.8	3.0	3.3	1.8

dressed about June 15. All the fertilizer was applied 3 inches to the side and 3 to 4 inches below the surface at planting time in the 1951 experiments. Manure was broadcast in the spring prior to plowing. All plots were four rows wide and either 50 or 60 feet long with the two center rows harvested for yield. Either four or five replications were used. Subsamples taken from measured distances in the yield rows were used for sugar analysis to avoid bias in selection.

Gypsum resistance blocks were used as guides in timeliness of irrigation. Plant populations were good and were never below 76 percent. Eight experiments had row widths of 22 inches; two, 26 inches, and one, 24 inches.

Statistical analysis of the combined experiments was conducted generally according to Cockran and Cox (1)[3]. The problem of analyzing combined experiments has been recently discussed by Salmon (3). Attempts were made to group the data as much as possible into homogeneous treatment effects. For example, in the thirteen experiments only one produced a phosphorus yield response, whereas the other twelve gave significant or near significant nitrogen yield increases. They were thus grouped accordingly and an F test showed the groups were not homogeneous and should not be combined. A K x location interaction was calculated and found not significant. In most cases an unweighted pooled error from all experiments was used for F tests and least significant difference calculations. However, where appropriate, a treatment x location interaction was used.

Soil samples were obtained from the 0-7 inch depth from each location. Organic matter, total N, exchange capacity, exchangeable Na, exchangeable K and conductivity were determined by standard methods. Nitrifiable N as determined here is the amount of nitrates produced when the soils were incubated at 30 percent moisture at 25° C. for three weeks. CO, soluble phosphorus is that amount soluble when a constant stream of CO_2 was bubbled through 10 grams of soil in 50 ml. of water for 30 minutes.

Percent sugar in the sugar beet roots was determined by a standard method/

Description of Experiment Sites

The soils in the area studied were developed from stratified sandy, silty and clayey alluvium on the lower stream terraces and fan terraces adjacent to the Yellowstone and Big Horn rivers. In general, the soils do not have well defined genetic horizons.

Past cropping practices were dominated by small grain and sugar beets with only two fields having grown alfalfa within the last 6 years.

The soil types at the experiment sites and chemical properties of the soils are presented in Table 2. Exchangeable Na and conductivity measurements indicate that neither Na nor soluble salts are seriously limiting sugar beet growth on the soils. Soil pH's varied from 7.4 to 7.8 and all soils were slightly calcareous as evidenced by effervescence with acid. Organic matter and total N range from 2.18 to 1.60 and 0.16 to 0.09 percent, respectively.

[3] Numbers in parentheses refer to literature cited.
[4] Sugar and tare determinations were made by the Holly Sugar Corporation and the Great Western Sugar Company.

Results and Discussion

The effects of N, P, K, manure fertilization and their interactions are discussed individually below. Results for the individual experiments are given in Table 3. Results for the manure experiments are presented in Table 4. The mean effects of N, P, K, and manure on yields of sugar beet roots and the effects of N on sugar percentage and total sugar are presented in Table 5.

Nitrogen

The mean yield increase for 40, 80 and 160 pounds of N per acre was 1.95, 2.10 and 2.09 tons per acre, respectively. Twelve experiments were included in this mean. The maximum and minimum yield increase on the individual experiments was 4.4 and 0.6 tons per acre, respectively. Eighty pounds of nitrogen produced more sugar beet roots than did 40 on only two of the experiments. In a few cases 160 pounds of N out-yielded 40 pounds but in no case produced more than 80 pounds of applied N.

Table 4.—Effect of Fertilizer and Manure on the Yield of Sugar Beets in 2 Experiments in South Central Montana during 1951.

Treatment per acre				
N lbs.	P_2O_5 lbs.	Manure Tons	MO9	MO13
0	0	0	19.6	11.9
0	80	0	19.6	10.7
80	80	0	22.3	13.9
0	0	15	20.2	12.5
0	80	15	20.6	11.8
80	80	15	22.8	14.6
	LSD (.05)		2.2	1.3
	LSD (.01)		....	1.8

Applied N fertilizer reduced the percent sugar on all 13 individual experiments and the mean of the combined experiments. Forty, 80 and 160 pounds of N reduced the mean sugar percent by 0.17, 0.52 and **1.19,** respectively. Each successive larger rate produced highly significant mean reductions. The percent sugar for the individual experiments is not given because of the uniform treatment x location effects and because of lack of space.

The mean total sugar increase per acre was 616, 563 and 335 pounds per acre for 40, 80 and 160 pounds of applied N, respectively. Rates of 80 or 160 pounds of N per acre produced significantly more total sugar than did 40 pounds on three of the individual experiments, reduced total sugar on six of the experiments and had no effect on sugar production on three experiments.

On the basis of these experiments, it appears that 40 pounds of N will give a profitable yield increase on most fields in the area. Eighty pounds will probably be profitable on some fields. It is doubtful whether 160 pounds will be a desirable rate on any field in the area with normal past cropping practices.

The efficiency of the N is illustrated by calculating the pounds of sugar produced per pound of N applied. The mean values for 40, 80 and **160** pounds of applied N from 12 locations are 15.4, 7.0 and 2.0 pounds per acre. The maximum amount of sugar produced per pound of N applied on any one experiment was 32.0.

It was thought that the reduction in percent sugar on the 1950 experiments was accentuated by late application of N. In addition, a period followed when the soil was too dry for effective N uptake. Therefore, in 1951 all nitrogen was applied at planting time. Because of differences in location, no definite conclusions can be drawn. However, reductions in sugar percent due to N were almost identical in 1951 and in 1950.

Neither total N, organic matter nor nitrifiable N gave significant correlations with yield response to N fertilizer.

Preliminary data has indicated that the poor physical condition of the soil together with excessive amounts of irrigation water has resulted in poor

Table 5.—The Mean Effect of Nitrogen on Yield, Sugar Percent and Total Sugar and the Effect of Phosphorus, Potassium and Manure on Yield of Sugar Beets in 13 Experiments during 1950 and 1951.

Item Tested	Total No. of Loc. Tested	No. of Loc. Grouped for Comparison	Check[1]	Difference from Check Due to Treatment Indicated per acre			Least Significant Difference 5%	1%
				Nitrogen (N) Lbs.				
				40	80	160		
Yield, T/A.	13	12	14.67	1.95	2.10	2.09	0.82	1.08
Sugar, %	13	13	17.03	—0.17	—0.52	—1.19	0.14	0.18
Sugar, lbs/A	13	12	5,005	616	563	335	222	294
				Phosphorus (P_2O_5) Lbs.				
					80	160		
Yield, T/A.	13	1	10.04	.....	5.40	4.66	1.71	2.25
				Potassium (K_2O) Lbs.				
					80			
Yield, T/A.	3	3	15.49	......	0.76	....	0.90	0.68
				Manure Tons				
					15			
Yield, T/A.	13	13	16.63	......	0.57	....	0.52	......

[1] Plots having nitrogen variables received a basic application of 80 or 160 pounds P_2O_5 per acre. Phosphorus variables received a Basic Application of 80 pounds N per acre. Potassium variables received 80 pounds N and 80 or 160 pounds P_2O_5 per acre. The value for manure is calculated from plots which received manure alone, manure and phosphorus, and manure, nitrogen and phosphorus with appropriate comparisons.

soil aeration on many fields. This factor may be important in limiting microbial action and in N mineralizing. If so, differential aeration would explain the poor relation between N yield response and nitrifiable N. These results are in general agreement with Nelson et al (2) although the yield increases reported here are somewhat larger and the reduction *in* percent sugar is greater.

Phosphorus

Phosphorus applications produced more roots and total sugar on only one of the thirteen experiments. Eighty and 160 pounds were equally effective and P had no effect on sugar percent.

Past management records revealed that P had been applied to the experimental sites approximately 50 percent of the time during the previous four seasons. The residual effect of this applied P probably accounts for the lack of P response on many of the fields.

The response data for P is too limited for correlation with CO_2 soluble phosphorus.

Potassium

Potassium produced a yield increase of more than 0.5 ton on six of the 13 fields although only one field showed significance. When combined the mean yield increase was 0.57 tons per acre for the 13 fields. Percent sugar was not affected.

Potassium has not previously been recognized as deficient in the area studied. Exchangeable K values of the soil from the experiments ranged from 0.82 to 1.79 M.e. per 100 grams of soil or from 640 to 1,396 pounds per acre six inches. There was no relation between exchangeable K and K response in the field. The amounts of exchangeable K are much in excess of those recognized as critically low in other areas. Several factors are unfavorable for optimum K uptake and were thought to have been present in the experiments. These include a crop with a large K requirement, free Ca CO_3 in the soil, poor soil aeration and a large amount of nitrates in the soil.

Manure

Manure produced no significant yield increases on the two individual experiments. A mean increase of 0.76 tons per acre for the two experiments approaches significance at the 5 percent level.

Interactions

There was no N x P interaction on any single experiment or to the mean of all experiments. This is probably because the deficiency of one element was at no time serious enough to limit the efficiency of the other.

No interaction was present between manure and P or N plus P. This indicates that on the fields studied much of the manures' effectiveness in increasing yields can be attributed to a more favorable soil physical condition.

Summary

Thirteen sugar beet fertilizer studies were conducted on the Huntley Reclamation Project and in the vicinity of Hardin in south central Montana during the growing seasons of 1950 and 1951. An attempt was made to keep other soil and crop management factors near optimum. The results can be summarized thus:

1. Nitrogen fertilizer increased the yield of sugar beet roots on 12 of the 13 locations, decreased the sugar percentage on all locations and increased the total sugar production on 10 locations. The mean yield increase for 40, 80 and 160 pounds of N per acre was 1.95, 2.10 and 2.09 tons per acres, respectively. Sugar percentage was decreased by 0.16, 0.52 and 1.19 by 40, 80 and 160 pounds of nitrogen, respectively. Forty, 80 and 160 pounds

of N increased total sugar production by 616, 563 and 335 pounds per acre, respectively.

2. Eighty and 160 pounds of P_2O_5 were equally effective in increasing yields on one of the thirteen locations, whereas the remaining 12 were not found deficient. Phosphorus had no effect on sugar percentage.

3. A nitrogen phosphorus interaction was not evident on any location.

4. Potassium produced a significant yield increase on one individual experiment. The mean yield increase for all experiments was 0.57 tons per acre and was significant.

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