The Responses of Sugar Beets to Fertilizers, Spacing, and Irrigation on Eastern Oregon Soils

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An intensive program of soil fertility research was initiated in 1950 on the irrigated soils of Malheur County, Oregon. The objectives of this program are to determine (A) the fertility status of the soils and the fertilizer and soil moisture needs of the crops in that area, and (B) the correlation between the field responses to fertilizer applications and laboratory soil test data. Some 35 field plot experiments have been carried out under this program during the 1950-51 seasons. Of these, 15 were with sugar beets.

Experimental Materials and Methods

All sugar beet experiments were carried out on the fields of cooperating farmers, who prepared seedbeds, planted; cultivated and irrigated (except one experiment, where irrigation was a variable) the beets according to their own schedules. Application of fertilizers, thinning and harvesting of beets were performed under direction of the authors. Fertilizers, plot stakes, thinning and harvesting labor, a portable rasp and other sampling equipment were supplied by the Amalgamated Sugar Company³; the Company also made sugar analyses on samples from all plots.

A belt-type, tractor-mounted fertilizer distributor with double-disk fur-row openers $(3)^4$ was employed to band-place fertilizers two to four inches from the row and one and one-half to three inches deep. Fertilizers were applied soon after planting, usually within two to four days. With one exception, fields were not irrigated until thinning time.

Ten experiments on sugar beets (48 plots each on six farms, 96 plots each on three farms, 198 plots on one farm) were conducted in 1950, five (48 plots on each of three farms, 56 plots on one farm, 90 plots on one farm) in 1951. Sites were widely scattered over the beet-growing area of the county. Plots were 30 feet long and six, or eight, rows wide. Row spacings were 16-24 (two farms), 18-24 (one farm), 20 (three farms), 20-22 (two farms), 21 (two farms), and 22 inches (five farms). At 13 sites the following fertilizer treatments (N-P205-K20 per acre, from ammonium sulfate, treble superphosphate, and muriate of potash) were replicated four times in randomized blocks.

(1)	0-0-0	(4)	150-0-0	(7)	0-80-0	(10)	150-80-0
(2)	50-0-0	(5)	$200-0-0^5$	(8)	50-80-0	(11)	200-80-0
(3)	100-0-0	(6)	0-40-0	(9)	100-80-0	(12)	100-80-80
						(13)	100-80-160

These treatments represent 4 N (or 5 N) x 2 P₂0₅ factorial combinations, with additional treatments. Two rates of stand were factorially combined with the above in three experiments.

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At one site in 1950 the above treatments 4, 5, 6, and 13 were omitted; to the nine remaining, two treatments, 50-40-0 and 20 tons manure, were added. Three irrigation treatments were factorially combined (six replications) with the 11 fertility treatments. To study the effects of N level and irrigation treatment on uptake of P₂0₅, radiophosphorus was applied in treatments 7 and 9. The effects of time and method of application of factorial combinations (three replications) of 0, 50, and 100 pounds of N and 0 and 100 pounds of P_5O_2 per acre were studied at one site in 1951.

At harvest the beets from the four center rows from each plot were lifted, topped, counted and weighed. A tare sample of 10 beets was randomly selected from each plot. Pulp from these 10 beets was then raspsampled for sugar analysis; these samples were frozen to prevent deterioration. The data from each site were subjected to analysis of variance. The significance of N and P_2O_5 effects was determined for the factorial portions of each experiment.

		Effects of N on	
No. Farms	Field T./A.	Percent Sugar	Sugar, Lbs./A.
1		Sig. ^p	Sig.
4	Sig.	N.S.	Sig-
1	Sig.	Sig.	N.S.
3	N.S.	Sig.	N.S.
1	N.S.	Sig.	Sig.
2	N.5.	N.8.	N.S.

Table 1.—Significance of	Effects of	N on	Sugar	Berts.
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¹ Sig. = significant at P == 0.05. N.S. == not significant. ² Increase on one farm. ³ Decrease.

In 1950 composite samples of the soil from each replication of each experimental site were obtained from the 0-6, 6-12, and 12-24-inch depths; in 1951 the depths were changed to 0-8, 8-16, and 16-24 inches. Samples were analyzed for pH, organic matter, total N, nitrifiable-N (2), exchange capacity, exchangeable Na and K, (1), water soluble (4) and CO_2 -soluble (5) PO_4 , and conductivity of saturation extract.

Results and Discussion

Effects of Fertilizers

Statistically significant (P = 0.05) effects of N were observed on a total of 12 farms. Significant effects of P_2O_5 were produced on only one farm. No significant effects of K₂0 were found.

A summary of the significance of the effects of N is presented in Table Yield of beets, percent sugar and yield of sugar were each affected significantly by N on nine farms.

Increases in yield of beets and sugar (decrease in sugar yield in one case) and decreases in percent sugar (increase in one case) were associated with significant effects of N. On eight of the nine farms where N significantly increased the yield of beets the yield of sugar was also significantly increased, even though on four of these farms the percentage of sugar was significantly lowered. On one farm the yield of beets was increased, but

sugar content was reduced, with the result that the yield of sugar was unaffected. On one farm the yield was not affected significantly but the percentage of sugar was lowered sufficiently to result in a significant decrease in sugar yield. On three farms the yield of beets and sugar were not affected by N, although the percentage of sugar was lowered. On three farms N had no significant effects.

In Table 2 are set forth summaries of the average effects of N, P_2O_5 and K_{20} on yield of beets, percent sugar, and yield of sugar. Data on effects of N are presented separately for the two years because of large differences in average yield.

The yield of beets was increased by N on six farms in 1950 and three farms in 1951. In 1950 the average increases from 50, 100, 150 and 200 pounds of N were 2.4, 4.1, 5.3 and 5.8 tons, respectively. (The last value is an average from only five farms and hence not strictly comparable with the first four values.) In 1951, on three farms, average increases of 2.4 and 4.7 tons, respectively, were obtained with 50 and 100 pounds of N. Five rates of N were employed on only two of the three farms; the average increase on these two farms was 2.1, 4.4, 5.3 and 5.0 tons for 50, 100, 150 and 200 pounds of N, respectively. Effects of N on yield of beets were not significant on four farms in 1950 and two farms in 1951. In both years the group of farms not giving significant response averaged considerably higher in yield than the responsive group.

The sugar content decreased with increasing N on five farms in 1950 and three farms in 1951; on one farm in 1950 percent sugar was significantly increased by N. The decrease from 100 pounds of N per acre ranged between 0.2 and 1.1 percent and averaged 0.3 percent in 1950 and 0.4 percent in 1951. The application of 200 pounds of N lowered the sugar content by about 1.1 percent each year, in comparison with no N. Effects of N on percent sugar were not significant on four farms in 1950 and two farms in 1951.

On six farms in 1950 and two farms in 1951 the yield of sugar was significantly increased by N; on one farm in 1950 the sugar yield was significantly lowered. (On this farm, although effects of N on yield were not significant, yield of beets tended to decrease with increasing N. Percent sugar was decreased by N). As an average of the seven farms in 1950 and two farms in 1951 on which N produced significant effects the yield of sugar increased substantially with N, up to 100 pounds of N per acre. On no farm, however, did 150 or 200 pounds of N significantly increase the yield of sugar over that obtained with 100 pounds of N. On three farms in each year the yield of sugar was not affected by N.

A significant increase in yield of beets and sugar was produced by P_2O_5 on only one farm in 1950. The yield was increased from 13.3 to 19.6 tons per acre by 80 pounds of P_2O_5 . (On this farm the phosphated plots had significantly greater number of beets per plot than the non-phosphated plots, averaging 14.2 inches apart in the row, against 17.7 inches, owing to the fact that the more vigorous beets on the phosphated plots were better able, when small, to withstand attacks of wireworms which killed or damaged numerous plants on the non-phosphated plots. On this field, therefore, the effects of P_2O_5 were partially secondary in nature). On 14 farms P_2O_5 had no significant effects. Applications of 0, 80 and 160 pounds of K_20 per acre were made in 1950 on 10 farms; 0 and 80 pounds were applied on four farms in 1951. In each case the application was made with 100 pounds of N and 80 pounds of P_20_5 . In no case was a significant response observed.

Fertilizer Treatment	Yjeid, '	Tans/A.	Percent	Sugar	Lbs. 8	ugar/A.
	<u> </u>	Effects of Averages for N	N on 10 farm	s in 1950 1 lbs, P2O5/A.	ι ι	
N. Lbs./A.	6 Farms Sig.	4 Farms N.S.	fi Farmø Sig.	4 Farms N.S.	6 Farms Sig.	4 Farm N.S.
0	16.7	23.3	16.1	15.5	5.610	7,150
50	19.1	24.3	15.9	15.5	6,210	7,670
100	20.8	24.3	15.8	15.5	6.610	7.580
1501	22.0	24.1	15.1	15.2	6,720	7,290
200	22.5	23.5	15.1	14.9	0,870	6,910
		Effects of Averages for N	i N on 5 farms with 0 and 80	in 1951 11bs- PrOa/A.		
N,	9 Farana ²	2 Farms	S Farms	2 Farms	2 Farms	S Farm
Lhs./A.	\$ig.	N.5.	Sig.	N.5.	Sig.	N.S.
•	24.3	28.1	17.0	17.8	8,590	8,330
50	26.7	26.1	16.8	17.1	9.010	9,200
100	29.0	29.6	16.6	17.1	10,020	9,700
150	33.6×	30.6	16.2	16.5	12.720	9.710
200	33.5	29.9	15.9	16.9	12,110	9,500
	Averag	Effects of P es for P2Os wit	2O: on 15 farm h 0, 50, 100, 15	n», 1950-51 0, and 200 lb	8. N/A.	
P2O3 Lbs./A.	l Farm Sig.	14 Farms N.S.		15 Farins N.S.	l Farm Sig.	14 Farmı N.5.
0	18.3	24.0	· · · · · · · · · · · · · · · · · · ·	16.0	4.520	7,560
BO	19.6	24.2		16.0	6,820	7,690
		Effects of K	20 on 14 farm	s", 1950-51	·	
N-P2O3-KxO, Lbs./A.	10 Farms 1950	4 Farms 1951	10 Farms 1950	4 Farms 1951	10 Farms 1950	4 Farms 1951
100-80-0	22.4	51.5	15.5	16.5	6,920	10,510
100-80-80	22.5	31.0	15.5	16.7	6,910	10,260
100-80-80	22.1		15.6		6,890	
³ 150 pm sponses to N pounds PeOs, not strictly of ² One fai 100 pounds 7 28.3, 30.4 and 8 On one	in 1950. C For these is mparable, rm received V respectively 1 32.7 tons; a farm an Kat	ere applied on these same i reasons, average N only at the i v for the two fa verages for perce verages for perce	only five of th five farms 200 is for the three 0., 50-, 100-pon rms where 150 cost sugar were	e six farms g pounds N w lower and 0 und rates, T and 200 pou 17.2, 17.0 an	riving significa ere applied on wo higher rat he averages fo inds N were a d 16.8.	nt yield re- nly with 80 es of N are r 0, 30 and pplied were

Table 2.-Summary of Effects of Fertilizers on Sugar Beets.

Effects of Spacing

Spacing within the row was a variable, in factorial combination with 12 fertilizer treatments, on three farms in 1950. Distances between rows were 16-24, 21 and 22 inches. Care was taken to initially thin the beets to spacings averaging 12 and 15 inches apart in the row. At harvest time the spacings on the three farms averaged 12.3 and 15.8, 12.6 and 15.7, and

13.6 and 16.2 inches, respectively, for the two rates of stand. Average yields for 48 plots of each of the two spacings were, respectively, for the three farms, 26.3 and 26.7, 23.8 and 22.4, and 19.5 and 18.3 tons of beets per acre. On the latter farm the difference was statistically significant, and 13.6-inch spacings outyielded the 16.2-inch spacings by one and two-tents tons per acre. On two out of three farms the wider spacing produced a significantly lower yield of sugar than the closer spacing. Effects on percent sugar were not significant.

Effects of Irrigation

Irrigation was a variable in one experiment. Three irrigation treatments were factorially combined with 11 fertility treatments. In these irrigation treatments the soil was irrigated thoroughout the season (beginning with a uniform irrigation on April 21, for germination, and on May 28, following thinning) when (M₁) the soil moisture tension of the 100-80-0 plots reached 750 cms. at the eight-inch depth, as indicated by tensiometers (10 irrigations), (M₂) the resistance of Bouyoucos and Mick gypsum blocks at the eight-inch depth of the 100-80-0 plots reached 100,000 ohms (five irrigations), and (M₃) as in M₁ until August 12, then irrigated no more (seven irrigations).

		Irrigatio	n Treatment	
	Mı	Ma	Ma	L.S.D. (0.05)
Yield, tons/A.	18.6	20.1	16.9	0.80
Percent sugar	17.2	16.4	17.9	0.15
Sugar, Ibs./A.	6.500	6.600	6.060	275
Spacing in row, ins.	15.5	14.7	15.4	0.35
Wt./beet, lbs.	2.05	2.07	1.82	

Table 3 .--- Effects of Irrigation Treatments on Sugar Beets'.

² Each value is the average for 6 replications of 11 fertilizer treatments, or 66 plots.

The effects of irrigation treatment are summarized in Table 3. In the M_1 treatment the plots were irrigated on June 21, July 5, 14 and 24; August 1, 12 and 21, and September 1 and 16. Irrigations of the M_2 plots occurred on June 21, July 24, August 16 and September 23. The greatest yield of beets was produced by the M_2 treatment. Plots of this treatment also had more beets at harvest time than the M1 and M3 plots, although original spacing was uniform (approximately 12 inches).

The beets in this experiment were attacked by wireworms very shortly after emergence. The higher moisture levels maintained in treatments M_1 and M_3 evidently favored destruction of the beets by wireworms and pathogenic organisms to a greater degree than the lower moisture levels of the M_2 plots. The average weight of beets in M_1 and M_2 plots was almost identical, indicating that differences in numbers of beets per plot were responsible for differences in yield. The M_1 and M_3 plots had similar spacing, but the yield of beets and sugar from the M_3 plots were significantly lower than those of the other treatments, although the sugar percentage was higher.

Effects of N Levels and Irrigation Treatment on Uptake of P205

To study the effects of variation in N and soil moisture levels on uptake of P_2O_5 , in the above described irrigation experiment radiophosphorus was

applied at seeding at the rate of 80 pounds P_2O_5 per acre in factorial combination with 0 and 100 pounds of N and the three irrigation treatments. At four sampling dates the P_2O_5 derived from the fertilizer was determined as a percentage of the total P_2O_5 contained in the plants. Soil moisture was not a variable until after the first two samplings.

On May 30, at thinning, approximately 75 per cent of the P_2O_5 in the plants was derived from fertilizer; effects of N were not significant. Significant effects of N were observed on June 18 and August 1; beets from the 0 and 100 pounds N plots, respectively, had derived from the fertilizer 78.5 and 68.3 percent, and 49.9 and 38.7 percent, of their P_2O_5 content from the fertilizer at the two dates. By September 19, N effects were not significant. Irrigation treatment effects were significant on September 19, at final sampling. The beets of the M₁, M₂ and M₃ plots, respectively, had obtained 32.6, 37.4 and 35.8 percent.

Without fertilizer the average yield of beets in this experiment was 12.5 tons of roots per acre. The yield was increased to 17.7 tons by 80 pounds of P_2O_5 . The 17.7 tons of roots arid accompanying tops contained 27.7 pounds of P_2O_5 . Of this amount 17.4 pounds were derived from that P_2O_5 initially in the soil. From the 80 pounds applied as fertilizer only 10.3 pounds, or 12.9 percent, were absorbed by the plants.

Effect of Time and Method of Fertilizer Applications

The effects of differences in time and method of application of factorial combinations of 0, 50, and 100 pounds of N and 0 and 100 pounds of P_{2O_5} per acre were investigated on one farm in 1951. Times and methods were as follows: (1) all fertilizer broadcast on the surface and disked in (March 23) before planting beets, (2) all fertilizers banded beside the row at planting, (March 30), (3) all the P_{2O_5} and half the N broadcast and disked in before planting, half the N banded July 9, (4) all the P_{2O_5} and half the N banded July 9, and (5) all fertilizers banded beside the rows at planting, half the N banded July 9, and ginning May 20, a total of 16 irrigations was given during the season.

Significant increases in yield of beets and sugar were produced by N. Effects of P_2O_5 and time and method of application were not significant. Average yields for 0, 50, and 100 pounds of N per acre, with both levels of P_2O_5 , were, respectively, 16.3, 19.1 and 21.6 tons per acre. The least significant difference was 1.03 tons. Average yields for the five times and methods of application were (1) 18.8, (2) 19.9, (3) 19.1, (4) 18.3, and (5) 19.1 tons per acre. Apparently the soil was able to supply sufficient N for the needs of the plants until thinning time, seven weeks after planting. Owing to this, and the fact that phosphate was not required, differences in time and method of application were without significant effect on this soil.

Laboratory Soil Tests and Fertilizer Responses

The general response to N and lack of response to P_2O_5 and K_2O in these experiments emphasizes the need for a laboratory test from the results of which the need for N may be predicted at the beginning of the cropping season.

Soil samples were taken from each replication, or block, of each experiment before application of any fertilizers. Sampling depths were 0-6, 6-12 and 12-24 inches in 1950 and 0-8, 8-16 and 16-24 inches in 1951. Each sample for the first two depths was composited from six random borings; three borings were composited for the 12-24 and 16-24 inch samples. Samples were analyzed for total N (Kjeldahl), nitrifiable-N (2) C0₂-soluble (5) and H₂Osoluble (4) P0₄, exchangeable K, organic matter, pH, exchange capacity and exchangeable Na.

Yield responses were not related to total N, organic matter, pH, exchange capacity, or exchangeable Na. Total N ranged from 0.04 to 0.2 percent, with most surface samples in the range 0.08 to 0.14 percent. The range in organic matter was 1.1 and 4.1 percent in the surface and 0.4 to 2.8 percent in the lower depths. Soil reactions were all within the favorable range from pH 6.8 to 8.2. Exchange capacities ranged from 16 to 48 m. e. per 100 g.; most samples had exchange capacities of around 25 m. e. per 100 g. Exchangeable Na ranged from 0.7 to 1.7 m. e. per 100 g. in the surface six inches of soil.

Treatment.	Table 4.—Yield of	Bcets	from	0 and	100 L	bs. N	and	ppm	Nittifiable—	N in	Soil	Before
	Treatment.											

		9 Fai	arms, Sig.						6 Farms, N.S.					
	Yield	T./A.	Ni	trifat	de N,	р рп).	J	Yield	T./A.	Nitrifiable N, ppm.				
	Lbs.	N/A.		D	cpth			Lbs.	N/A.		Ð	cpth		
Farm	0	160	0-6"	6-12"	12-247	Mean	Farm	0	100	0-6"	6-12"	12-24"	Mean	
- 1	17.2	21.9	39	30	13	24	7	21.5	23.5	43	38	22	31	
2	22.1	26.1	51	34	25	53	18	25.1	\$1.0	68	51	33	46	
3	7.9	12.9	33	22	7	17	9	21.5	19.9	į 40	26	22	27	
4	22.2	27.0	23	20	13	17	10	25.1	22.8	i 94	98	32	64	
5	16.1	19.3	45	26	10	23				5				
6	15.0	17.4	48	20	7	20 {								
			0.8"	8-16"	16-24	,	·	1		0.8	8-16"	36-247		
11	16.3	21.6	48	20	9	25	14	26.6	30.B	54	37	22	36	
12	31.8	36.8	41	40	34	58	15	29.6	28.5	60	17	8	28	
15	24.9	28.6	44	26	19	50	5							
Mean	19.3	29.5	41	28	161	25		24.9	26.1	59	18	251	39	

1951 values corrected to 0-6, 6-12, 12-24-inch depths.

In Table 4 are presented the data for nitrifiable-N found in the soils after three weeks' incubation at 35° C. Soils are grouped on the basis of yield response to N. Each datum is the average of four samples. In general, there was less nitrifiable-N in each depth of the nine farms giving significant yield response to N than in the same depths of the six farms on which there was no response to N fertilizers. The mean values for the 0-6, 6-12 and 12-24 inch depths of the two groups of farms were, respectively, 41, 28 and 16 ppm. and 59, 48, and 25 ppm. The responsive soils averaged 25 ppm. N for the 24 inches, while the non-responsive group averaged 39 ppm. The most consistent differences between the two groups of soils appear to be in the 12-24 and 16-24 inch depths. Two farms in the responsive group gave N value similar to those of the non-responsive group. The organic matter content of the soil of Farm 2 was 4.1, 3.5 and 2.8 percent for the three depths, which values were twice as high as those for the other soils. Farm 12 produced an exceptionally high yield of beets, 31.8 tons per acre, without N, and five tons additional with 100 pounds of N. The nitrifiable-N in the soil from this farm was fairly high. It would appear that good cultural practices or other factors may account for the response to additional N on this soil.

Soils were tested for both water-soluble (4) and CO_2 -soluble PO_4 (5). A beet yield response to P_2O_5 obtained on only one farm. By both methods of testing the soil of that farm was distinctly lower in PO_4 than the soil of other farms, the values being 0.2-0.3 ppm. water-soluble, and 1-3 ppm. CO_2 -soluble PO_4 . None of the 14 soils unresponsive to P_2O_3 -tested below 0.5 ppm. water-soluble, or 5 ppm. CO_2 -soluble PO_4 in the surface six, or eight, inch depth. Two of the non-responsive soils tested 0.2-0.3 ppm. watersoluble PO_4 in the 6-12-inch depth and 2-3 ppm. CO_2 -soluble PO_4 fell between five and 20 ppm. at the three depths; values for CO_2 -soluble PO_4 fell between for the most part, in the range 0.5 to 3 ppm. These data indicate that responses of sugar beets to P_2O_5 would probably not occur on soils similar to these if more than 0.5 ppm. water-soluble or 5 ppm. CO_2 -soluble PO_4

Analyses for exchangeable K showed a range from 1,030 to 2,800 pounds K_{20} per acre in the plow layer and additional large amounts in the lower depths. The total exchangeable K_{20} ranged from 2,360 to 8,900 pounds in the 24-inch depth of soil. No beneficial response to K_{20} was observed on any of these soils. There were indications of decreased yields from additional K_{20} on some of them.

Summary

During the 1950 and 1951 seasons 15 fertilizer experiments with sugar beets were conducted on widely distributed farms in Malheur County, Oregon. Fertilizer variables were N at 0, 50, 100, 150 and 200 pounds; $P_{2}0_5$ at 0, 40 and 80 pounds, and $K_{2}0$ at 0, 80 and 160 pounds per acre, in factorial combinations. Fertilizer treatments were replicated four times in randomized blocks. Further variables were plant density (three tests), irrigation treatment (one test) and time and method of fertilizer application (one test).

Substantial increases in yield of beets and sugar per acre were produced by N on nine farms, although high applications of N tended to reduce percent sugar. A yield increase from P_2O_5 was obtained on only one farm; 13.3 and 19.6 tons per acre, respectively, were produced with 0 and 80 pounds P_2O_5 . The use of radioactive fertilizer revealed that on this P-deficient soil about 65 percent of the P in the plants was derived from the initial soil supply and only about 13 percent of the 80 pounds P_2O_5 applied in fertilizer was absorbed during the season. No beneficial response to K_2O was observed. Closer plant spacing increased yield of beets on one farm, yield of sugar on two farms. Irrigation treatment had significant effects. Differences in time and method of fertilizer applications were without effect.

Soil samples were taken to the 24-inch depth, in three increments, before application of fertilizers. The soils not responsive to N averaged about 50 percent higher in nitrifiable-N than the responsive soils. The one soil responsive to P_2O_g tested markedly lower than the other soils in both water- and CO_2 -soluble PO_4 . Large amounts of exchangeable K_2O were found in all soils.

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