Soil Temperature and Nitrogen Effects on Yield and Phosphorus Uptake by Sugar Beets[1]

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Received for publication April 13, 1964

About 45,000 acres of sugar beets are planted annually in southern Alberta. Growers have been applying 100 lb of 11-48-0 fertilizer per acre, and the need for additional nitrogen has been reported previously (8)[3]. Beets are planted from the second week in April to the middle of May. The relatively cool temperatures that may be encountered in spring together with the increased use of nitrogen fertilizer merits the study of the effect of these factors on the early growth of the plant.

Review of Literature

There is very little published information available on the effect of soil temperature on the growth of sugar beets. The percentage emergence of sugar beet seedlings at soil temperatures of 13°, 18°, and 24° C was significantly increased (6) over that at 6° C, and the speed of emergence increased as the temperature increased. Nielsen *et al.* (10) found that the yield of roots and foliage of lucerne increased with increase in temperature to at least 19.4° C. The phosphorus content of the roots and foliage tended to increase with increasing temperature. Oats produced higher yields (11) of grain and straw when soil temperature was increased from 41° to 67° F (19.4° C). There was a trend toward increased concentration of phosphorus in the oat plants with increasing temperature. Low soil temperature depressed the growth of corn seedlings (9), and the percentage phosphorus and total phosphorus were also lower at the low temperature.

In his review of the effects of nitrogen on the availability of phosphorus to plants, Grunes (13) separates them into biological and chemical effects. Some of the biological effects include stimulation of root and top growth, thereby increasing absorbing capacity and phosphorus uptake. The chemical effects are related to alterations of the phosphorus solubility in the soil. Rennie and Soper (14) reported an increase in fertilizer phosphorus absorption at a very early stage of growth of cereal crops when nitrogen in the ammonium form was mixed with the phosphorus carrier. Caldwell (4), working with corn, also found that ammonium forms of nitrogen had to be intimately

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[3] Numbers in parentheses refer to literature cited.

mixed with phosphorus before phosphorus absorption by the plant occurred. He stated that the N to P_2O_5 ratio had to be 1:4 or narrower for significant uptake of phosphorus to take place and suggested that the effects of nitrogen on phosphorus absorption were brought about by chemical interactions.

Balba (2) found that nitrogen increased yields but had almost no effect on the phosphorus percentage of onion plants. He suggested that nitrogen enabled the onion roots to "forage" for more phosphorus, hence the percentage phosphorus tended to remain constant, and that the amount of phosphorus taken up by the plant was proportional to the yield.

The purpose of the experiments reported in this paper was to study the effect of temperature and the time of application of nitrogen fertilizer on the growth and phosphorus uptake of sugar beets.

Materials and Methods

The experiment was conducted in a greenhouse and consisted of one soil type, four soil temperatures, five fertilizer treatments, and two harvest dates.

The soil used was a Chin silt loam (3), which is the predominant soil type on which sugar beets are grown in southern Alberta. Ten pounds of soil were placed in 1-gallon plastic pots. The pots were placed in constant temperature tanks similar to those described by Cooper *et al.* (5). The temperatures used in the tanks were 7°, 12°, 19°, and 27° C.

Sugar beet seeds (Alberta blend) were germinated in flats containing compost soil. When the seedlings were 4½ weeks old they were transplanted, three to a pot in duplicate pots. Prior to transplanting, all of the pots received triple superphosphate fertilizer (0-43-0) at the rate of 40 lb P_2O_5 per acre. Ammonium nitrate fertilizer (33½-0-0) at the rate of 40 lb N per acre was applied to one set of pots at transplanting time and to three other series of pots at 2-week intervals for 6 weeks.

The soil surface was insulated with a ½-inch layer of beaded polystyrene. Copper constantan thermocouples set at ½-inch depth in the soil and connected to a recorder showed that the temperature at this depth varied ± 2° C. The temperature in the air-conditioned wing of the greenhouse was 21° C ± 3°.

Water was added to maintain the soil water in the upper half of the available range as determined by periodic weighing.

The first harvest of sugar beets, from half the pots, was 8 weeks after transplanting when the plants were 12½ weeks old, and the second harvest was taken 10 weeks after transplanting. The experiment was repeated two more times to permit statistical analysis with three replications in time.

After harvest the tops and roots from each pot were dried at 180° F in a forced draft oven and weighed. The phosphorus content of the plant material was determined colorimetrically (15) after preparation by the wet digestion method with perchloric acid (13).

At the time of each harvest the available phosphorus content of the soil in each pot was determined by the sodium bicarbonate method (1). Golden (7) found that the control of temperature at which soil extractions were made was highly desirable. Therefore, freshly prepared solutions were kept in the respective temperature tanks for several hours, and the extraction was then carried out in the tanks.

Results and Discussion

As the soil temperature increased from 7° to 27° C, the dry weights of sugar beet tops increased significantly (Table 1).

Table 1.—Effect of four soil temperatures on sugar beet seedlings and on extractable soil phosphorus, and significant differences[1] between means (means per pot calculated from three replications and two harvests).

Temperature	Dry Matter	Phosphorus	Phosphorus	Soil phosphorus
°C	gm	%	mgm	ppm
		Sugar beet roots		
7	0.95 a	.346 a	3.12 a	11.4 a
12	4.31 b	.336 ab	14.08 b	8.9 a
19	7.92 c	.296 c	22.40 c	9.8 a
27	8.40 c	.308 bc	24.94 c	10.9 a
		Sugar beet tops		
7	3.51 a	.342 a	12.28 a	
12	6.15 ab	.490 a	28.70 b	
19	8.35 b	.450 a	35.28 c	
27	11.51 c	.390 a	43.60 d	

[1]Any two means followed by the same letter are not significantly different.

The yields of roots increased significantly with temperature increases to 19° C only. The optimum temperature for root growth appears to be around 20° C. While the percentage of phosphorus in the beet tops was not significantly affected by soil temperature, there was a tendency for it to decrease in the roots with increasing soil temperature. Total phosphorus uptake by tops and roots increased with increasing soil temperature in proportion to increased plant material. The amount of available phosphorus extracted from the soil was not significantly affected by soil temperature. This can be partially attributed to the increased growth and, therefore, increased total uptake as temperature increased.

Table 2.—Effect of phosphorus and nitrogen applied at successive dates on sugar beet seedlings and on extractable soil phosphorus, and signficant differences[1] between means (means per pot calculated from three replications and two harvests).

Fertilizer treatment		Dry matter	Phosphorus	Phosphorus	Soil phosphorus
lb/acre		gm	%	mgm	ppm
P_2O_5	N				
			Sugar beet roots		
40[2]	0	4.88 bc	.332 ab	15.0 c	11.1 a
40[2]	40[2]	6.48 a	.302 c	18.3 a	9.6 b
40[2]	40[3]	5.66 ab	.311 bc	16.3 b	8.9 b
40[2]	40[4]	5.48 b	.321 abc	16.3 b	9.6 b
40[2]	40[5]	4.16 c	.341 a	14.7 c	9.8 b
			Sugar beet tops		
40[2]	0	5.68 a	.481 a	26.4 a	
40[2]	40[2]	8.07 b	.410 b	33.0 b	
40[2]	40[3]	7.73 b	.400 c	30.0 b	
40[2]	40[4]	8.02 b	.387 d	30.2 b	
40[2]	40[5]	7.48 b	.411 b	30.2 b	

[1]Any two means followed by the same letter are not significantly different.
[2]Applied at transplanting time when seedlings were 4½ weeks old.
[3]Applied 2 weeks after transplanting.
[4]Applied 4 weeks after transplatning.
[5]Applied 6 weeks after transplanting.

Root yields were highest when nitrogen was applied either at transplanting time or 2 weeks later (Table 2). The percentage of phosphorus in the roots was higher from the treatment that received the last application of nitrogen than from either of the two treatments that received the earliest application of nitrogen. The first application of nitrogen resulted in roots that were higher in total phosphorus than those of the other treatments. These results agree with those of Balba (2), who found that nitrogen increased the total uptake of phosphorus as a result of increased plant growth. There was no evidence of an apparent increase in the solubility of phosphorus as indicated by the percentage of phosphorus in sugar beets grown in the presence of nitrogen.

Nitrogen at 40 lb per acre at any of the four dates of application resulted in yields of beet tops and total phosphorus content of tops that were higher than from the treatment that did not receive any nitrogen. The percentage of phosphorus in the tops was higher when no nitrogen was used, and there did not appear to be any pattern among treatments that received nitrogen.

The lower extraction of available soil phosphorus from the pots that received nitrogen further illustrates that total uptake of phosphorus was increased with nitrogen fertilizer.

In roots and tops the dry matter weights and total phosphorus were higher while the percentage phosphorus was lower between dates of harvest. There were no significant temperature-fertilizer interactions.

In general, these results showed that as the soil temperature increased from 7 to 27° C the dry matter and total phosphorus increased in both roots and tops of sugar beet seedlings. The early applications of nitrogen resulted in the highest dry matter and phosphorus content of seedling roots. Time of nitrogen application had no effect on seedling beet tops. The results would indicate that early availability of nitrogen to the seedling would promote a more rapid root growth.

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