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Table Beet Yield and Boron Deficiency as Influenced by Lime, Nitrogen, and Boron

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Table Beet Yield and Boron Deficiency as Influenced by Lime, Nitrogen, and Boron[1]

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ABSTRACT

Yield, occurrence of root canker (B deficiency), and leaf nutrient concentrations of the Morse strain of 'Detroit Dark Red' table beet (*Beta vulgaris* L.) as influenced by combinations of lime and N, B, and P fertilizers were evaluated in three studies. Greatest total yields and most favorable distribution of root sizes for processing occurred with 280 kg N/ha and at soil pH of 6.6. Boron and P did not affect yield but B application reduced incidence of root canker. High rates of N application also reduced canker even though the production of large roots, which are more susceptible to canker, was increased by high rates of N. In the presence of soil-applied B, high rates of N increased beet leaf B concentration. Application of lime tended to decrease leaf B concentration but increased canker incidence only in the absence of applied B. Liming increased P and decreased Mn concentration of leaves. The yield response to lime application may be attributed in part to reduction of Mn toxicity.

***Additional Index Words: Beta vulgaris* L., root canker, P, Mn, Ca.**

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Western Oregon is an important producer of table beets (*Beta vulgaris* L.) for processing and for the local fresh market. Soil acidity, N, and B have been identified as the most important soil fertility factors affecting table beet yield and quality in this area (8, 10, 11, 12). Prices paid to growers depend on the root size distribution as well as total yield. Soil fertility, row spacing, and harvest date all influence root size (6, 12, 14).

Application of lime to an acid soil increases yield of many vegetable crops including beets (8), and these yield increases are often associated with a reduction in plant uptake of Mn and Al (4, 5, 9). Since leaf tissue Mn levels were reduced over fourfold with increase in soil pH from 5.8 to 6.3, reduced Mn toxicity may be partially responsible for increased beet yields with liming (8).

Boron deficiency symptoms on table beet roots usually occur as a tissue breakdown near the root surface, generally referred to as canker. Incidence of canker decreases with B application to the soil (10, 11). Liming an acid soil may decrease the amount of plant-available B (13, 16). An increase in the Ca-to-B ratio in the soil and in plant tissue, as may occur after lime application, has been implicated in boron deficiency symptoms (3). Thus, liming might simultaneously increase beet yield but reduce quality on the often B-deficient soils of western Oregon.

Increased application of N fertilizers has decreased B deficiency in beet. Boron deficiency was also more effectively alleviated by application of N plus B than by soil-applied B alone (10, 11).

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The purpose of these experiments was to evaluate the effects of several combinations of N, B, P, and lime on table beet yield, root size distribution, leaf elemental concentrations, and canker incidence.

MATERIALS AND METHODS

Four years prior to the first beet experiment, agricultural lime (99% $CaCO_3$, 95% passing 60-mesh sieve) was applied in randomized block design with three replications to field plots of Willamette silt loam soil (Pachic Ultic Argixeroll, fine-silty, mixed, mesic) at rates of 0, 9.0, or 18.0 t/ha. The plots were plowed, disked, and cropped each year with winter wheat or vegetables. Soil pH in the surface 16 cm at the start of Experiment 1 was 5.8, 6.3, and 6.6, respectively, for the three lime treatments.

In Experiment 1 these main lime plots were split by application of B (as Solubor) at 0, 3.4, or 6.7 kg/ha, and the B subplots split by application of N at 168 or 280 kg/ha. Nitrogen, phosphorus, and sulfur (as ammonium phosphate sulfate) at 72, 39, and 63 kg/ha, respectively, were banded at planting, and the remaining N (as NH_4NO_3) was broadcast within 24 h. Planting date was 10 May and roots were harvested 16 weeks later and graded into size categories. Canker incidence was recorded for roots with diameter > 5.1 cm.

The main plots used in Experiments 2 and 3 were established 9 months before planting the second crop and were previously in a winter wheat–fallow rotation. Lime of the above analysis was applied at 9.0 and 18.0 t/ha, and elemental S was applied at 2.25 t/ha, resulting in soil pH at time of planting of 6.2, 6.6, and 5.2, respectively, compared to 5.7 for untreated soil. Fertilizer treatments in Experiment 2 were applied in randomized, split plot design with four replications. Main plots were split by application of B at 1.1 or 4.5 kg/ha and the B subplots split by N at 56, 168, or 280 kg/ha. Nitrogen, phosphorus, and sulfur at 56, 64, and 58 kg/ha, respectively, were banded at planting. Planting date was 18 June. Soil compaction and "damping off" of seedlings caused poor stands and yield was not estimated.

In Experiment 3 the main plots were split by application of 3.4 kg/ha of B to the subplots which had received 4.5 kg B/ha in Experiment 2 and no further application to subplots which received 1.1 kg B/ha in Experiment 2. These subplots were further split by application of 56, 168, or 280 kg N/ha as in Experiment 2, and again by a banded P application of 0 or 44 kg/ha. Planting date was 1 June and plots were harvested 14 weeks later.

Table 1—Main effects of soil acidity and N fertilizer on table beet yield, Experiment 1.

Treatment	Soil pH	Size grade (cm in diam)				Total
		<2.5	2.5–5.1	5.1–6.4	>6.4	
		t/ha				
Lime rate, t/ha						
0	5.8	1.4	16.2	4.7	2.4	24.7
9.0	6.3	1.2	18.5	9.4	9.2	38.3
18.0	6.6	1.6	20.5	12.3	4.8	39.1
Significant effects†		NS	L*	L**	Q**	L**Q*
N rate, kg/ha						
168		1.6	17.9	4.8	0.3	24.6
280		1.1	18.8	12.8	10.6	43.3
Significant effects		NS	NS	**	**	**

† Not significant (NS), 5% level (*), 1% level (**), linear (L), quadratic (Q).

In each experiment the Morse strain of 'Detroit Dark Red' beet was used. Between-row spacing was 0.46 m and seeding rate was 30/1 m. Irrigation and weed control programs were in accord with standard commercial practice in western Oregon.

Samples of recently fully expanded leaves were taken when the average root diameter reached 2 cm (5 cm in Experiment 3). Petioles and leaf midribs were removed and the blades dried at 70°C, ground with a Wiley Mill to pass through a 20-mesh screen, and digested with $HNO_3/HClO_4$. The Ca, Mg, K, and Mn were determined by atomic absorption. Phosphorus was determined by the molybdate–vanadate method (7). Boron was measured by the procedure of Dibble et al. (1).

RESULTS AND DISCUSSION

Total yield of table beet roots increased with increasing N application and increasing soil pH in Experiments 1 and 3 (Tables 1 and 2). In Experiment 1, a yield response to lime occurred with the application of 9.0 t/ha (pH 6.3), but application of 18.0 t/ha did not further increase yield. Highest yields were obtained with 280 kg N/ha and at either pH 6.3 or 6.6 (Table 1). In Experiment 3, the lime and S treatments produced a wider range of soil pH. Highest yields were obtained at 280 kg N/ha and the yield at pH 6.6 exceeded that at pH 6.2. Responses to lime and N were approximately additive (Table 2). There were no significant pH × N interactions in either experiment.

Highest prices are usually paid for 2.5- to 5.1-cm diameter beet roots. In Experiment 1 the rate of N fertilizer or lime had little effect on yield of beets < 5.1-cm in diameter while both N and lime greatly increased the yield of larger beets (Table 1). However, the product value would have been highest at pH 6.6 and 280 kg N/ha. In Experiment 3 the roots were smaller at harvest than in Experiment 1 and most roots were in the 2.5- to 5.1-cm range. Highest total yield and greatest yield of 2.5- to 5.1-cm beets occurred at the highest pH and N rate (Table 2). Highest product value again occurred at pH 6.6 and 280 kg N/ha. Similarly, Shannon et al. (14) reported that rate of N application had no effect on yield of table beets < 4.4 cm in diameter, but yield of the larger sizes increased with N rate up to 336 kg/ha (14).

Boron treatments in Experiment 1 and B and P treatments in Experiment 3 had no significant effect on gross yields or root size distribution (data not shown).

Beet leaf P concentration significantly increased with application of 18.0 t/ha of lime in Experiment 1 or 9.0 t/ha in Experiment 2 (Table 3). This increased availability of P may be critical at early seedling growth stages, particularly at low soil temperature (15) and may be partly responsible for the yield response to lime. The much lower leaf P concentrations in Experiment 3 may be related to the development stage of the plants when sampled (5- vs. 2-cm root). Tissue elemental concentrations of several vegetables vary with stage of growth (2, 5).

Leaf Ca concentration increased with lime application in Experiments 2 and 3 but was lower in plants grown on untreated soil than in plants from S-treated soil (Table 3). This decrease in Ca concentration is probably a dilution effect caused by greatly increased foliar growth at pH 5.7 compared to pH 5.2 and is consistent with previous results for lettuce (5) and beets or spinach (8) on Willamette soil.

Beet leaf Mn concentration also consistently decreased with increasing soil pH (Table 3). Most of the reduction occurred between pH 5.2 (S, 2.25 t/ha) and 6.2 (lime, 9.0 t/ha) consistent with the greatest yield increase in the same pH range. Below pH 6.2, the leaf Mn concentration was well in excess of the normal range of 70 to 200 mg/kg for table beets (2). Possible symptoms of Mn toxicity including stunting and interveinal chlorosis, particularly near the leaf margins, were observed on plants growing on soil with the lowest pH.

Increasing applications of N were associated with decreasing leaf P concentration (Table 4). This re-

Table 2—Main effects of soil acidity and N fertilizer on table beet yield, Experiment 3.

Treatment	Soil pH	Size grade (cm in diam) <2.5	2.5–5.1	>5.1	Total
		t/ha			
S/lime rate, t/ha					
S, 2.25	5.2	2.4 c‡	13.4 d	1.5 c	17.3 d
check	5.7	4.6 b	27.6 c	2.4 b	34.6 c
lime, 9.0	6.2	5.5 a	43.1 b	3.0 ab	51.6 b
lime, 18.0	6.6	6.0 a	47.2 a	3.6 a	56.8 a
Significant effects†		**	**	**	**
N rate, kg/ha					
56		5.0	21.7	1.1	27.8
168		4.9	25.8	2.0	32.7
280		3.8	41.0	4.8	49.6
Significant effects		NS	L**Q*	L**Q*	L**Q*

† Not significant (NS), 5% level (*), 1% level (**), linear (L), quadratic (Q).
‡ Mean separation within columns by Duncan's Multiple Range Test, 5% level.

Table 3—Mean effect of soil acidity on beet leaf tissue P, Ca, and Mn concentrations.

S/lime rate	Exp. 1 P	Exp. 1 Ca	Exp. 1 Mn	Exp. 2 P	Exp. 2 Ca	Exp. 2 Mn	Exp. 3 P	Exp. 3 Ca	Exp. 3 Mn
t/ha	%	%	mg/kg	%	%	mg/kg	%	%	mg/kg
S, 225	NA‡	NA	NA	0.34 b	1.88 a	523 a	0.21	1.62 c	788 a
Check	0.53 b§	2.40	993 a	0.37 b	1.73 b	303 b	0.22	1.43 d	372 b
Lime, 9.0	0.63 ab	2.37	374 b	0.42 a	1.98 a	131 c	0.24	1.70 b	153 c
Lime, 18.0	0.68 a	2.59	292 c	0.37 b	1.96 a	104 c	0.24	1.86 a	109 d
Significant effects†	*	NS	**	*	*	**	NS	**	**

† Note significant (NS), 5% level (*), 1% level (**).
‡ Treatment not applied in Experiment 1.
§ Mean separation within columns by Duncan's Multiple Range Test, 5% level.

Table 4—Effect of N fertilizer on beet leaf tissue P, Ca, and Mn concentrations.

	Experiment								
	1			2			3		
N rate	P	Ca	Mn	P	Ca	Mn	P	Ca	Mn
kg/ha	%	%	mg/kg	%	%	mg/kg	%	%	mg/kg
56	NA‡	NA	NA	0.42	1.84	299	0.25	1.47	372
168	0.77	2.39	430	0.36	1.97	275	0.21	1.63	349
280	0.45	2.52	677	0.35	1.84	293	0.22	1.92	346
Significant effects†	**	*	*	L*	NS	NS	L*Q*	L**	NS

† Not significant (NS), 5% level (*), 1% level (**), linear (L), quadratic (Q).
‡ Treatment not applied in Experiment 1.

duction in leaf P concentration can be attributed to increased vegetative growth and dilution of P. Leaf P concentration was not affected by the banded P fertilizer variable in Experiment 3 (data not shown). Increasing N tended to increase leaf Ca concentration but had no consistent effect on leaf Mn concentration (Table 4).

Boron treatments did not significantly affect leaf P, Ca, or Mn concentrations in any experiment. No treatment significantly affected leaf K or Mg concentrations (data not shown). There were no significant N × soil pH or B × soil pH interactions affecting leaf P, Ca, or Mn concentrations in any experiment.

In Experiment 1 leaf B concentration decreased with increasing N in the absence of B fertilizer but increased with increasing N in the presence of added B (Table 5). In either case, the incidence of canker decreased with increasing N application. Canker occurs almost exclusively on beets with > 2.5-cm diameter (10). Since the higher N rate greatly increased the proportion of larger roots (Table 1), occurrence of canker might be expected to increase at the higher N rate. However, in agreement with previous reports (10, 11), canker incidence decreased at the higher N rate, even in the absence of added B.

Application of B increased leaf B concentration and decreased canker incidence at either N rate (Table 5). Canker was reduced most effectively by application of both B and the high rate of N. In Experiment 1, soil acidity did not significantly affect leaf B concentration or canker incidence in the presence of added B. However, addition of lime significantly increased canker in the absence of applied B (data not shown).

Table 5—Effects of N and B fertilizers on beet leaf B concentration and on the incidence of root canker† (Experiment 1).

	B applied, kg/ha							
	0		3.4		6.7		N rate means‡	
N applied	Leaf B	Canker	Leaf B	Canker	Leaf B	Canker	Leaf B	Canker
kg/ha	mg/kg	%	mg/kg	%	mg/kg	%	mg/kg	%
168	18	57	36	34	40	16	31	36
280	12	37	43	8	52	4	36	16
B rate means‡	15	47	39	21	46	10		

† Percentage of roots > 5.1 cm in diameter showing canker.
‡ Effects of N and B on canker, and B on leaf B concentration significant at the 1% level. Effect of N on leaf B concentration not significant; interaction of N × B on leaf B concentration significant at the 5% level.

Table 6—Main effects of soil acidity and B fertilizer on beet leaf B concentration (Experiment 2).

S/lime rate	Leaf B concentration	B rate	Leaf B concentration
t/ha	mg/kg	kg/ha	mg/kg
S, 2.25	41	1.1	32
Check	36	4.5	39
Lime, 9.0	30		
L.S.D. (0.05)	5		5

In Experiment 2 liming decreased leaf B concentration significantly at either rate of B application (Table 6). However, N application had no consistent effect on leaf B concentration and no canker was observed. Levels of leaf B (30 to 40 mg/kg) which were associated with high canker incidence in Experiment 1 were not associated with significant canker incidence in Experiment 2 (Tables 5 and 6). Apparently, factors such as soil moisture, temperature, and plant growth rate may affect canker development independently of an effect on leaf B concentration. In Experiment 3 no canker was observed, possibly because of the lack of large roots. Leaf B concentration was not measured.

In summary, maximum table beet yields occurred at the highest lime and N application rates. Boron and P application did not affect yield. Increased rates of both N and B decreased canker incidence.

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