USE OF STARTER FERTILIZER TO REDUCE BROADCAST APPLICATIONS OF PHOSPHORUS

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Phosphorus (P) fertilizer is a significant investment in the production of sugar beets. The application rates of P fertilizer are generally based on the soil test P levels in the top six inches of the soil and the root yield goal set by the grower. Sugar beets frequently show P deficiency symptoms in the early part of the growing season on low P testing soils, but as the season progresses these deficiencies seem to disappear. However, if the P deficiency persists for prolonged periods of time during the early growing season, reduced root yields and recoverable sucrose could result (Sims and Smith, 1997, 1998, 2001). Some growers have reported that they apply three to five gallons of 10-34-0 fertilizer as a starter at planting and forgo the applications of pre-plant broadcast P fertilizer. Three to five gallons of 10-34-0 fertilizer supplies 12 to 20 lbs P_2O_5 A^{-1}, which is considerable less than the 60 to 70 lbs P_2O_5 A^{-1} that would be recommended as a broadcast application to a low P testing soil with a beet yield goal of about 18 to 20 tons A^{-1}.

The objectives of this experiment were to evaluate and compare the effects of combinations of starter P fertilizers and broadcast P fertilizers applications on sugar beet performance in a low soil P testing soil.

Materials and Methods

Field experiments were conducted at two locations: University of Minnesota Northwest Research and Outreach Center (NWROC) near Crookston, Minnesota, and four miles east of the NWROC (Jannsen) on light textured soils. The experimental design was a randomized complete block with four replications. Treatments consisted of five rates of broadcast P fertilizer (0, 15, 30, 45, and 60 lbs P_2O_5 A^{-1}) without any starter fertilizer at planting, four rates of broadcast P fertilizer (0, 15, 30, and 45 lbs P_2O_5 A^{-1}) with 3 gallons of starter fertilizer, and three rates of starter fertilizer (3, 4, and 5 gallons A^{-1}) with no broadcast P fertilizer. At the Janssen site an additional broadcast P fertilizer rate of 75 lbs P_2O_5 A^{-1} was included without starter fertilizer. Broadcast P fertilizer was hand broadcast as triple superphosphate (0-46-0) and incorporated and the starter fertilizer was liquid 10-34-0. The initial soil P tests were determined to be 5 ppm at both sites.

Plots were planted with a six-row planter equipped with liquid fertilizer applicators. Sugar beet seed (Beta 3636) was over seeded and manually thinned to stand when the plants had exposed two true leaves. Plots were 11 ft wide (six rows spaced 22 inches apart) and 35 feet long. Appropriate amounts of nitrogen fertilizer, herbicides, insecticides, and fungicides were applied prior to and during the growing season to promote optimal sugar beet production.

Plant samples were taken from the NWROC experimental site on July 17 and August 1 from rows 2 and 5 in each plot by harvesting every other plant over a 20 feet distance. Plants were pulled from the soil, separated into tops and roots, ground or chopped to facilitate drying, dried at 60^o C, ground, and analyzed for dry matter and P concentration. Final harvest at both experimental sites was taken from the entire 35 feet of the center two rows of each plot using two passes of a single row beet lifter. Beets were weighed and piled at the end of each plot. Ten randomly selected, but representative beets were sent to the American Crystal Analytical Laboratory in East Grand Forks, Minnesota to determine tare, sugar concentration, and loss to molasses.

Statistical determinations were conducted using three separate analyses. The first analysis considered only the broadcast P fertilizer rates without starter fertilizer to determine the sugar beet response to P fertilizer. The second included all broadcast P rates from 0 to 45 lbs P_2O_5 A^{-1} with and without three gal A^{-1} of starter fertilizer to determine if the sugar beet response to broadcast P fertilizer was different with starter fertilizer than without. And the third analysis included only the three starter fertilizer rates to determine sugar beet response to increasing rates of starter.

Results

Increasing rates of starter fertilizer after three gallons had no effect on final roots harvested or recoverable sucrose at either experimental site. There will be no further discussion about starter fertilizer rates since the response to four and five gal A^{-1} of 10-34-0 treatments was similar to that for three gallons of 10-34-0. Any discussions about starter fertilizer from this point on will consider only three gal A^{-1} of 10-34-0.

The root yield response to broadcast rates of P fertilizer was highly significant at both experimental sites (Tables 1 and 2). At the NWROC experimental root yields increased about 8 tons A^{-1} over the range of broadcast P fertilizer rates of 0 to 45 lbs P_2O_5 A^{-1} (Fig 1). Yields maximized at the 45 lb P_2O_5 A^{-1} rate. At the Janssen experimental site root yields increased 4 ton A^{-1} root yield with the application of broadcast P fertilizer compared to the 0 check, however all of this increase occurred with the application of 15 lbs P_2O_5 A^{-1} (Fig 2). Significant interactions between broadcast P fertilizer rates and starter fertilizer application occurred at both experimental sites (Tables 1 and 2). The interaction resulted from a positive root yield response to broadcast P fertilizer rates without starter fertilizer, but no response to broadcast P fertilizer when three gal A^{-1} starter fertilizer was applied (Fig 1 and 2). The strong response to P fertilizer without starter fertilizer indicates that P was deficient for optimal sugar beet production. At the NWROC experimental site, 45 lbs of P_2O_5 A^{-1} were required for maximum root yield while at the Janssen site 15 lbs was required. A root yield response to the application of three gal A^{-1} starter fertilizer regardless of additional broadcast P fertilizer similar to the maximum root yield observed with broadcast P fertilizer alone, suggests that the starter alone supplied sufficient P for optimal sugar beet production.

Recoverable sucrose response to the experimental treatments was similar to that of root yields (Tables 1 and 2; Fig 1 and 2). Sucrose concentration and loss to molasses were not affected by broadcast P fertilizer rate with or without starter fertilizer nor the various rates of starter fertilizer without broadcast P fertilizer at either location. Sugar concentration and loss to molasses averaged about 17.47% and 1.14%, respectively, at the NWROC experimental site and 16.9 %and 1.05 %, respectively, at the Janssen site. Since P fertilizer treatments did not affect either of these variables, the response of recoverable sucrose was due primarily to the response in root yields.

During the Growing Season

Root dry matter accumulation and total P accumulation in the plant in mid-July and early August were significantly increased with the application of starter fertilizer compared to no starter application (Table 1). Starter fertilizer resulted in greater accumulations of root dry matter and total plant P accumulation. In mid-July, root dry matter accumulation and total P accumulation response to broadcast P fertilizer rates was similar with and without starter fertilizer application (Fig 3). By early August it would appear that the response to broadcast P fertilizer rates may be different between the starter treatments (Fig 4). The interaction between the root dry matter accumulation and P accumulation response to broadcast P fertilizer rates and starter application was not significant at either sampling date (Table 1). However, this interaction was significant at the $P = 0.07$ level of significance for root dry matter accumulation. Combined, the data indicate that there is a similar response to increasing broadcast P rates with or without starter fertilizer in the early growing season period, however the application of starter fertilizer may change the response to broadcast P fertilizer rates as the season progresses. Applications of starter fertilizer alone or the larger amounts of broadcast P fertilizer alone may reduce a sever P deficiency early in the growing season, allowing greater accumulation of root dry matter during the latter part of the growing season. If this can be duplicated and further defined in the following years, it may provide insight into the physiological functioning of the sugar beet plant as it enters the period when root growth is most rapid.

First Year Summary (1999)

Preliminary experiments in 1999 showed root and recoverable sucrose yields with starter fertilizer alone were similar to maximum yields observed with the application of broadcast P fertilizer. This occurred at two experimental sites. However, maximum yields were obtained with broadcast applications of 15 lbs P_2O_5 A^{-1}. Three gal. A^{-1} of 10-34-0 would have delivered about 12 lbs P_2O_5 A^{-1}. In the 2000 growing season there was a much stronger response to increasing P fertilizer rates at the NWROC experimental site where maximum yields occurred with the broadcast rate of 45 lb P_2O_5 A^{-1}. Again three gallons of 10-34-0 resulted in similar yields. This may be suggesting that P fertilizer utilization efficiency is enhanced with starter fertilizer applications with or near the seed compared to broadcast P fertilizer applications because of better P placement relative to the root system. Earlier research has shown that placement of P fertilizer directly below the seed where the taproot can gain quick access was a more efficient placement than below and to the side of the seed (Anderson and Peterson, 1978, ASSBT).

References

Anderson, F.N., and G.A. Peterson. 1978. Optimum starter fertilizer placement for sugarbeet seedlings as determined by uptake of radioactive ^{32}P isotope. Amer. Soc. Sug. Beet. Tech. 20:19-24.

Sims, A.L., and L.J. Smith. 2001. Early growth response of sugarbeet to fertilizer phosphorus in phosphorus deficient soils of the Red River Valley. Amer. Soc. Sug. Beet Res. In press.

Sims, A.L., and L.J. Smith. 1999. Phosphorus dynamics affecting sugarbeet. 1998 Sugarbeet Research and Extension Reports.

Sims, A.L., and L.J. Smith. 1998. Phosphorus dynamics affecting sugarbeet. 1997 Sugarbeet Research and Extension Reports.

Table 1. Statistical analysis of various measured variables in response to broadcast P fertilizer with or without starter fertilizer applied at planting at the NWROC experimental site during the 2000 growing season.

Variation Source	df	Final Harvest		Root DM		Total P Accumulation	
		Harv. Roots	Recov. Sucrose	July	August	July	August
				-------------------- PR > F? -------------------			
Statistical Analysis of Broadcast P Fertilizer rates Without Starter Fertilizer							
Broadcast P rates	4	***	***	*	ns	ns	*
P rate linear	1	***	***	**	**	*	**
P rate quadratic	1	***	ns	ns	ns	ns	ns
Statistical Analysis of Broadcast P Fertilizer Rates With and Without Three Gallons of Starter Fertilizer							
Starter Fertilizer	1	***	***	***	***	***	**
Broadcast P rates	3	***	***	ns	ns	ns	*
P rate linear	1	***	***	*	ns	*	**
P rate quadratic	1	ns	ns	ns	ns	ns	ns
Start. Fert. by Broad. Fert.	3	***	***	ns	ns	ns	ns
Start. by P rate linear	1	***	***	ns	ns	ns	ns
Start by P rate quad.	1	ns	ns	ns	ns	ns	ns

?? *, **, ***, and ns represent significance at the PR level of 0.05, 0.01, 0.001, and non-significance, respectively.

Table 2. Statistical analysis of harvested roots and recoverable sucrose response to broadcast P fertilizer with or without starter fertilizer applied at planting at the Janssen experimental site during the 2000 growing season.

Variation Source	df	Final Harvest	
		Harv. Roots	Recov. Sucrose
		----- R > F? -----	
Statistical Analysis of Broadcast P Fertilizer rates Without Starter Fertilizer			
Broadcast P rates	5	***	**
P rate linear	1	***	***
P rate quadratic	1	**	ns
Statistical Analysis of Broadcast P Fertilizer Rates With and Without Three Gallons of Starter Fertilizer			
Starter Fertilizer	1	***	**
Broadcast P rates	3	***	*
P rate linear	1	***	**
P rate quadratic	1	**	ns
Start. Fert. by Broad. Fert.	3	**	*
Start. by P rate linear	1	**	ns
Start by P rate quad.	1	ns	**

?? *, **, ***, and ns represent significance at the PR level of 0.05, 0.01, 0.001, and Non-significance, respectively.

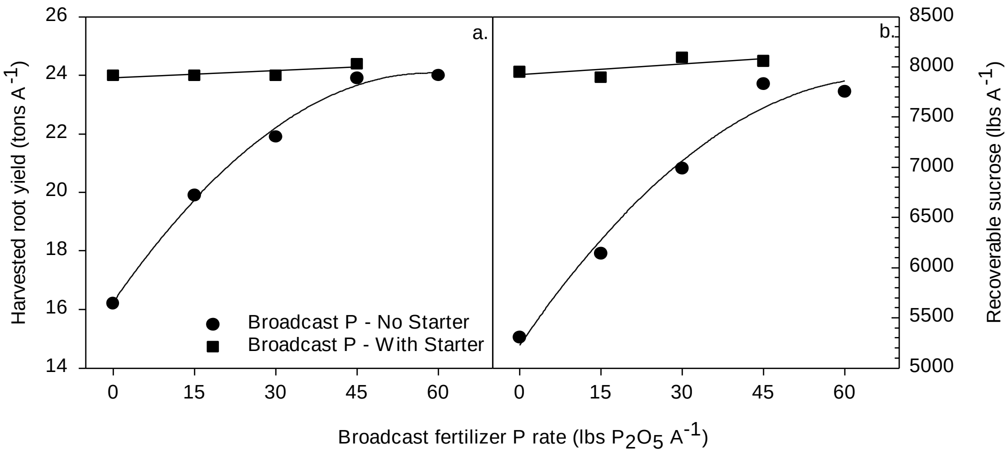

Figure 1. Final root yield and recoverable sucrose response to broadcast P fertilizer with and without starter fertilizer applied at planting at the NWROC experimental site in the 2000 growing season.

a. Broadcast P - No Starter: $y = 16.2 + 0.268x - 0.00227x^2$ $R^2 = 0.996$
Broadcast P - With Starter: $y = 23.9 + 0.008x$ $R^2 = 0.600$

b. Broadcast P - No Starter: $y = 5227 + 78.56x - 0.578x^2$ $R^2 = 0.979$
Broadcast P - With Starter: $y = 7923 + 3.49x$ $R^2 = 0.530$

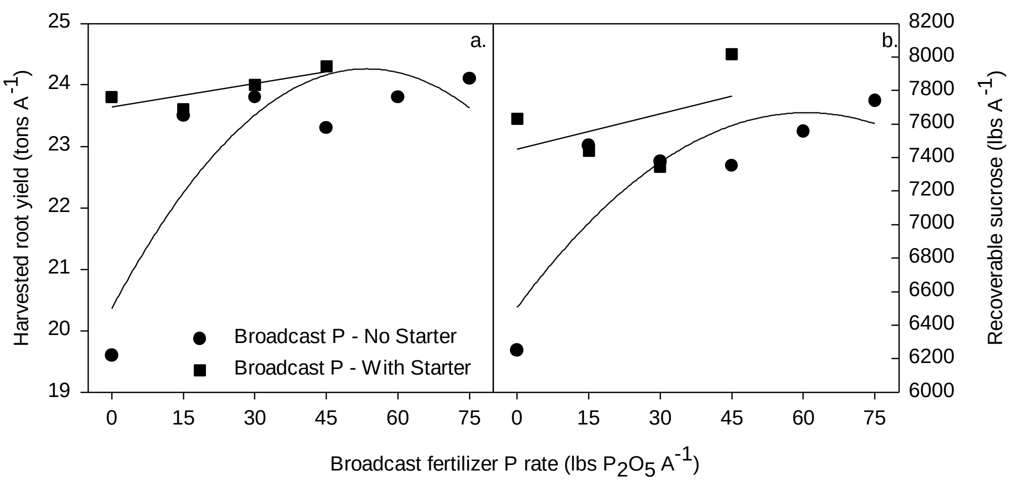

Figure 2. Final root yield and recoverable sucrose response to broadcast P fertilizer with and without starter fertilizer applied at planting at Janssen experimental site in the 2000 growing season.

a. Broadcast P - No Starter: $y = 20.4 + 0.146x - 0.00137x^2$ $R^2 = 0.765$
Broadcast P - With Starter: $y = 23.6 + 0.0127x$ $R^2 = 0.675$

b. Broadcast P - No Starter: $y = 6505 + 38.4x - 0.317x^2$ $R^2 = 0.737$
Broadcast P - With Starter: $y = 7450 + 7.07x$ $R^2 = 0.213$

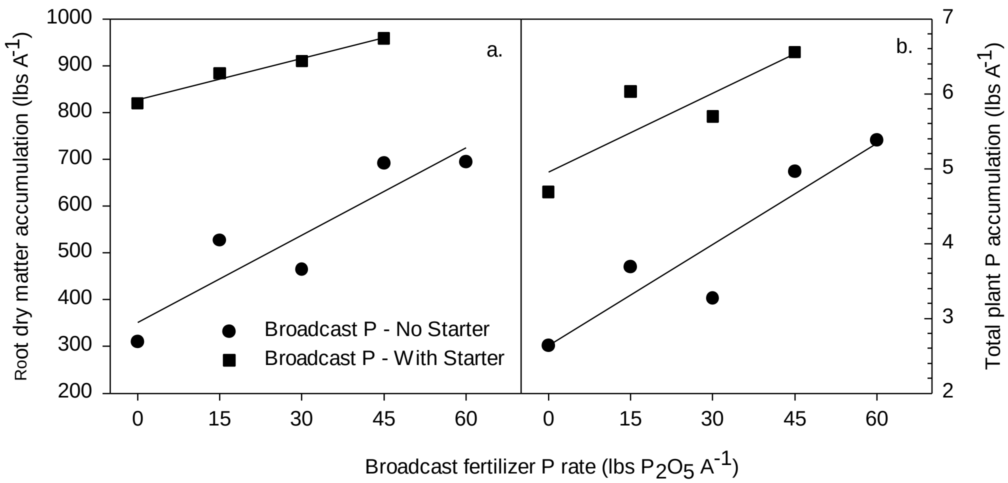

Figure 3. Mid-July 2000 sugar beet root dry matter and total plant P accumulation response to broadcast P fertilizer with and without starter fertilizer applied at planting at the NWROC experimental site.

a. Broadcast P - No Starter: $y = 351.8 + 6.233x$ $R^2 = 0.826$
Broadcast P - With Starter: $y = 826.8 + 2.953x$ $R^2 = 0.976$

b. Broadcast P - No Starter: $y = 2.638 + 0.045x$ $R^2 = 0.859$
Broadcast P - With Starter: $y = 4.953 + 0.0352x$ $R^2 = 0.749$

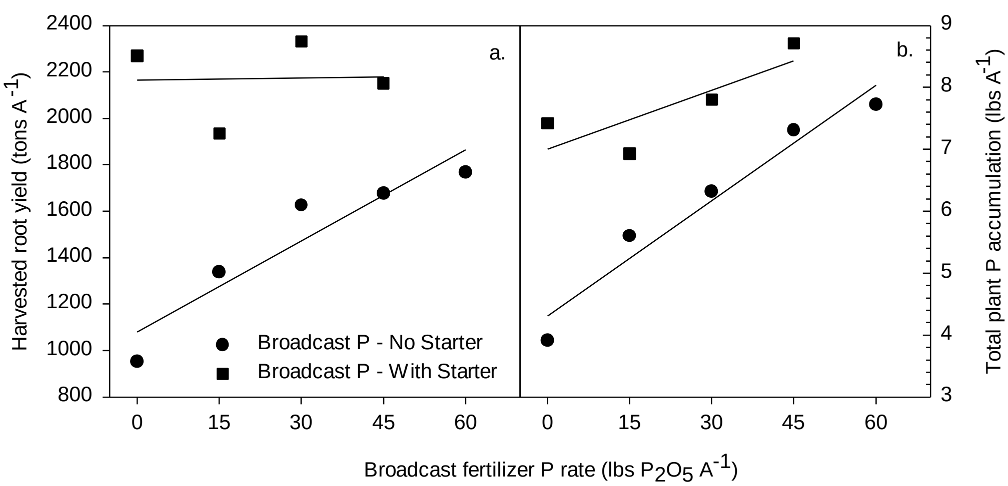

Figure 4. Early August 2000 sugar beet root dry matter and total plant P accumulation response to broadcast P fertilizer with and without starter fertilizer applied at planting at the NWROC experimental site.

a. Broadcast P - No Starter: $y = 1079 + 13.11x$ $R^2 = 0.878$
Broadcast P - With Starter: $y = 2165 + 0.280x$ $R^2 = 0.001$

b. Broadcast P - No Starter: $y = 4.306 + 0.0622x$ $R^2 = 0.951$
Broadcast P - With Starter: $y = 7.004 + 0.0316x$ $R^2 = 0.661$.