BANDED P PLACEMENT FOR SUGARBEETS IN CALCAREOUS SOIL

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ABSTRACT

Phosphorus (P) is an essential element for sugarbeet (*Beta vulgaris*) nutrition. Soils in the Western US tend to be calcareous and alkaline, resulting in low P solubility. Sugarbeets have difficulty exploiting soluble P in surface soil due to its tap root system. Research in the North-Central US supports P applied in a band in contact with the seed or below the seed for best results. However, grower concerns about germination problems and seedling vigor have prevented adaptation of these techniques in Idaho. The objective of this project is to determine optimal P starter fertilizer placement for sugarbeets grown in calcareous soil. The initial study (2002) evaluating the effectiveness of two fertilizers (ammonium polyphosphate, APP and phosphoric acid, PA) with four placement techniques (broadcast and 0, 2, and 6 in band below soil surface) and three rates (0, 20, and 220 lb-P_2O_5/a). The results of this study showed increases in sugar production when APP was band applied, regardless of rate or depth. The other treatments did not result in yield increases. The treatments were revised in 2003 to better evaluate the effectiveness of P bands. Two starter fertilizers (ammonium polyphosphate, APP and urea ammonium nitrate, UAN) were applied at two locations with similar techniques as in the initial study. Similar to the first study, the banded application of APP at the 6 in depth resulted in increased sugar production at one location. Contrary to the findings of the initial study, sugar yield was significantly reduced for the surface applied APP. The other treatments did not result in yield effects. No treatment effects were observed at the second location. Although the results are slightly different at each site, it is noteworthy that the deep banded APP resulted in the highest sugar yield at two of the three locations.

INTRODUCTION

Studies in the North-Central US show significant increases in yield and revenue with the use of 3-5 gallons/acre of ammonium polyphosphate (APP) starter bands (12-20 lbs.-P_2O_5) in sugarbeets (Lamb, 1986; Moraghan and Etchevers, 1980; Sims and Smith, 2001). These researchers found increased yields when a starter band was placed: 1) in direct seed contact, 2) two in below the seed, and 3) two in below and two in to the side of the seed. The magnitude of the response, however, was delayed and reduced as the distance between the seed and the starter fertilizer band increased. Sims and Smith (2001) concluded that direct seed contact was the best option due to the rapid, vigorous response and because much of the soil in which the sugarbeets are being grown in that region is high in clay and susceptible to implement-soil interface compaction, thus creating a poor seed bed. Unlike many other crops, this study found little advantage in placing the starter band two in to the side of the seed. Other research also supports the fact that optimum placement of phosphorous (P) for sugarbeets seems to be directly below the seed (Anderson and Peterson, 1978).

Although sugarbeet growers in other regions have research based starter fertilizer recommendations, the soil and management conditions are very different in the Western US. Recent research has elucidated optimum P rates in sugarbeets (Stark, personal communication, 2002), but no scientific studies evaluating optimum starter P fertilizer techniques have been report for this region. Many growers in these areas do not apply starter fertilizer with sugarbeets, due to previously observed problems with germination and emergence (Gallian, personnel communication, 2002). However, these observations were primarily made at high rates of starter fertilizer and with materials with a relatively high potential for salt, ammonia, and biuret injury to seeds and seedlings in alkaline soils. No scientific evaluations of low rates of starter fertilizer or other types of starters in these conditions have been conducted in alkaline soils. Western soils tend to have relatively high pH, carbonates, and salts and low organic matter and clay content and, as a result, have increased likelihood of P deficiency, ammonia toxicity, salt injury, and surface crusting, all of which may be affected by starter fertilizers.

Although researchers have shown declining impact as P bands increase in distance from the seed, Idaho soils tend to be very high in surface P and very low in subsurface P. This scenario works well for shallow rooted crops, such as potato, but may be problematic for sugarbeets because of their dominate tap root system (Anderson and Peterson, 1978). It is probable that sugarbeet seedling have adequate P at germination in soils with very high P levels, but there is concern that P availability is insufficient as the sugarbeet tap root explores relatively less of the surface soil and more of the subsurface soil during the first weeks of growth. Phosphorus availability and diffusion rates increase when P is applied in a band application (Anderson and Peterson, 1978; Lamb, 1986; Moraghan and Etchevers, 1980; Sims and Smith, 2001). Banded P may enhance subsurface P uptake if placed relatively deep and in the path of the sugarbeet tap root. The objective of this project is to determine if deep-banded P enhances sugarbeet P nutrition and, if so, how does this impact final yield and sugar content?

MATERIALS & METHODS

APP & PA Study - This field experiment was conducted in 2002 in south central Idaho near Minidoka on an irrigated sugarbeet crop growing in an alkaline (pH 8.2-8.4), calcareous (10-16% free $CaCO_3$) soil with high soil test P (25-38 ppm bicarbonate extractable P). Twelve treatments (Table 1) were selected to evaluate various combinations of APP (10-34-0) and phosphoric acid (PA: 0-53-0) fertilizer bands. The treatments were replicated six times in a RCBD experimental design. The PA was included to provide a P only source in an effort to isolate the N contribution in the APP starter fertilizer. Also, many growers in Idaho apply an acidic starter band over the seed to relieve crusting problems.

Nitrogen was balanced across all plots with a broadcast application of ammonium nitrate. The plots were established as six – 40 foot rows on 22 in centers. The broadcast applications were applied and tilled into the soil at final ground preparation on the day of planting. The subsurface bands were applied after hilling and prior to planting. These bands were placed directly below the seed zone at 2 and/or 6 inches below the soil surface. The surface band was applied immediately after planting by spraying the fertilizer material directly over the seed zone in a two inch wide band.

Fertilizer application and planting occurred on April 24. High winds and freezing temperatures over the first two weeks resulted in a need to replant on May 13. Unfortunately, the replant operation broke the heavy surface crust and negated the evaluation of the effects of PA on crusting. Normal cultural management practices were followed in raising the crop.

Plant samples were taken to ascertain differences in plant growth, dry matter accumulation, and nutrient partitioning. Above and below ground whole plant samples were taken twice during the season at 45 and 74 d after planting. Harvest occurred on October 17 or 157 d after planting. The sugarbeets were weighed to determine total yield and analyzed for conductivity and sugar and nitrate concentration. Adjustments were made for tare (contaminates such as soil) after cleaning and reweighing. Sugar yield was determined by multiplying sugar concentration by yield. Statistical analysis was performed using ANOVA and means were separated by LSD with an alpha level of 0.05.

APP & UAN Study - These field experiments were conducted in 2003 near Twin Falls and Blackfoot, Idaho on irrigated sugarbeet crops growing in an alkaline (pH 8.0-8.4), calcareous (5-12% free $CaCO_3$) soil with high soil test P (20-35 ppm bicarbonate extractable P). The treatments included four placement methods of two fertilizer sources. The placement methods included: broadcast and bands at 0, 3, and 6 in below the soil surface (directly above or below the seed). The two fertilizer sources were APP and urea ammonium nitrate (UAN: 32-0-0) applied at 6 lb-N + 20 lb-P_2O_5 or 6 lb-N + 0 lb-P_2O_5/ac, respectively. The UAN source was included as an N only check to serve the purpose of isolating the response of N and P in the APP treatments. Humic acid was applied with all fertilizer solutions at 0.5 gal/ac to match local grower practices. No additional fertilizer P was applied. Additional broadcast N fertilizer was applied based on need according to soil and petiole analyses.

Experimental design, replications, plot size, spacing, placement timing, harvest parameters, and statistical analysis procedures were similar to those described above for the APP & PA study. Fertilizer application and planting occurred on April 8-9 at the field near Blackfoot and on May 5-6 in Twin Falls. Normal cultural management practices were followed in raising the crop. The air and soil temperatures were characterized by unusually warm late winter/early spring temperatures, followed by cool air temperatures during most of May, and then unusually warm temperatures throughout the remainder of the season. Plant samples were taken at 77 (Blackfoot) and 87 (Twin Falls) d after planting for N and P analysis (analysis not yet complete). Harvest occurred on October 3 (151 d) in Twin Falls and October 13 (188 d) at the field near Blackfoot.

RESULTS AND DISCUSSION

In general, banded P fertilization increased overall yield (Fig. 1) when applied as APP, regardless of rate or placement. Starter band applications of APP applied either on the soil surface (treatment 3) or 2 in below the seed (treatment 5) increased yield compared to the check, although treatment 3 was only significant when α=0.10. All of the deep banded P (6 inches below surface) treatments increased yield, although treatment 11 with PA was only significant when α=0.10. Treatments with banded PA alone or broadcast APP alone did not increase yield. No further yield advantage was observed in the treatments with the APP starter bands combined with the deep band.

Combining treatments for orthogonal comparisons reveals similar trends as those discussed above. Broadcast and PA only treatments were not significantly different from the check plots. Adding APP in a starter band, either at the soil surface or 2 in below, resulted in nearly a 2 ton per acre yield advantage. Similarly, adding APP at a high rate 6 in below the soil surface resulted in a significant yield increase whether or not it was combined with the various bands.

It seems apparent that the sugarbeet crop in this study benefited from banded application of APP regardless of rate or depth. Why did the APP bands show a yield response when the PA bands did not? The first possibility is that the banded ammonium and/or a combination of banded ammonium with P are responsible for the yield increase. Unpublished research from Wyoming showed that banded N applications to sugarbeet resulted in significant yield increases (Blaylock, personal communication, 2002). Another possibility is that the precipitation products formed from the application of the PA actually reduced P availability over the course of the season. There is evidence that the P precipitates that form after PA is applied to calcareous Idaho soils have enhanced solubility in the short term, but as the overall soil pH dilutes the acidic soil band, the calcium phosphates that form are actually less soluble than those that are present if a higher pH form of P is applied (Stark, personnel communication, 2002). Further work is being conducted to elucidate whether the lack of response for the PA bands is primarily due to the absence of banded ammonium or the formation of insoluble P precipitates.

Although sugar percentages were not significantly different, differences in total sugar yield were observed when sugar percentage was combined with total yield (data not shown, see Hopkins and Ellsworth, 2003). In general, the treatments with P banded 6 in below the surface resulted in increased sugar yield, although the 6 in band combined with a 2 in PA band (treatment 11) was not significantly different from the check plots.

The results of the second study enhance those of the first. The results from the Twin Falls location showed no significant differences in total yield, conductivity, sugar percentage, nitrate concentration, and total sugar production (data not shown, see Hopkins and Ellsworth, 2004). It is likely that a combination of the late planting date, unusually warm soils in 2003, and early harvest date resulted in increased P solubility/reduced P need.

The results from the field near Blackfoot also showed no significant differences in total yield, conductivity, sugar percentage, and nitrate concentrations (data not shown, see Hopkins and Ellsworth, 2004). However, significant differences were observed for total sugar production (Fig. 2). The APP applied 6 in below the soil surface was the only treatment significantly greater than the check. In contrast to the other sites, the surface applied APP (0 in) resulted in a significant decline in sugar production. Although the results from the two locations this year and the 2002 study were different, it is interesting to note that the APP band 6 in below the soil surface performed better than all other treatments evaluated at two of the three sites.

Although the nutrient analysis for the 2003 study is not yet available, the 2002 study shows substantial increases of N and P in the stems/leaves and of P in the roots when sampled early in the season (data not shown). These tissue concentration differences disappeared late in the season for the stems/leaves, but not so for the root P concentrations. The banded P treatments consistently exhibited higher root P concentrations than the broadcast or unfertilized check. The tissue nutrient concentration results combined with the evidence from the results of this study lead one to believe that all or much of the yield response observed with the deep banded APP treatment is due to enhanced P uptake and utilization.

During the early half of the season, sugarbeet roots are oriented dominantly downward, as compared to a more diagonal orientation for most other plant species. The architecture of sugarbeet roots results in more exploration of the subsoil and less of the surface soil. Subsurface P concentrations tend to be very low, especially in alkaline, calcareous soils common in the western states, even if the surface soil is high in P. This combination of sugarbeet roots not effectively exploring the surface soil and low subsoil P levels results in a potential problem for P availability early in the season. Deep banding APP seems to effectively correct this problem.

CONCLUSIONS

The results of these studies indicate that deep banded (6 in below the soil surface) APP fertilizer placed directly below the seed enhances P availability and results in increased sugar production for sugarbeets grown in high P testing calcareous soils. This increase in sugar production due to deep banding was observed at two of the three sites evaluated in these studies. Shallower placement or surface banding also resulted in increased yields in some cases, but the effect was neither as great nor as consistent as the deep banded treatment. In fact, in one instance it appeared that the surface applied APP resulted in significantly decreased yields, probably due to salt injury to the seeds/seedlings. Starter UAN or PA bands alone did not enhance sugar production. Although these studies represent only three site years of data, the trends are compelling and warrant further investigation.

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LITERATURE CITED

Anderson, F.N. and G.A. Peterson. 1978. Optimum starter fertilizer placement for sugarbeet seedlings as determined by uptake of radioactive 32P isotope. J. Am. Soc. Sugarbeet Technol. 20:19-24.

Hopkins, B.G. and J.W. Ellsworth. 2003. Starter and Deep Banded P on Sugarbeets in Alkaline Soil. p. 219-225. *In* L. Murphy (ed.) 2003 Fluid Forum Proceedings. Vol. 20. Fluid Fertilizer Foundation, Manhattan, Kansas.

Hopkins, B.G. and J.W. Ellsworth. 2004. Banded P Placement in Sugarbeets in Calcareous Soil. (*In Press*). Murphy (ed.) 2004 Fluid Forum Proceedings. Vol. 21. Fluid Fertilizer Foundation, Manhattan, Kansas.

Lamb, J.A. 1986. Starter phosphorus fertilizer effect on sugarbeet. Station Publication 50-52. Misc. Publ. Univ. MN Ag Exp. Station.

Moraghan, J.T. and J.D. Etchevers. 1980. Method of phosphorus fertilization for sugarbeets in the Red River Valley. J. Am. Soc. Sugarbeet Technol. 21:103-111.

Simms, A.L. and L.J. Smith. 2001. Early growth response of sugarbeet to fertilizer phosphorus in phosphorus deficient soil of the Red River Valley. J. Sugarbeet Res. 38:1-17.

Table 1. Sugarbeet P placement study fertilizer treatments (Minidoka, ID 2002). APP = ammonium polyphosphate; PA = phosphoric acid.

		P_2O_5	Broadcast	Surface		2" Band		6" Band	N
			APP	APP	PA	APP	PA	APP	APP
1	Check	0							
2	Low Broadcast	20	20						
3	Low Surface Band APP	20		20					6
4	Low Surface Band PA	20			20				
5	Low 2" Band APP	20				20			6
6	Low 2" Band PA	20					20		
7	High Broadcast + 6" Band	220	20					200	65
8	High Surface Band APP + 6 " Band	220		20				200	65
9	High Surface Band PA + 6" Band	220			20			200	65
10	High 2" Band APP + 6" Band	220				20		200	65
11	High 2" Band PA + 6" Band	220					20	200	65
12	High Broadcast	220	220						

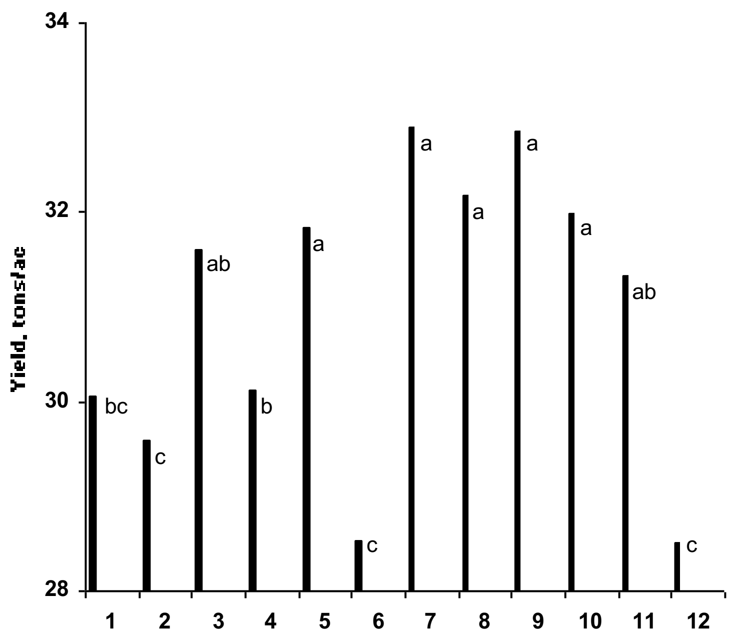

Fig. 1. Sugarbeet yield data for P placement study (Minidoka, ID 2002). Compare Treatment numbers with Table 1. Band applications of ammonium polyphosphate applied either on the soil surface (trt. 3) or 2 in below the seed (trt. 5) increased yield, although trt. 3 was only significant at the alpha 0.10 level. All of the treatments with deep banded P (6 in below surface) increased yield, although trt. 11 with phosphoric acid (PA) was only significant when α=0.10. Banded treatments were all placed directly above or below the seed. Treatment bars with the same letters to the side are not significantly different from one another (α=0.05).

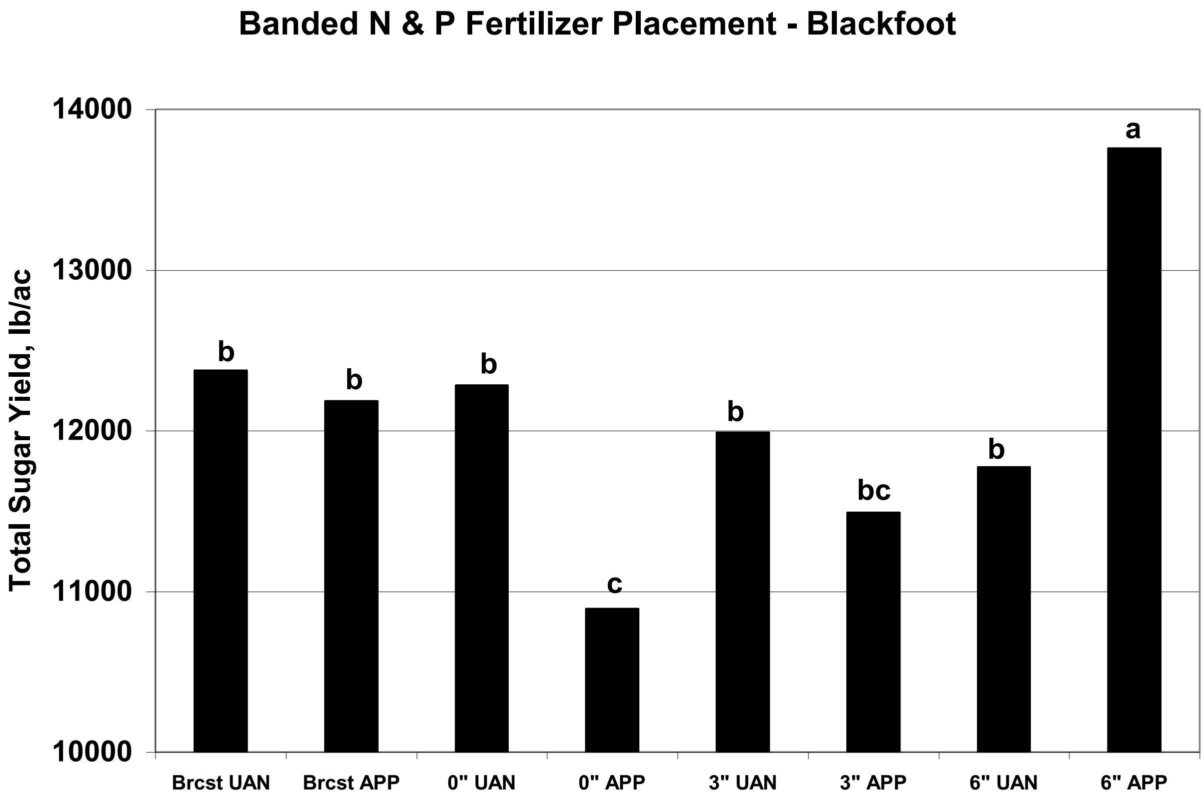

Fig. 2. Total sugar yield results from the field near Blackfoot, Idaho of a banded N & P fertilizer placement study (2003). Fertilizer was applied either as ammonium polyphosphate (APP) or urea ammonium nitrate (UAN). Fertilizer was applied either as a broadcast/incorporated or as bands at 0, 3, or 6 in at or below the soil surface. The APP applied 6 in below the soil surface was the only treatment significantly greater than the check (Brcst UAN). The surface applied APP (0 in) resulted in a significant decline in sugar production, although this effect was not observed at the other location this year nor the site tested in the previous year. Treatment bars with the same letters above them are not significantly different from one another (α=0.05).