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USE OF BANDED IN-FURROW PHOSPHORUS TO REDUCE BROADCAST APPLICATIONS IN SUGARBEET PRODUCTION

Drs. Albert L. Sims and Larry J. Smith, Associate Professors, University of Minnesota, Northwest Research and Outreach Center.

The term 'banded' has been confusing to many when related to fertilizer because of its common use with herbicides or insecticides. While there are similarities between the two uses of 'banded' there are also some differences worth noting. With herbicides or insecticides, 'banded' generally means application in a narrow row several inches wide that covers the seed row and a few inches on either side. With fertilizers, 'banded' can mean the same thing, but generally refers to a very narrow row, perhaps one inch wide. In fertilizer, the term 'banded' is a loosely used term that can have many sub-descriptions that provide more meaning such as: Row – placement of fertilizer in bands on one or both sides of the seed row; Starter – placement of fertilizer in bands the same as Row or with the seed (seed-placed) at the time of planting; Pop-Up – placement of fertilizer in a band directly with the seed or seed-placed similar to Starter and; Strip – placement of fluid or dry fertilizer in a band directly with the seed, which is the same as Pop-Up for row crops (Randall and Hoeft, 1986). It is easy to see that many of these terms are interchangeable and can be quite confusing to anyone trying to make a management decision. For purposes of this discussion I will use the term 'banded' or 'banded in-furrow' instead of 'starter' to emphasize differences in objectives of the fertilizer application even though the actual implementation of the two methods is exactly the same. In this discussion 'starters' are applied as banded seed-placed phosphorus (P) fertilizer with the planting operation even though the soil P availability is already adequate. That is, the soil test P levels are already in the high category or recommended rates of broadcast P fertilizer have already been applied. The objective of applying 'starter' is to make sure the sugarbeet crop gets off to a good start with vigorous early growth. The objective of 'banded in-furrow' fertilizer, in this discussion, is to supply P fertilizer when soil P test levels are low and no broadcast P fertilizer has been applied.

Banding has often been shown to be an effective or efficient means of applying P fertilizer compared to broadcast applications. Part of this difference has been attributed to less soil-fertilizer contact in the bands resulting in less P tied up by the soil and more availability to the crop. This may be partly true, but other factors are involved as well. Phosphorus moves from the source (fertilizer granule or soil P) to the crop root by diffusion. Some factors reducing diffusion rate of P to the root are relatively dry soil conditions or cold temperatures. Some factors increasing diffusion rate of P to the root are warmer soil temperatures and/or an increase in the P concentration at the source. Banding (regardless of location or methodology) applies a small amount of P compared to a full broadcast rate, but the P is concentrated in a smaller volume of soil near the root of the crop. Effectively, this increases the concentration of P and thus the rate of diffusion of P to the root. This is why banding P fertilizers is often recommended and effective in those years with cold soil temperatures, especially at planting. Broadcast applications of P fertilizer, with significantly greater amounts of P than in banded applications, will also increase P concentration at the source, but to a lesser extent because the fertilizer is more evenly distributed across the entire soil volume (soil surface and depth of incorporation). The advantage of broadcast applications is that more of the root system is exposed to P compared to a smaller proportion of the root system being exposed to P in banded applications. The volume of soil, whether a small volume as with narrow bands, a large volume as with broadcast and incorporated, or something in-between, that needs to be fertilized to provide the most efficient use of P fertilizer depends on the amount of P being applied, P tie-up capacity of the soil, and the maximum P absorption capacity of the roots needed to meet crop demand (Anghinoni and Barber, 1980; Borkert and Barber, 1985). Put another way, the more tie-up capacity of the soil the smaller the volume of soil that should be fertilized (banded) unless the tie-up capacity is compensated for with greater amounts of P fertilizer, which could fertilize a greater volume of soil (broadcast). In addition, the greater the crop P demand compared to the crop root P absorption capacity the greater the soil volume that needs to be fertilized to supply P to more of the root system.

In sugarbeet production, banding was recognized as an effective means of applying P fertilizer in the 1950's. Schmehl et al. (1955) reported no sugarbeet yield difference between P banded below and to the side of the seed (Row), banding directly below the seed row, or broadcast and incorporated Grunes et al, (1958), however, did report significant yield increases with banded P fertilizer compared to broadcast applications. Ulrich et al. (1959) found that P fertilizer placed in a band several cm below the sugarbeet seed row was effective in overcoming early season P deficiency in the crop. In 1958, the National Joint Committee of Fertilizer Application recommended that P could be banded in sugarbeet production if placed about two inches below the seed row. If nitrogen (N) or potassium (K) were included with the P, then the fertilizer band should be placed 2-3 inches to the side and 1-2 inches below the seed row. These and other research results have shown the potential advantage in P fertilizer efficiency (sugarbeet yield produced per pound of P applied) with banded applications compared to broadcast applications. Most university recommendations suggest that banded P rates can be reduced by half compared to broadcast P rates for many crops. This recommendation reflects recognition of increased P utilization efficiency by the crop when P fertilizer is banded compared to when it is broadcast.

Research in the Red River Valley of Minnesota and North Dakota has indicated a sugarbeet early season growth response to starter fertilizers in five out of six years, but a yield response only occurred in two out of six years (Smith, 1983). This indicates that starter fertilizers banded with the seed could be economically important about 30% of the time. Keep in mind that the soil had adequate amounts of P available for sugarbeet production from either a high soil test P level and/or the application of broadcast rates of P fertilizer. More recently, some sugarbeet growers have indicated they no longer apply any broadcast P to some of their soils that usually test low for soil test P. Instead they band 3 gals 10-34-0 A^{-1} in-furrow with the seed at planting and have been very happy with the results. Originally, we thought this practice was occurring primarily in areas with loam to sandy loam soils, but we now know some growers with low soil P testing clay soils are also using this strategy. For low soil P testing soils the university recommendations would be 55-60 lbs P_2O_5 A^{-1} as broadcast or 30 lbs P_2O_5 A^{-1} in a band. Three gallons of 10-34-0 A^{-1} supplies about 12 lbs P_2O_5 A^{-1}, which is about 40% of what would be recommended in a band. This suggests greater P utilization efficiency with the 3 gal 10-34-0 A^{-1} than the recommendations are accounting for. Peterson et al., (1981) reported that the relative utilization efficiency of banded P fertilizer compared to broadcast P fertilizer increased as the soil P test level decreased in winter wheat production. Research was needed to investigate this further, especially since banded 3 gals 10-34-0 A^{-1} was being used where soil P test levels indicated insufficient available P for the sugarbeet crop and no broadcast P fertilizer was being applied. This was a different approach than that reported by Smith (1983) where soil P availability was sufficient for the sugarbeet crop prior to appling the starter fertilizer.

The objective of this experiment was to examine the sugarbeet root and sucrose yield response to the application of various rates of 10-34-0 banded in-furrow at planting and compare that response with those of various rates of P fertilizer broadcast and incorporated by themselves or in addition to the banded 10-34-0.

Materials and Methods

In 2003, two sites were selected for this experiment. One was at the Northwest Research and Outreach Center at Crookston, Minnesota (NWROC) on a Wheatville loam soil with a fall 2002 $NaHCO_3$ soil P test of 6 ppm. The second site was about 10 miles north of Alvarado, Minnesota (Alvarado) on a Fargo-Colvin clay complex with a fall 2002 $NaHCO_3$ soil P test of 4 ppm. The same experimental procedure and treatments were done at both locations. Treatments consisted of: 3, 4, and 5 gals 10-34-0 A^{-1} banded in-furrow at planting with no additional P fertilizer added; 0, 15, 30, 45, and 60 lbs P_2O_5 A^{-1} as 0-44-0 broadcast and incorporated prior to planting with no additional P fertilizer added; and 3 gals 10-34-0 A^{-1} banded in-furrow at planting plus 0, 15, 30, and 45 lbs P_2O_5 A^{-1} broadcast and incorporated prior to planting (Table 1). Two additional treatments were added at each site. Dry fertilizer (11-52-0) was also banded in-furrow at planting at rates that supplied 12 and 16 lbs P_2O_5 A^{-1}, which is similar to the amount of P supplied in 3 and 4 gals 10-34-0 A^{-1}. The experimental design was a randomized complete block with four replications at each site.

Urea fertilizer was broadcast over the entire experimental area at rates based on University of Minnesota/North Dakota State recommendations and a four feet deep soil NO_3-N test. For each plot receiving broadcast P fertilizer, appropriate amounts of P fertilizer were weighed for individual plots and evenly distributed by hand within the designated plot. All fertilizer was applied in the spring a day or two prior to any tillage. Spring tillage, to incorporate the fertilizer and prepare the seedbed for planting, was done with a field cultivator at both sites. At the NWROC site, soil was packed with rolling baskets after the field cultivation operations. Sugarbeet cultivar Beta 6600 was over seeded in each experiment on May 2 at NWROC and May 8 at Alvarado. The liquid (10-34-0) and dry (11-52-0) banded fertilizers were applied during the planting operation by tubes positioned to place the fertilizer with the seed prior to the disk covers throwing soil over the seed row. All the liquid fertilizer was diluted with water such that 6 gals A^{-1} of mixed material was banded with the seed. For 3 gal 10-34-0 A^{-1}, the mixture was actually 3 gals 10-34-0 and 3 gals water. For the 5 gals 10-34-0 A^{-1} the mixture was 5 gals 10-34-0 and 1 gal water. Row widths were 22 inches and each plot was 6 rows wide and 35 feet long. Rows 1 and 6 are considered boarder rows, were seeded to stand, and were not used for any measurements. Rows 2, 3, 4, and 5 were over-seeded at planting and later hand-thinned to 30,500 plants A^{-1}. Appropriate herbicides, insecticides, and fungicides were applied as needed and determined through field scouting. Each site was cultivated twice during the growing season. Final harvest was done on September 23 at NWROC and October 6 at the Alvarado site by machine harvesting the middle two rows of each plot. Harvested beets were weighed and 10 randomly selected beets were collected, bagged, and sent to the American Crystal Quality Laboratory in East Grand Forks, Minnesota to be analyzed for tare, sucrose concentration, and impurities leading to a loss to molasses calculation.

Statistical analysis was done using SAS Proc GLM procedures (SAS, 2002). Three sets of comparisons were made on the data: 1) comparison of the banded fertilizer sources and rates with no additional P fertilizer; 2) comparison of the five rates of 0-44-0 with no additional P fertilizer; and 3) comparison of four 0-44-0 rates with and without banded 3 gals 10-34-0 A^{-1}.

Results

One of the major concerns of banding fertilizer with sugarbeet seed is the impact on seedling emergence. Recommendations warn of potential plant stand problems if 5 lbs A^{-1} of N or K_2O are applied in contact with the seed. Emerged seedlings were counted in rows 2, 3, 4, and 5 of all plots prior to hand thinning and compared to the check where no P fertilizer had been applied. At NWROC there was no significant difference in emerged seedlings among any of the treatments. In previous years, 5 gals 10-34-0 A^{-1} banded in-furrow tended to reduce seedling emergence compared to other treatments. This indicates that soil moisture conditions were sufficient in 2003 to reduce the potential stand loss that might have resulted with the higher rate of 10-34-0. At Alvarado banding P in-furrow tended to increase seedling emergence compared to the check regardless of rate or source of the banded fertilizer. Banding 4-5 gals 10-34-0 A^{-1} in-furrow increased seedling emergence 129% over the check with no difference between the two rates. Banding 3 gals 10-34-0 A^{-1} or the two rates of dry (11-52-0) in-furrow increased seedling emergence 152% over the check with no difference among the two sources. There was no difference in seedling emergence among the various rates of broadcast P and the check. At this time we cannot explain why banding P fertilizer in-furrow increased seedling emergence. This has not been observed in previous years of this experiment. It is worth noting, however, the 5 gals 10-34-0 A^{-1} resulted in fewer emerged seedlings than 3 gals 10-34-0 A^{-1}, which is consistent with previous observations. After the plots were hand thinned these emergence differences were negated and are not affecting the various measured variable responses to the treatments.

P Fertilizer Banded In-Furrow

Banding P fertilizer in-furrow with the seed without any other P fertilizer being applied significantly increased sugarbeet root yield and recoverable sucrose compared to the check at both sites (Table 2). Liquid 10-34-0 was also significantly more effective than dry 11-52-0 even though similar rates of P were applied in the band. In previous years the higher rate of 11-52-0 resulted in root yields and recoverable sucrose similar to those achieved with 3 gals 10-34-0. This was not the case in 2003 at either location (Fig 1 and 3).

Source and rate of banded P fertilizer did not impact sugar concentration or loss to molasses and thus no effect on root quality at NWROC. Therefore the increase in recoverable sucrose (Fig 2) with banded P fertilizer compared to the check and greater recoverable sucrose with liquid compared to dry banded fertilizer was entirely due to the affects on root yield. Root yields achieved with 3 gals 10-34-0 A^{-1} were not enhanced with additional P in the band at higher rates of 10-34-0 (Fig 1).

At Alvarado, the increased root yield with banded P compared to the check was highly significant as at the NWROC site. However, at Alvarado, 4 gals 10-34-0 banded in-furrow resulted in similar root yields (Fig 3), but significantly greater sugar concentration and thus higher root quality than 3 gals 10-34-0. Ultimately, banding 4 gals 10-34-0 in-furrow increased recoverable sucrose compared to banding 3 gals 10-34-0 in-furrow (Fig 4).

Banded In-Furrow vs Broadcast Fertilizer

Root yields increased with increasing rates of broadcast P fertilizer at both sites in 2003. While lsd's (0.05) indicated no differences in root yields between the 45 and 60 lbs P_2O_5 A^{-1} rates (data not shown), single degree of freedom contrasts indicated a highly significant linear relationship. When the 0-45 lb P_2O_5 A^{-1} rates are considered there were highly significant interactions between the broadcast P rates and whether or not there were 3 gals 10-34-0 A^{-1} banded in-furrow at both sites (Table 3). There were no significant effects on sugar concentration or loss to molasses, and thus no effects on root quality at either site. Therefore, the significant effects on recoverable sucrose were almost entirely due to the treatment effects on root yield.

At NWROC, root yields ranged from about 17 ton A^{-1} with no P fertilizer applied to about 25 ton A^{-1} at the highest rate of broadcast P fertilizer resulting in an 8 ton A^{-1} yield increase with adequate P (Fig 5). When 3 gals 10-34-0 A^{-1} were banded in-furrow, the root yield was also about 25 ton A^{-1}. The recoverable sucrose response was similar (Fig 6) with maximum sucrose production being achieved with either high rates of broadcast P fertilizer or 3 gals 10-34-0 A^{-1} banded in-furrow.

The results at Alvarado were quite similar as those observed at NWROC except the yield increase with adequate P fertilizer was about 5 ton A^{-1}. With no P fertilizer, root yields were about 20 ton A^{-1} and at high rates of broadcast P, the root yields were about 25 tons A^{-1} (Fig 7). Three gals 10-34-0 A^{-1} banded in-furrow also resulted in about 25 tons A^{-1} root yield. Recoverable sucrose response followed similar trends (Fig 8). There was no significant effect on net sucrose concentration with increasing P fertilizer rates.

Summary

Phosphorus fertilizer application was beneficial at both sites in 2003. There were significant yield increases over the check (no P fertilizer) with P fertilizer applied either as a band in-furrow or broadcast and incorporated prior to planting. Three gals 10-34-0 A^{-1} banded in-furrow at planting was sufficient to maximize root yields and recoverable sucrose in most situations. At the Alvarado site, there was an indication that 4 gals of 10-34-0 may have improved recoverable sucrose yields above those of 3 gals A^{-1} due to an increase in net sucrose concentration in the root (Table 2). This was not the case at the NWROC site.

At both sites, banding dry 11-52-0 in-furrow improved sugarbeet yields above that of the check, but was not adequate to achieve maximum production levels. In previous years, the production level with 12 lbs P_2O_5 A^{-1} rate of 11-52-0 was not at the same level as 3 gals 10-34-0, but last year the 16 lb P_2O_5 A^{-1} rate gave results similar to 3 gals of 10-34-0. This did not happen in 2003 at either site as yield levels were not optimum when either rate of 11-52-0 was banded in-furrow.

The application of recommended rates of P fertilizer through broadcast and incorporation methods gave maximum sugarbeet production levels at both sites in 2003. However, these same production levels were also achieved with 3 gals 10-34-0 A^{-1} banded in-furrow at planting. Additional P either as additional rates of banded 10-34-0 or preplant broadcast P fertilizer did not improve yields over that of banded 3 gals 10-34-0 A^{-1} at either location. The increase in net sucrose concentration with 4 gals of banded 10-34-0 compared to 3 gals A^{-1} at Alvarado (Table 2) may have been an anomaly because additional rates of P applied as a broadcast in addition to banding 3 gals 10-34-0 A^{-1} did not significantly improve net sucrose concentration (Table 3).

Our data indicate that banding 10-34-0 in-furrow is an adequate strategy to apply P fertilizer to a sugarbeet crop. Over the numerouse site-years this experiment has been conducted, there have been site-years with very little yield response to the application of P fertilizer as well as site-years with a substantial yield response. There have also been site-years when the yield response to broadcast P fertilizer was minimal and a more substantial response was observed with banded in-furrow applications of 10-34-0. In most cases the response has always been an increase in root yield and very little impact on net sucrose concentration. Increased recoverable sucrose response was primarily the result of increased root yield. Regardless of the level of yield response to the application of P fertilizer, banding 3 gals 10-34-0 A^{-1} in-furrow has always resulted in yields similar to or exceeded yields achieved with high rates of broadcast P fertilizer. In addition, yields with banded 3 gals 10-34-0 A^{-1} were never improved with additional rates of banded 10-34-0 or P fertilizer broadcast and incorporated prior to planting. Banding 11-52-0 at rates to supply P rates similar to 3 gals 10-34-0 has not been adequate to achieve maximum sugarbeet yields. Banding 11-52-0 at rates to supply P rates similar to 4 gals 10-34-0 has only been adequate in 1 out of 3 site-years. Even more convincing is that these results have been consistent over soil types that ranged from very sandy to loam to clay.

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Table 1. Treatments combinations of 10-34-0 and 11-52-0 banded in-furrow with the sugarbeet seed and 0-44-0 broadcast and incorporated prior to planting used at both the NWROC and Alvarado sites in 2003.

	Treatment	
Banded 10-34-0	Banded 11-52-0	Broadcast 0-44-0
--- gals A^{-1} ---	--- lbs P_2O_5 A^{-1} ---	--- lbs P_2O_5 A^{-1} ---
5	0	0
4	0	0
3	0	0
3	0	15
3	0	30
3	0	45
0	0	0
0	0	15
0	0	30
0	0	45
0	0	60
0	12	0
0	16	0

Table 2. Single degree of freedom orthogonal contrasts comparing the effects of various treatments of fertilizer banded in-furrow and the check on selected measured variables at two sites in 2003.

Source of Variation	NWROC			Alvarado		
	Root Yield	Root Quality	Recov. Sucrose	Root Yield	Root Quality	Recov. Sucrose
Single degree Contrasts[dd]	---- significance level[d] ----					
Check vs rest	***	Ns	***	***	Ns	***
Wet vs Dry	***	Ns	***	***	Ns	***
Wet rate linear	Ns	Ns	Ns	Ns	Ns	Ns
Wet rate quadratic	Ns	Ns	Ns	Ns	*	**
Dry 12 vs Dry 16	Ns	Ns	Ns	Ns	Ns	Ns

[d] Ns, ***, **, and * represent non-significant and 0.001, 0.01, and 0.05 level of significance, respectively.
[dd] single degree contrasts compared check (no P fertilizer) to all banded P fertilizers, Wet (10-34-0) to dry (11-52-0), linear and quadratic compare increasing rates of Wet fertilizer, and Dry 12 vs Dry 16 compare the two rates of Dry fertilizer.

Table 3. Single degree of freedom contrasts comparing the effects of increasing rates of P fertilizer broadcast and incorporated prior to planting on selected measured variables and their interactions with 3 gals 10-34-0 A^{-1} banded in-furrow at planting at two sites in 2003.

Source of Variation	NWROC		Alvarado	
	Root Yield	Recov. Sucrose	Root Yield	Recov. Sucrose
Single degree Contrasts[dd]	---- significance level[d] ----			
Banded vs Broadcast linear	***	***	***	**
Banded vs Broadcast quadratic	Ns	Ns	Ns	Ns

[d] Ns, ***, **, and * represent non-significan and 0.001, 0.01, and 0.05 level of significance, respectively.
[dd] single degree contrasts comparing the difference in linear or quadratic regression response to increasing rates of broadcast P fertilizer when P fertilizer was banded in-furrow at planting and when no banded P was applied.

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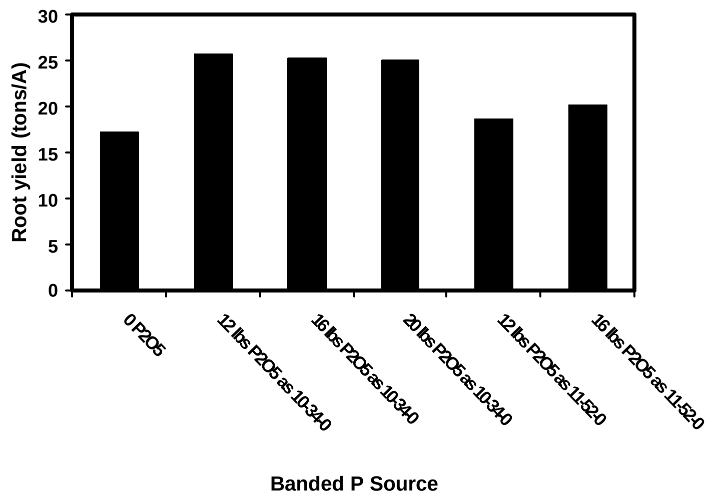

Figure 1. 2003 Sugarbeet root yield response to various rates and sources of fertilizers banded in-furrow at NWROC.

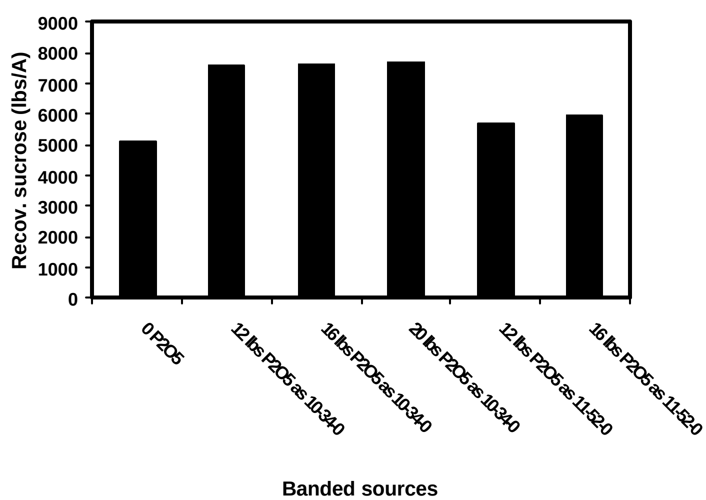

Figure 2. 2003 Sugarbeet recoverable sucrose response to various rates and sources of fertilizers banded in-furrow at NWROC.

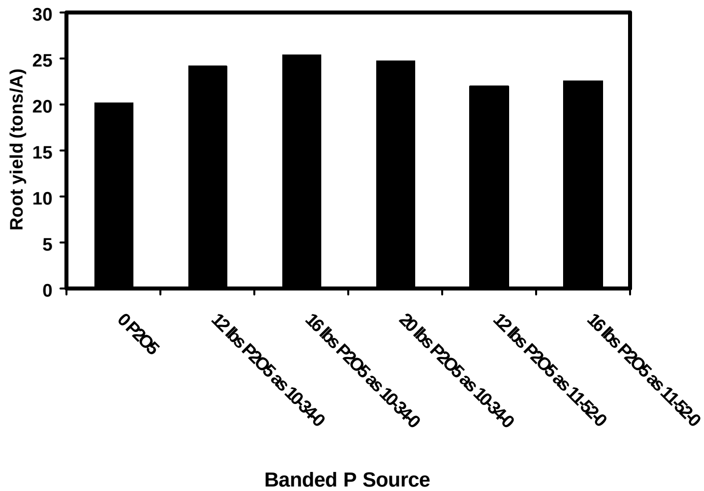

Figure 3. 2003 Sugarbeet root yield response to various rates and sources of fertilizers banded in-furrow near Alvarado.

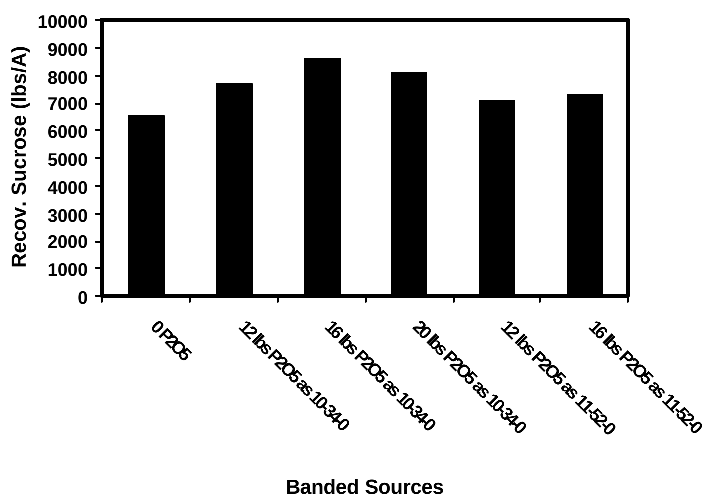

Figure 4. 2003 Sugarbeet recoverable sucrose response to various rates and sources of fertilizers banded in-furrow at Alvarado.

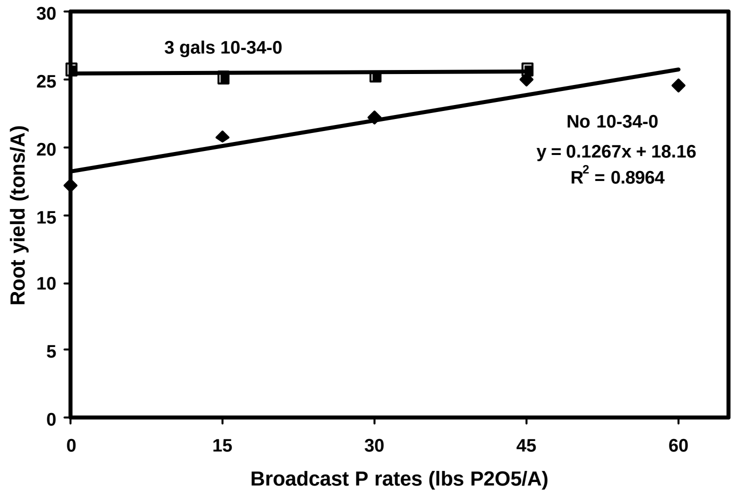

Figure 5. Sugarbeet root yield response to increasing rates of broadcast P fertilizer applied prior to planting with and without 3 gals 10-34-0 A^{-1} banded in-furrow at planting at NWROC in 2003.

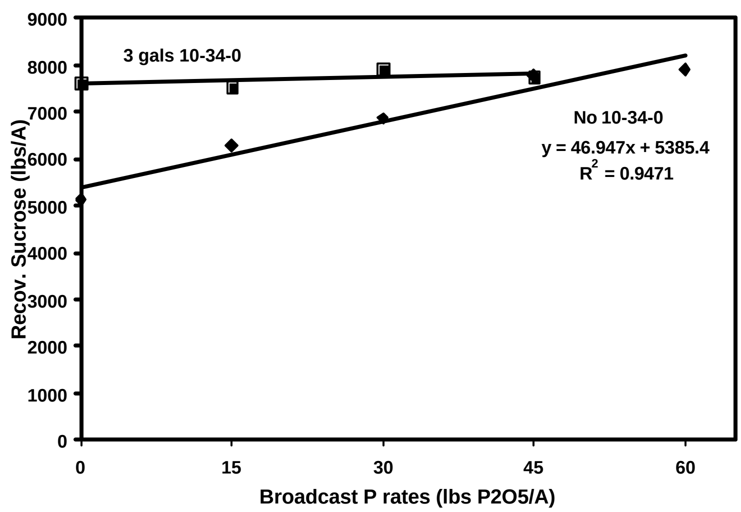

Figure 6. Sugarbeet recoverable sucrose response to increasing rates of broadcast P fertilizer applied prior to planting with and without 3 gals 10-34-0 A^{-1} banded in-furrow at planting at NWROC in 2003.

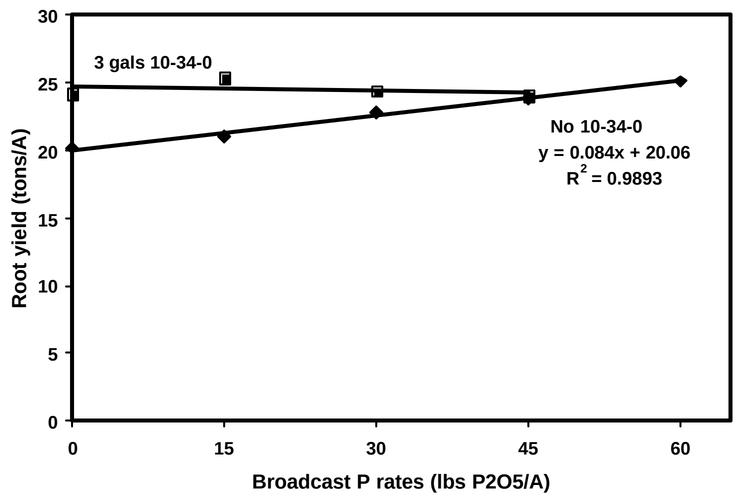

Figure 7. Sugarbeet root yield response to increasing rates of broadcast P fertilizer applied prior to planting with and without 3 gals 10-34-0 A^{-1} banded in-furrow at planting at Alvarado in 2003.

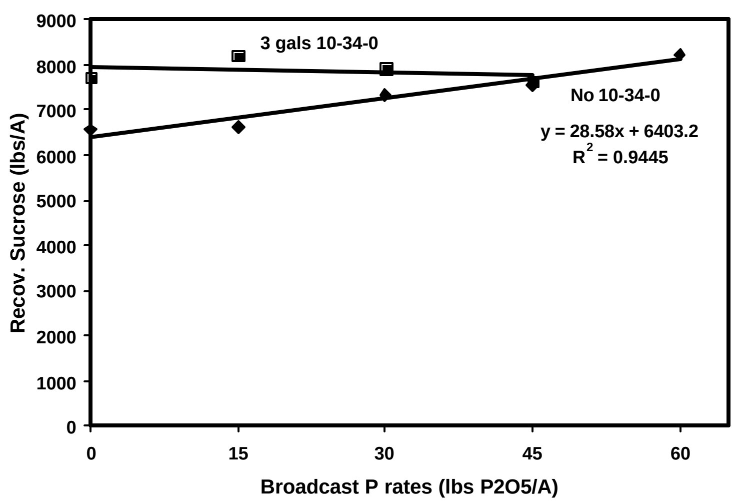

Figure 8. Sugarbeet recoverable sucrose response to increasing rates of broadcast P fertilizer applied prior to planting with and without 3 gals 10-34-0 A^{-1} banded in-furrow at planting at Alvarado in 2003.