USE OF STARTER FERTILIZER TO REDUCE BROADCAST APPLICATIONS OF PHOSPHORUS

Albert L. Sims and Larry J. Smith
Associate Professor of Soil Science and Associate Professor of Agronomy, respectively
Northwest Research and Outreach Center, University of Minnesota, Crookston

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. Sugar beets will frequently show P deficiency symptoms in the early part of the growing season, 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 and 1998 SBREB reports; 2001 SSBR). Some growers have reported that applying three to five gallons of 10-34-0 with the seed at planting yielded satisfactory results without any additional broadcast P fertilizer. Three to five gallons of 10-34-0 supplies 12 to 20 pounds of P_2O_5 A^{-1}. This is considerably less P fertilizer applied than recommended rates of broadcast fertilizer that might range from 60 to 70 pounds P_2O_5 A^{-1} in a low soil P testing soil.

The objectives of this experiment were to evaluate and compare the effects of combinations of liquid 10-34-0 fertilizer applied with the seed at planting and broadcast P fertilizers applied prior to planting on sugar beet performance in a low soil P testing soil.

Materials and Methods

Field Experiments:

Field experiments were conducted at two locations in the 2001 growing season: University of Minnesota Northwest Research and Outreach Center (NWROC) and; 5 miles north east of Climax, Minnesota (Climax). Soil at the NWROC site was a Wheatville loam (mixed, smectitic, coarse silty over clayey, superactive, frigid, Aeric Calciaquoll) and at the Climax site a Colvin-Perella Complex (mixed, fine-silty, superactive, frigid, Typic Endoaquoll). The experimental design was a randomized complete block with four replications. At the NWROC site, treatments consisted of four rates of broadcast P fertilizer (15, 30, 45, and 60 lbs P_2O_5 A^{-1}) without any 10-34-0 P fertilizer at planting, three rates of broadcast P fertilizer (15, 30, and 45 lbs P_2O_5 A^{-1}) with 3 gallons of 10-34-0 P fertilizer at planting, and three rates of 10-34-0 P fertilizer at planting (3, 4, and 5 gallons A^{-1}) with no broadcast P fertilizer (0 P_2O_5 A^{-1}) . At the Climax site, six rates of broadcast P fertilizer (15, 30, 45, 60, 75, and 90 lbs P_2O_5 A^{-1}) without any 10-34-0 P fertilizer at planting, five rates of broadcast P fertilizer (15, 30, 45, 60, and 75 lbs P_2O_5 A^{-1}) with three gallons of 10-34-0 P fertilizer at planting, and three rates of 10-34-0 P fertilizer at planting (3, 4, and 5 gallons A^{-1}) with no broadcast P fertilizer. Broadcast P (0-46-0) fertilizer was evenly distributed over the specified plot area and incorporated with tillage prior to sugar beet planting. Liquid 10-34-0 was dribbled in the furrow with the seed at planting us CO_2 pressure to ensure even distribution in the seed row. At both locations, an additional treatment was added to apply dry P fertilizer (11-52-0) in the furrow with the seed at planting at a rate that would supply the equivalent amount of P as three gallons 10-34-0 with no broadcast fertilizer. The initial soil P tests at NWROC and Climax was 5.0 ppm and 3 ppm, respectively.

Plots were planted with a six-row planter equipped with liquid fertilizer applicators. Sugar beet seed (Beta 6600) was over seeded and manually thinned to 35,640 plants A^{-1} (150 plants per 150 feet of row) when the plants had exposed two true leaves. Plots were 6 rows spaced 22 inches apart (11 feet wide plots) and 35 feet long. Appropriate amounts of nitrogen fertilizer as well as herbicides, insecticides, and fungicides were applied prior to and during the growing season to promote optimal sugar beet production.

At both locations plants were sampled at three different times during the growing season and spaced at 3 wk intervals starting June 18 and 26 at the NWROC and Climax sites, respectively. Rows 2 and 5 of each plot were divided in half providing four equal distance sampling zones. At each sampling date every other plant was sampled from the specified sampling zone. Plants were pulled from the soil, separated into tops and roots, ground or chopped to facilitate drying, dried at 60° 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 was analysis of broadcast P fertilizer rates without 10-34-0 fertilizer. The second was an analysis of broadcast rates through 45 and 75 lbs P_2O_5 A^{-1} at NWROC and Climax, respectively, with and without 10-34-0 fertilizer. And the third was an analysis of the three rates of liquid 10-34-0 and dry 11-52-0 fertilizer without any broadcast P fertilizer.

Greenhouse Experiments:

Greenhouse experiments were conducted during the winter months of 2001 at the NWROC Controlled Environmental Science Facility in Crookston, Minnesota. Three soils were selected, two from sites where the field experiments were conducted in the 2000 growing season (NWROC and Janssen) and one from a farmers field near Whapeton, North Dakota (Whapeton). Soil was placed in round pots that were 8 inches in diameter and 16 inches deep. Approximately 1600 gms of soil was placed in each pot and wetted from underneath until the soil was saturated. Once saturated, the pots were left on the greenhouse bench for 24 hrs and weighed. The difference between wet weight and dry weight (after 24 hours of drainage) was assumed to be the field capacity and would dictate when the pots were watered once the plants began to grow.

Treatments consisted of three rates of broadcast P fertilizer mixed in the top 3 inches of soil with four placements of liquid fertilizer in a 3 by 4 factorial treatment design. Broadcast rates were equivalent to 0, 15, and 30 lbs P_2O_5 A^{-1}. Ten lbs P_2O_5 A^{-1} as fertilizer was applied in a narrow band with the seed, 2 inches below the seed, or 2 inches below and 2 inches to the side of the seed. A check with no banded fertilizer was included with all rates of broadcast P fertilizer. The fertilizer source for both the broadcast and banded P fertilizer was a solution of KH_2PO_4 A^{-1}. Nine sugar beet seeds were planted in a straight line across the surface middle of each pot. After seedling emergence, plants were thinned to leave three plants remaining in each pot. Plants were grown and observed for vigorous growth. When the visual differences in growth due to liquid fertilizer placement began to disappear, the two plants towards the outside of the pot were harvested and evaluated for dry matter accumulation. This occurred about 22 to 26 days after planting in each of the soils. The remaining plant was left until a later date (47 to 53 days after planting) then harvested for dry matter accumulation.

Results

Field Experiments:

There was little difference in harvested root yields and recoverable sucrose among the three rates of liquid 10-34-0 fertilizer (no broadcast P fertilizer). Less than 0.2 and 0.5 tons A^{-1} root yield and 150 and 400 lbs recoverable sucrose A^{-1} separated the three liquid fertilizer rates at the NWROC and Climax sites, respectively. These differences were not statistically significant. Dry fertilizer (11-52-0) applied in the furrow at planting produced less roots and recoverable sucrose than liquid fertilizer at both locations. At Climax this difference was not significant, but dry fertilizer produced 1.5 tons roots A^{-1} and 570 lbs recoverable sucrose A^{-1} less than the average of the three liquid fertilizer rates. At NWROC these differences were greater (2.2 tons roots A^{-1} and 850 lbs recoverable sucrose A^{-1}) and were statistically significant.

The overall root yield and recoverable sucrose yield response to the application of P fertilizer, whether applied at planting or broadcast prior to planting, was less at both locations in 2001 than at the NWROC site in 2000. This may be a result of later planting in 2001 due to cold, wet soil conditions. In 2000, sugar beets were planted earlier in May and the period of time that apparent P deficiency occurred was greater than in 2001. Nevertheless, there was an increase in root and recoverable sucrose yields with the application of P fertilizer compared to the check and it was significant (Table 1).

At NWROC there was a highly significant linear response to broadcast P rates (Table 1) from both the harvested roots and recoverable sucrose. In both cases, however, there was also a highly significant interaction between broadcast P rates and whether liquid fertilizer was applied or not (Table 1). Root yields and recoverable sucrose increased over the entire range of broadcast P rates (Fig 1), but the greatest increase over the check (no P fertilizer) was 2.6 tons roots A^{-1} and 1000 lbs recoverable sucrose A^{-1}. When liquid fertilizer was applied at planting (three gallons of 10-34-0) there was an increase of 5 ton roots A^{-1} and over 1700 lbs recoverable sucrose A^{-1} over the check. Applying additional P fertilizer as a broadcast when liquid fertilizer was applied at planting did not increase either root yield or recoverable sucrose relative to liquid fertilizer alone.

At Climax there was also a highly significant response to broadcast P rates (Table 1) from both harvested roots and recoverable sucrose. Like at NWROC, there was a highly significant interaction with between the broadcast treatments and whether liquid fertilizer was applied at planting or not (Table 1). Root yields and recoverable sucrose increased with increasing broadcasted P fertilizer rates (Fig 2) with increases of 5 tons roots A^{-1} and 1400 lbs recoverable sucrose A^{-1} compared to the check. When three gallons of 10-34-0 was used at planting the increase in both yields over the check were similar (Fig 2). Additional applications of broadcasted P fertilizer did not improve yields.

The two sites varied in their production potential. The NWROC produced on average 6 tons of roots A^{-1} and 2500 lbs recoverable sucrose A^{-1} more than the Climax site. Part of the difference in sucrose production is also attributed to 1.5 % greater net sucrose concentration at NWROC. The production differences between the two locations may be a reflection of the differences in soil types and characteristics. The soil at the Climax site was finer textured, especially below the 3 inch depth, and tended to remain wet for greater periods of time after a rainfall event than the NWROC site. Internal drainage is better at the NWROC site. Nevertheless, the relative response to the application of liquid fertilizers at planting and the comparisons with broadcast P fertilizer were similar between the two sites.

During the Growing Season

Plant samples taken during the growing season are being analyzed for P concentration at this time. However, when evaluating the dry matter accumulation in these plants, two things have become apparent. There is considerable variability among plots as well as plants within individual plots. During our sampling process we sampled every other plant within the sampling zone regardless of plant appearance. Frequently the sampled plant might be substantially smaller or larger than the surrounding plants. Since we were sampling only 11 or 12 plants, one abnormal plant can cause substantial variability in the treatments. Statistical analysis of the dry matter data from the early to mid- season samplings indicate no significant differences among the various treatments in this experiment. Yet we could observe growth differences in the field. In addition, the overall experimental variability was quite high in the early to mid-season samplings compared to the final harvest data where the experimental variability was quite low. The final harvest data were derived from 90 plants or so from rows 3 and 4 in each plot. We propose that in the 2002 growing season we will sample more plants at each of the sampling dates, perhaps at least twice as many plants, but will need to sampler fewer times. In the mean time, we will continue to analyze the data from the 2001 season.

Greenhouse Experiments:

Response of sugar beet dry matter accumulation response to the P fertilizer treatments differed among the three soils. Visual observations indicated that banding P fertilizer was more effective at stimulating early growth than broadcast P fertilizer alone. Further more, it was apparent that the farther away the band was from the seed the longer the period of time after seedling emergence before the increased plant growth occurred. That is, increased plant vigor was observed almost immediately after seedling emergence when P fertilizer was banded with the seed. About 5 days later increased growth was observed where the P fertilizer band was 2 inches below the seed. It was took an additional week before increased growth was observed when the band was 2 inches below and 2 inches to the side of the seed. This is consistent with the results reported by Anderson and Peterson (1978, ASSBT). The most pronounced effects of banded or the broadcasted P fertilizer occurred in the NWROC soil. The effects were less noticeable in the Janssen soil. The visual effects were quite variable in the Whapeton soil.

Total above soil or shoot dry matter (DM) accumulations in the three soils in the first sampling are shown in Figure 3. In both the NWROC and Whapeton soil, there was a significant increase in shoot dry matter when the P fertilizer band was with or below the seed compared to no banded fertilizer or fertilizer banded to the side and below the seed (Table 2). Compared to the check (no P fertilizer) when no broadcast P fertilizer was applied banding P fertilizer with the seed and below the seed increased shoot DM almost 4 and 2.5 times, respectively, in both soils (Fig 3). These differences were somewhat maintained as the rate of broadcast P fertilizer increased. Statistically there was a significant linear response to broadcast P rates, regardless of band placement, in both the NWROC and Whapeton soil (Table 2), but when banded P was present this was obvious only in the Whapeton soil (Fig 3). In the Janssen soil there was linear response to broadcast P rates and a response to banding fertilizer P compared to not banding (Table 2). However, there was little difference between the band placements and there were no significant interactions between the banded treatments and broadcast treatments (Table 2, Fig 3). These results verified the visual observations during this very early growth period. Applying P fertilizer improved plant vigor in all soils whether the fertilizer was applied as a band or broadcast. In two of the three soils the closer the band was placed to the seed, the earlier the observed vigor and the larger the plants at the first sampling date.

At the time of the second sampling, about 3 wks after the first, there was little difference in shoot growth or root growth in the Janssen soil (Table 2, Fig. 4 and 5). The plant vigor and growth response to the fertilizer treatments observed in the early sampling were no longer apparent. In the NWROC soil, the advantage in plant growth when P fertilizer was banded with or below the seed was still apparent and highly significant (Table 2) for both shoot DM (Fig 4) and root DM (Fig 5) accumulations. However, the difference among the three band treatments was small at the highest rate of broadcast P fertilizer. Sugar beet plant growth response, both shoot and root, in the Whapeton soil, was more complicated in that there was little difference between banded treatments at the higher rates of broadcast P fertilizer rates (Fig 4 and 5). At this later sampling DM accumulation in both shoots and roots were greater when P fertilizer was banded with the seed compared to below the seed when there was no broadcast P fertilizer. However, the band two inches below and 2 inch to the side resulted in greater shoot DM than any other band treatment (Fig 4) and root DM was similar to the with-seed band (Fig 5).

The greenhouse component of this experiment demonstrates that very early season growth response to banding P fertilizer compared to broadcast P alone was similar in the three soils tested. However, by seven weeks after planting the growth response to the treatments varied among the soils. Since this experiment did not take the sugar beet plants to final harvest, it is unknown how these early season responses to banded P placement would effect root yield. In the field, both the Janssen and Wahpeton soil have shown some problems in sugar beet production. This may indicate that there are factors other than P availability may be controlling production in some of these soils. What was consistent in all three soils, however, was the improvement in early season plant growth with banded P fertilizers and that the closer the band is to the seed, the earlier the improvement will occur.

Acknowledgements

The authors wish to thank DuWayne Engelstad for allowing us to inconvenience him by placing this experiment in his field (the Climax site). We wish to express our appreciation to thank Kim Hoff, Todd Cymbaluk, and Jeff Nielsen for their technical assistance in getting these experiments completed and analyzed. We also thank the summer crews in both the sugar beet and soils projects for their help in set up, thinning, weeding, and sample processing.

Table 1. Statistical analysis of final root harvest and total recoverable sucrose in response to broadcast P fertilizer and starter P fertilizer in the 2001 growing season at the NWROC and Climax sites.

	NWROC			Climax		
Source of Variation	df	Harv. Roots	Recov. Sucrose	df	Harv. Roots	Recov. Sucrose
		----- PR>F$^{\delta}$ -----			----- PR>F$^{\delta}$ -----	
Statistical Analysis of Broadcast P Fertilizer Rates Without Starter Fertilizer						
Broadcast P rates	4	*	**	6	***	***
P rate linear	1	**	***	1	***	***
P rate quadratic	1	ns	ns	1	**	ns
Statistical Analysis of Broadcast Fertilizer Rates With/Without 3 Gallons of Starter Fertilizer						
Starter Fert.	1	***	***	1	***	***
Broadcast P rates	3	ns	ns	5	***	**
P rate linear	1	*	ns	1	***	***
P rate quadratic	1	ns	ns	1	ns	ns
Start. Fert. by Broad. Fert.	3	*	***	5	***	**
Start. by P rate linear	1	**	***	1	***	***
Start. by P rate quadratic	1	ns	ns	1	ns	ns

$^{\delta}$ *, **, ***, and ns represent significance at the PR level of 0.05, 0.01, 0.001, and non significance, respectively.

Table 2. Statistical analysis of shoot and root dry matter accumulation in response to banded and broadcast P fertilizer treatments in a greenhouse experiment in three soils: NWROC = 1; Janssen = 2,; and Wahpeton = 3.

		1st Sample Tops DM			2nd Sample Tops DM			2nd Sample Root DM		
Source	**df**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**
				------------	------------	PR>F$^{\delta}$	------------	------------		
Bdst P rate	2	*	***	***	***	ns	***	***	**	***
Linear	1	**	***	***	***	ns	***	***	**	***
Quad	1	ns	ns	ns	ns	ns	ns	ns	ns	ns
Band Place	3	***	**	***	***	ns	**	***	ns	ns
Check vs Band	1	***	**	***	***	ns	**	***	ns	*
Side vs Seed	1	***	ns	***	***	ns	*	***	ns	ns
Below vs With	1	**	ns	*	ns	ns	ns	ns	ns	ns
Bdst P rate by Band Place	6	ns	ns	ns	***	ns	*	***	ns	*
Lin by Check vs Band	1	ns	ns	ns	***	ns	ns	***	ns	ns
Lin by Side vs Seed	1	ns	ns	ns	ns	ns	ns	**	ns	ns
Lin by Below vs With	1	ns	*	ns	na	ns	ns	ns	ns	ns
Quad by Below vs With	1	ns	ns	ns	ns	ns	**	ns	ns	***

$^{\delta}$ *, **, ***, and ns represent significance at the PR level of 0.05, 0.01, 0.001, and non significance, respectively.