STARTER POTASSIUM FOR CORN: WHY AND WHEN?

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Introduction

Starter fertilizer application can complement broadcast P and K fertilization for corn and other crops. Questions about its use relate mainly to the conditions in which it is most effective (such as soil-test level, tillage system, and broadcast fertilization rates among others), application methods and rates that do not damage seedlings, and nutrient ratios. Many studies in Iowa and the Midwest have shown that starter mixtures (usually N-P or N-P-K) often increase early corn growth. Corn yield responses to starter fertilizer are inconsistent in high-testing soils or when the starter is applied in addition to broadcast fertilization. In these instances occasional yield responses are observed mainly with minimum tillage and high residue cover, very early or late planting dates, or cold and wet soils (Randall and Hoeft, 1988, Hoeft et al., 1995; Scharf, 1999; Bermudez and Mallarino, 2002 and 2003), and responses often have been attributed to N and P in the starter mixtures.

A recent Iowa study including 16 trials over 3 years (Kaiser and Mallarino, 2005) assessed corn grain yield, early plant growth, and early P and K uptake responses to in-furrow, liquid P-K starter application with or without broadcast P-K fertilization in fields managed with no-till or tillage. Treatments were a control, 3-18-18 liquid starter at 10 to 14 lb of P_2O_5 and K_2O/acre, broadcast P-K before corn to supply the P and K needs of 2-yr corn-soybean rotations, and broadcast plus starter. Starter P-K application in high-testing soils or in addition to pre-plant broadcast fertilization often increased corn early growth and both P and K uptake but never increased grain yield. The starter applied alone increased yield less than broadcast fertilization at most sites testing low in P (< 16 ppm, Bray-1), increased yield as much as broadcast fertilization in several other sites, and there was no clear relationship between response to starter and soil-test K. Therefore, this study suggested that starter K may increase corn early growth yield when soil K is deficient but seldom in high-testing soils or in addition to broadcast fertilization.

Use of liquid N-P-K starter mixtures in most previous studies precludes firm conclusions about starter K effects. Therefore, the goal of this study was to investigate corn response to in-furrow starter K fertilizer without the confounding effects of other nutrients in the mixture. The plan calls for one more year of field trials for a portion of the project, so this article should be considered a summary of preliminary findings.

Trials and Procedures

The study included two different set of trials with corn, both conducted on Iowa farmers' fields. One set used a conventional small-plot methodology (Small Plot Trials) and the other a strip-trial methodology based on GPS, yield monitors, and GIS (Strip Trials).

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Small plot trials.
Six trials were conducted during 2 years (Table 1). Treatments were (1) a control, (2), 3-18-18 in-furrow starter, (3) broadcast P-K in mixture, (4) broadcast P-K plus 3-18-18 starter, (5) 0-0-30 starter, and (6) broadcast P-K plus 0-0-30 starter. The 3-18-18 starter was applied at 5-6 gal/acre in the furrow, which applied 10 to 14 lb of P_2O_5 and K_2O/acre. The 0-0-30 starter was calculated to apply a similar rate of K_2O/acre (3.0 to 3.6 gal/acre). The broadcast treatment was designed to apply in spring before corn the P and K needs of 2-yr corn-soybean rotations based on current Iowa recommendations for soils testing Optimum or lower, but at least maintenance rates of 100 lb of P_2O_5/acre (triple super phosphate) and 120 lb of K_2O/acre (potassium chloride) were applied even to high-testing soils. A uniform rate of 50 lb N/acre (ammonium nitrate or urea) was broadcast at planting time in addition to the farmers' normal N rate. Only Site 1 was managed with no-tillage. Corn row spacing was 30 inches. Soil samples were taken before applying fertilizer and planting corn from the top 6-inch layer of soil. Only Bray-1 soil P results are shown because results for Olsen and Mehlich-3 tests indicated the high pH in Sites 1 and 2 did not affect the Bray-1 extraction. The aboveground parts of corn plants were sampled at the V5 to V7 growth stage to measure dry weight, P and K concentration, and P and K uptake. Plant P concentration and uptake data are not shown or discussed in this article. Grain yield was adjusted to 15.5% moisture.

Strip trials.
Three field-scale strip trials with corn were conducted in 2007 in central, east-central, and southeast Iowa (Table 2). Results from five more trials established in 2008 are not available at this time). Treatments replicated three times at each field were a non-fertilized control, broadcast K that supplied the K needed for the 2 years of corn-soybean rotations (but at least 120 lb K_2O/acre), 0-0-30 in-furrow starter K that applied 15 to 22 lb K_2O/acre, and broadcast K plus starter K. Strip length was 960 feet (excluding field borders) and strip width varied across fields according to the width of planters and fertilizer spreaders. The farmers managed corn and soil using their common practices, including N and P fertilizer rates. Field 3 was managed with no-tillage. Soil samples were taken from a 6-inch depth before applying the treatments by collecting 12-core composite samples the center of grid cells 0.10 to 0.25 acres in size. The aboveground parts of corn plants were sampled at the V5 to V7 growth stage to measure dry weight, K concentration, and K uptake. Grain yield was measured with combines equipped with calibrated yield monitors and GPS, and was adjusted to 15.5% moisture. The yield data were imported into ArcGIS, and analyzed and corrected for errors that commonly occur when using yield monitors before for GIS and statistical analyses. Yield maps were subdivided into polygons defined by the replications, treatment strips, and digitized soil survey maps to study crop response to fertilization for each soil type present at each field. Data from each strip trial were analyzed in two ways. A first analysis consisted on studying the corn plant and grain yield responses along the entire lengths of the strips. The second analysis recognized the presence of different soils in the fields, and data were analyzed for each soil series that encompassed at least two field replications and strip length was at least 150 feet for all treatments.

Results from Small Plot Trials

Early corn growth responded to one or more fertilizer treatments at five sites (Table 3). The only exception was at Site 1, which was managed with no-tillage and where soil P was Optimum, soil

K was Low, and the planting date was the latest of all sites. Starter P-K applied alone increased early growth more and more frequently than starter K alone. Although the broadcast P-K rate was almost 10 times higher than the starter P or K rates, broadcast fertilization increased growth more than starter P-K only at Site 4, while starter P-K alone increased growth more than broadcast alone in two sites (Sites 5 and 6). Application of starter P-K in addition to broadcast P-K increased corn growth further in two sites (Sites 5 and 6) but application of starter K in addition to broadcast fertilizer never did. Therefore, the results demonstrate that a small starter P rate can stimulate early growth as much as or more than much higher broadcast rates and sometimes even in addition to broadcast fertilization, but this was not the case for starter K.

The K concentration of young corn plants was increased by one or more treatments at all sites (Table 3). Broadcast fertilization was more effective at increasing K concentration than either starter P-K or starter K alone, probably due to the higher amount of K applied. The only exception was at Site 1, where the broadcast plus starter K treatment showed the highest K concentration. There was little or no K concentration response to starter K alone and, in fact, starter P-K increased K concentration more than starter K in two sites. Early corn K uptake was increased at all six sites (Table 3). Starter P-K always increased K uptake over the control but starter K alone never did. A K uptake response to starter P-K and not to starter K may indicate that starter P plays a major role in root growth and K uptake of K early in the growing season when root expansion is limited. Only at one site there was a small benefit from applying K both broadcast and in-furrow.

Corn grain yield was increased by one or more fertilizer treatments at five sites (Table 3). The only non-responsive site had the highest soil-test values (Site 3). According to current Iowa State University soil-test interpretation categories, the probability of corn response is 80% for Very Low, 65% for Low, < 25% for Optimum, and < 5% for High (Sawyer et al., 2002). At Site 1, all treatments increased grain yield over the control and the increases were statically similar. At Site 2, all treatments increased yield but the increase was less for starter K applied alone. At Site 4, broadcast fertilization increased yield while the starter fertilizers did not. We do not understand the reason why starter fertilizer did not increase yield at this field (there was only a small increasing trend) because both soil-test P and K were Very Low. At Sites 5 and 6, broadcast fertilization increased yield more than the starter fertilizers. At Site 5 both soil P and K were Low while at Site 6 P was Low and K was Optimum. Applying starter in addition to broadcast P-K fertilization never increased yield. These results showed that frequent early growth and nutrient uptake responses to starter P-K, even in addition to broadcast fertilizer, do not necessarily result in grain yield increases.

Results from Strip Trials

Analyses of data for the entire length of the strips indicated that one of more K treatments increased ($P < 0.10$) early corn growth, K concentration, or K uptake at Field 2 and 3 (not shown). At Field 2, which on average tested 156 ppm in K, both fertilizers increased K concentration but only starter increased K uptake probably as a result of non-responsive and variable plant dry weights. At Field 3, which tested 175 ppm in K, broadcast K fertilization increased the three plant measurements, while starter K only increased K concentration and uptake. No fertilization treatment increased corn yield significantly, although there were

responsive trends to both broadcast and starter fertilization in Field 1 and to broadcast fertilization in Field 3. A yield response was expected in Fields 2 and 3 according to previous Iowa research and Iowa soil-test interpretations. Starter K seldom affected plant measurements when applied in addition to broadcast K fertilization (it increased early K concentration and uptake further only in Field 3).

Analyses of data for the two predominant soil series in each field showed that treatments seldom increased early corn growth and grain yield but frequently increased early K concentration and uptake (Table 4). Fertilization increased early K concentration at both soils in Fields 2 and 3 and early K uptake at one soil of these two fields. Differences between broadcast and starter K fertilizers applied alone were inconsistent in these responsive instances, and starter application in addition to broadcast fertilization increase K concentration or uptake in about one-half of the instances. The grain yield responses in general followed trends observed for the strip averages with one notable exception. A non-significant responsive trend observed for Field 3 became significant for the Clarion soil, where the three fertilized treatments did not differ but increased yield over the control. This soil had the lowest average soil-test K value of all six field-soil combination except for the Kenyon soil in Field 2.

General Conclusions

Broadcast or starter P or K fertilization did not increase ($P < 0.10$) corn yield in high-testing soils. Results from the study that compared starter containing only K or both P and K showed that starter P very often increased early corn growth and nutrient uptake even in high-testing soils, and sometimes even after applying much higher broadcast fertilizer rates. Results for starter K applied alone from both studies showed that it seldom increased early growth but sometimes increased early plant K concentration and uptake. These responses to starter P or K were poor indicators of grain yield response to starter, however. Although corn yield increases from starter containing P or K sometimes were similar to increases from much higher broadcast application rates designed to buildup or maintain soil-test values, starter applied in addition to broadcast fertilization never increased yield further.

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Table 1. Small plot trials locations, years, and summary field information.

				Soil-Test Values †				Planting	Corn
Year	Site	County	Soil	STP	STK	pH	OM	Date	Hybrid
				--- ppm ---			%		
2004	1	Iowa	Sparta	16	103	7.7	3.2	May 8	NK 5299
	2	Bremer	Readlyn	5	103	7.3	3.8	Apr 28	DK C58-78
	3	Bremer	Readlyn	56	148	6.4	3.8	Apr 28	DK C60-19
2005	4	Bremer	Readlyn	4	82	6.6	3.2	Apr 18	DK C58-80
	5	Bremer	Marshan	15	117	6.8	6.6	Apr 18	DK C58-80
	6	Calhoun	Webster	13	143	5.6	5.5	May 2	P 35Y67

† STP, Bray-1 P; STK, ammonium acetate K; OM, organic matter.

Table 2. Strip trials locations, years, and summary field information.

			Soil-Test Values †				Planting	Corn
Field	County	Dominant Soils	STK	KCV	pH	OM	Date	Hybrid
			--- ppm ---			%		
1	Iowa	Zook/Koszta	214	23	7.4	5.9	May 1	P 34A12
2	Bremer	Readlyn/Kenyon	156	20	6.5	3.8	May 5	DK C58-13
3	Greene	Clarion/Webster	175	19	6.5	4.6	May 14	NT 2503HX

† STK, ammonium acetate K; KCV, K coefficient of variation; OM, organic matter.

Table 3. Fertilization effects on early corn dry weight, K concentration, and K uptake at the V5 to V7 growth stage and grain yield (small plot trials).

			3-18-18 Starter		0-0-30 Starter	
Site	Control	Broad P-K	Alone	+ Broad P-K	Alone	+ Broad P-K
	---------- Plant Dry Weight (g/plant) † ----------					
1	10.7	11.5	10.2	11.7	10.7	11.3
2	2.0b †	2.4a	2.5a	2.6a	2.2ab	2.6a
3	1.2bc	1.7a	1.8a	1.9a	1.1c	1.6ab
4	2.5bc	3.9a	3.2ab	3.6a	2.0c	3.2ab
5	2.7bc	3.1bc	3.5ab	4.4a	2.4c	3.6ab
6	3.3c	4.6b	4.6bc	6.4a	3.5bc	4.5bc
	---------- Plant K Concentration (%) ----------					
1	2.53c	3.95ab	2.17c	3.53b	2.55c	4.54a
2	2.40bc	3.09ab	2.38c	3.51a	2.38c	3.38a
3	4.17c	4.42b	4.07c	4.67a	4.08c	4.62ab
4	2.25b	3.87a	2.61b	4.10a	1.91b	3.84a
5	2.34cd	3.86ab	3.22bc	4.52a	2.22d	3.69ab
6	1.62e	3.26ab	2.47c	3.60a	2.10d	3.02b
	---------- Plant K Uptake (mg/plant) ----------					
1	281.3b	459.9a	236.5b	413.7a	266.9b	515.6a
2	47.8c	75.5ab	59.3bc	93.4a	53.2bc	87.6ab
3	50.3b	73.1a	70.9a	86.4a	45.8b	74.5a
4	57.0c	154.4a	87.0bc	149.5a	39.2c	124.8ab
5	68.8cd	120.9bc	117.0bc	199.2a	56.8d	134.6b
6	55.0c	152.2b	133.3b	244.1a	74.4c	136.3b
	---------- Grain Yield (bu/acre) ----------					
1	161.2b	192.8a	182.0a	183.6a	184.5a	188.7a
2	158.7b	176.3a	176.3a	184.7a	171.2ab	177.5a
3	179.3	177.1	182.7	183.3	172.5	182.7
4	170.5b	210.4a	172.0b	208.9a	175.4b	209.0a
5	169.2c	204.2a	184.1bc	204.9a	184.0bc	194.5ab
6	128.9b	169.5a	146.9ab	162.6a	153.7ab	171.5a

† Different letters indicate significant differences (P # 0.05) between treatments at each site.

Table 4. Potassium fertilization effects on early corn growth, K concentration, and K uptake at the V5 to V7 growth stage and grain yield (strip trials).

				Broadcast K	
Field	Soil series	No K	Starter K	No Starter	Starter
		--- Plant Dry Weight (g/plant) † ---			
1	Zook	10.9	11.1	11.8	10.9
	Koszta	11.3	10.0	10.0	9.2
2	Readlyn	4.3b	5.0a	4.1b	4.0b
	Kenyon	3.9	4.0	3.3	3.5
3	Clarion	3.5	4.3	3.8	3.8
	Webster	3.9	3.6	4.7	4.4
		--- Plant K Concentration (%) ---			
1	Zook	4.3	4.5	4.8	4.8
	Koszta	4.7	4.6	4.9	4.2
2	Readlyn	4.1c	4.3b	4.5a	4.4b
	Kenyon	4.0b	4.3a	4.5a	4.4a
3	Clarion	2.8d	4.1b	3.8c	4.6a
	Webster	3.9b	4.7a	4.6a	5.1a
		--- Plant K Uptake (mg/plant) ---			
1	Zook	452	502	565	548
	Koszta	516	447	494	386
2	Readlyn	175c	216a	185b	177c
	Kenyon	156	171	152	150
3	Clarion	99b	184a	146a	177a
	Webster	152	167	218	225
		--- Grain Yield (bu/acre) ---			
1	Zook	169.3	183.9	181.6	181.2
	Koszta	179.9	181.5	179.2	184.5
2	Readlyn	149.5	148.8	150.1	147.6
	Kenyon	152.6	154.5	141.2	147.5
3	Clarion	124.2b	134.9a	135.4a	136.8a
	Webster	135.6	131.9	147.7	153.2

† Mean soil-test K values for the six soil areas were 236, 213, 154, 137, 145, and 180 ppm, respectively. Letters by each mean indicate significant differences at $P < 0.10$.

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