A Look At Effects Of In-furrow Applications Of Potassium On Corn

Iowa on-farm fluid trials show mixed results regarding nutrient uptake, early growth, and actual grain yield after applying starter K.

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Summary: *Fluid starter containing potassium (K) and phosphorus (P) often increased early corn growth and uptake of both nutrients more than a higher broadcast rate, even in the high-testing soils, but this response did not translate into higher grain yield with starter. Starter K alone seldom increased early growth or K uptake (sometimes decreased it) and often increased early plant K concentration but this response often was not reflected in increased grain yield. Starter P-K or K applied in addition to broadcast fertilization never increased yield further. Larger and more frequent starter effects from P than from K are in agreement with results of basic studies conducted during the '70s and '80s, which showed a higher maximum root uptake rate for K than P in the nutrient-concentrated zone but more root proliferation for P. A grain yield response to broadcast fluid starter sometimes was observed in soils testing high in K, but not with soils high in P. An important result was that fluid starter often resulted in corn yield increases similar to those from much higher broadcast fertilizer rates. However, in-furrow starter was not an effective practice when it was applied in addition to broadcast P-K rates planned to maintain or build up soil test values for 2-year corn/soybean rotations.*

Placement of small amounts of nutrients in bands beside and below the seeds or in the seed furrow significantly increases the concentration of nutrients in the small soil volume where seedling roots grow. Common fluid starters are nitrogen (N)-P or NPK products or mixtures to which other nutrients often are added. Research summarized in thorough reviews indicates that starter fertilizer often increases early corn growth and nutrient uptake more than similar or higher broadcast rates. The growth response to starter usually is larger and more frequent where 1) conditions limit root growth or activity, 2) where there is concentration in the soil of nutrient forms plants can absorb, or 3) where there is nutrient diffusion to the root. Research has shown, however, that starter effects on grain yield are not consistent.

Phosphorus is a relatively immobile nutrient, its diffusion to seedling roots is limited by cold soil temperature and it is critical for plants, especially during early growth. Research has shown that N also often explains corn response to starter, especially in soils testing high in P.

Some studies have suggested that K may explain the early corn growth and yield response to starter in low-testing soils but provided poor evidence of a true starter K effect. Recent research with liquid 3-18-18 starter provided no clear clues, but suggested little or no true starter effects from K.

Knowledge of the existence of a starter K effect, and the conditions in which it is more likely, is important to improve the efficiency and economics of fertilizer use. This is because many producers' fields test optimum or high in soil test K and most fertilization guidelines recommend starter for soils only under certain conditions. Another very important point to keep in mind for in-furrow starter application is that K compounds are the most common cause of salt damage, so some fluid fertilizers are expensive because they use low salt K compounds to minimize seedlings damage. A few decades ago starter fertilizers used in the Corn Belt were mostly granulated products, but use of liquid starter fertilizers predominates today. Larger corn planters have also brought about a steady change from the classic "2 x 2" placement method to in-furrow application. Therefore, the goal of this study was to investigate corn response to in-furrow liquid starter K without the confounding effects of other nutrients.

Small plot trials

Early corn growth responded to one or more fertilizer treatments at five of six sites (Table 1). The only exception was site 1, under no-till management, where soil P was optimum, soil test for K was low (not shown), and the planting date was the latest of all the sites. Starter PK applied alone increased early growth in the five responsive sites while starter K alone increased growth in two sites but decreased it in three sites. Although the broadcast PK rate was almost ten times higher than the starter rate, broadcast fertilization alone increased growth more than starter PK only at site 4, while starter PK increased growth more than broadcast at site 5. Application of starter PK in addition to broadcast PK increased corn growth at sites 5 and 6 but starter K, in addition to broadcast fertilizer, never increased growth but decreased it at three sites. Therefore, the results demonstrated that starter P can stimulate early growth as much as or more than much higher broadcast rates and even in addition to broadcast fertilization. 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 1). Plant P concentration and uptake data are not shown or discussed. Broadcast fertilization was more effective at increasing K concentration than either starter PK or K at all sites, probably due to the higher amount of K applied. Starter PK increased K concentration more than starter K in sites 5 and 6. Starter PK, applied in addition to broadcast PK, increased K concentration further at four sites. Starter K, in addition to broadcast fertilization, increased K concentration further in three sites. Early corn K uptake data integrated results for growth and concentration (Table 1). Starter PK increased K uptake over the control in five of six sites, but starter K alone increased uptake at site 2 and decreased uptake at site 5. Starter PK applied in addition to broadcast PK increased K uptake further at sites 2, 5, and 6, but starter K decreased uptake at site 4 and increased it at site 5. Therefore, these results show that P, or PK together, play a major role in early growth and K uptake.

Corn grain yield was increased by one or more treatments at five sites (Table 1). Site 3, the only non-responsive one, had the highest soil test values. According to current Iowa State University soil test interpretation categories, the probability of corn response is 80 percent for very low, 65 percent for low, less than 25 percent for optimum and less than 5 percent for high. At site 1 all treatments increased yield over the control and the increases were statistically similar. At site 2 all treatments increased yield but the increase was less for starter K applied alone (soil P was very low). At site 4, broadcast fertilization increased yield while the starter fertilizers did not. We do not understand why starter fertilizer did not increase yield at this site (there was a small increasing trend) since soil test P and K were very low. At sites 5 and 6, broadcast fertilization increased yield more than the two 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 PK never increased yield further. These results showed that early growth and nutrient uptake responses to starter do not necessarily result in grain yield increases.

Table 1. Phosphorus and potassium fertilization effects on early corn growth and K concentration (V5 to V7 stage) and grain yield for six small-plot trials.

		Broadcast	3-18-18 Starter		0-0-30 Starter	
Site	Control	P-K Alone	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	2.0a†	2.4c	2.5c	2.6c	2.2b	2.6c
3	1.2b	1.7d	1.8d	1.9d	1.1a	1.6c
4	2.5b	3.9d	3.2c	3.6d	2.0a	3.2c
5	2.7b	3.1b	3.5c	4.4d	2.4a	3.6c
6	3.3a	4.6c	4.6c	6.4d	3.5b	4.5c
	Plant K Concentration (%)					
1	2.53a	3.95c	2.17a	3.53b	2.55a	4.54d
2	2.40b	3.09c	2.38a	3.51d	2.38a	3.38d
3	4.17a	4.42b	4.07a	4.67d	4.08a	4.62c
4	2.25a	3.87b	2.61a	4.10b	1.91a	3.84b
5	2.34b	3.86d	3.22c	4.52e	2.22a	3.69d
6	1.62a	3.26e	2.47c	3.60f	2.10b	3.02d
	Plant K Uptake (mg/plant)					
1	281a	460b	237a	414b	267a	516b
2	48a	76c	59b	93d	53b	88c
3	50a	73b	71b	86b	46a	75b
4	57a	154d	87b	150d	39a	125c
5	69b	121c	117c	199e	57a	135d
6	55a	152b	133b	244c	74a	136b
	Grain Yield (bu/acre)					
1	161a	193b	182b	184b	185b	189b
2	159a	176c	176c	185c	171b	178c
3	179	177	183	183	173	183
4	171a	210b	172a	209b	175a	209b
5	169a	204d	184b	205d	184b	195c
6	129a	170c	147b	163c	154b	172c

Numbers in a row followed by no letter or a similar letter do not differ ($P < 0.10$)

Strip trials

By field. Potassium fertilization effects on corn early growth were significant ($P \leq 0.10$) in five sites, but effects were inconsistent (Table 2). In field 2, starter K alone increased early growth slightly but all other treatments decreased it. In field 3 (a no-till site), broadcast K increased growth slightly, starter K did not affect it, and application of starter in addition to broadcast decreased growth compared with broadcast applied alone. In field 4 (the other no-till site), broadcast K did not affect growth but starter K decreased it when applied alone or in addition to broadcast K. In field 8, broadcast K did not affect growth but starter K applied alone decreased it.

The inconsistent and small early growth responses to broadcast or starter K fertilization across fields could not be explained by the soil test K level or any other measurement taken. Salt effects on roots and water uptake might explain a growth reduction from applied K, but we doubt this was the case in our study. Field observations indicated that no treatment reduced corn plant population significantly at any field. Broadcast rate of K_2O at 120 lbs/A as potassium chloride did not decrease early growth at the no-till fields but decreased it in some fields managed with tillage. This K rate incorporated into the soil with tillage should not affect growth. The low salt 0-0-30 fertilizer (potassium carbonate) applied to the seed furrow at K_2O rates of 15 to 22 lbs/A did not result in obvious salt effect symptoms nor decreased stands. Therefore, we believe that the results reflect no K effect on early corn growth, and that the inconsistent (and often small) increases or decreases resulted from variability in other growth factors. The results of the small-plot studies also showed infrequent and inconsistent effects of starter K on early corn growth.

In contrast to results for early corn growth, K fertilization often increased early plant K concentration (Table 2). In four fields (3, 5, 6, and 7) all treatments increased plant K concentration with the increases being largest for broadcast K alone, then for starter K alone, although the difference was not statistically significant in field 6. Application of both broadcast and starter K resulted in the highest early K concentration except in field 7. At field 8, however, and for unknown reasons, application of broadcast or starter K alone did not affect plant K concentration but application of both decreased it. It is interesting that increases in plant K concentration were observed when fertilization decreased or increased early growth. The previous research with 3-18-18 and 0-0-30 starter fertilizers also showed large plant K concentration increases, even when 0-0-30 seldom increased and sometimes decreased it. Early corn K uptake responses (Table 2) reflected mainly effects on plant growth and, therefore, effects were infrequent and inconsistent across fertilizer and sites. At field 2, only starter K increased K uptake. At field 3, both fertilizers increased K uptake but the increase was largest for broadcast K. At field 8, broadcast K did not affect growth but starter K decreased it. These inconsistent results for starter K are in agreement with results from the other set of small plot trials.

The K fertilization effects on corn grain yield were significant in three fields (1, 4, and 6), where both broadcast K and starter K applied alone increased yield (Table 2). In field 1, broadcast K alone increased yield more than starter K, and the increases over the control were 11 bu/A for starter and 21 bu/A for broadcast. In field 4 the effects of broadcast K alone and starter K alone on yield were statistically similar, although the increase seemed greater for starter K than broadcast K (6 bu/A greater). In field 6 the effects of broadcast K alone and starter K alone on yield were also statistically similar, but the increase seemed greater for broadcast K than for starter K (7 bu/A greater). An important result was that starter K applied in addition to broadcast K did not increase yield further at any field. Another important result was that there was no yield response to any K fertilizer at fields where at least some treatments increased early plant growth. The soil test K values for these fields (Table 3) and current interpretations in Iowa explained the yield responses only partially. A small or no yield increase also was expected in field 1 because mean soil test K was borderline between high and very high, but values across the field ranged from low to very high (Table 3). A yield increase was expected in field 4 because mean soil test K was low and values ranged from very low to borderline between low and optimum. A yield increase also was expected in field 6, although smaller than for field 4 because mean soil test K was borderline between low and optimum, although values ranged from very low to high. On the other hand, no statistically significant yield increase was observed in field 2 where a small response was expected because mean soil test K was optimum. The unexpected increase response in field 1 or lack of response in field 2 might be explained by variability of soil test K or soil types within the fields.

By soil type. Soil types may affect corn response to K fertilization within a field because of potential differences in soil test K and other properties that may affect crop growth and response to K fertilizer. There were two dominant soil types in seven of the fields, so we analyzed corn response to K fertilizer for each dominant soil. Fertilizer K effects on early corn growth and K uptake by soil type were as inconsistent as for the whole-field analysis, while both fertilizers usually increased early-plant K concentration. Therefore, we show in Table 4, and discuss only results for grain yield, the four sites in which there was a differential yield response to K fertilization across soils.

In field 1, a whole-field yield increase was explained by a response only in areas with Zook soil, and responses were similar for broadcast and starter K fertilizers. Soil test K was very high for both soils, being only slightly higher for Zook. Therefore, we believe that the higher response for the Zook soil is explained by properties that increase the likelihood of crop response to K, such as finer texture and poorer drainage. In Field 3 the whole-strip analysis showed no yield response, but the analysis by soil type showed a response for the Webster soil. In areas with Webster soil the broadcast K increased yield by 15 bu/A compared with the control, but starter K did not increase yield. We cannot explain the lack of response to starter K. Although soil test K was similar (optimum) for both soils, other soil properties may explain a yield

Table 2. Potassium fertilization effects on early corn growth and K concentration (V5 to V7 stage) and grain yield for eight strip trials.

	No Broadcast K		Broadcast K	
Field	No K	Starter K	No Starter	Starter
	Plant Dry Weight (g/plant)			
1	11.1	10.7	11.2	10.0
2	4.1c	4.4d	3.5a	3.9b
3	3.5a	3.8a	4.3c	3.9b
4	6.6c	6.3b	6.6c	6.1a
5	15.1c	12.9a	12.0a	11.2a
6	9.9	9.5	8.6	8.6
7	3.9	4.3	4.1	3.9
8	6.4b	5.6a	6.8b	6.4b
	Plant K Concentration (%)			
1	4.3	4.3	4.7	4.6
2	4.1	4.2	4.5	4.3
3	3.6a	4.0b	4.2c	4.7d
4	3.0	3.3	3.2	3.7
5	3.0a	3.2a	3.5b	3.7c
6	2.8a	3.4b	3.6b	4.1d
7	4.1b	3.9a	4.2c	4.2c
8	4.0b	3.9b	3.8b	3.5a
	Plant K Uptake (mg/plant)			
1	465	456	536	461
2	165a	187b	160a	165a
3	127a	153b	182c	183c
4	196	208	205	218
5	455	412	416	411
6	296	331	326	357
7	162	169	173	165
8	260b	222a	266b	230a
	Grain Yield (bu/acre)			
1	174a	185b	195c	190c
2	149	151	149	149
3	133	133	140	141
4	172a	189c	183c	180b
5	200	206	211	204
6	205a	217b	224b	224b
7	222	231	230	230
8	221	222	222	224

Numbers in a row followed by no letter or a similar letter do not differ ($P < 0.10$)

Table 3. Strip trials locations, years, and summary field information.

					Soil-Test Values†				
			Planting	Corn	Soil-Test K				
Year	Site	Company	Date	Hybrid	Min	Avg	Max	pH	OM
					----------ppm----------				
2007	1	Iowa	1 May	P34A12	116	214	283	7.4	5.9
	2	Bremer	5 May	DK C58-13	111	156	229	6.5	3.8
	3	Greene	14 May	NT 2503HX	124	175	251	6.5	4.6
2008	4	Jasper	19 May	Crows 4940 T	71	102	133	5.7	2.7
	5	Bremer	15 May	DK 61-69	113	180	213	6.6	4.9
	6	Iowa	2 May	P 33F12	91	130	197	7.0	7.1
	7	Washington	8 May	DK 61-69	132	220	433	7.4	4.6
	8	Washington	8 May	DK 58-16	110	223	280	6.9	4.1

†Ammonium-acetate test for K; Min, minimum; Avg., average; Max, maximum; OM, organic matter.

response to K only for the Webster soil because it is more poorly drained and finer-textured than Clarion. In field 5 the whole-strip analysis did not show a yield response but the analysis by soil type showed a yield response for areas with Tripoli soil. The yield increase was similar for broadcast and starter K, but application of both reduced yield to the control level. The magnitude of the yield increase was even larger for areas of Floyd, although soil test K was similar (optimum) for both soils. Therefore, the statistically significant response only for the Tripoli soil might be explained by a more consistent corn response across the replications. In field 7 the whole-strip analysis did not show a yield response but the analysis by soil type showed a response for areas with Mahaska soil, where broadcast or starter K increased yield by about 10 bu/A compared with the control. A larger response for the Mahaska soil is reasonable because soil test K was borderline between high and very high classes while areas of Taintor tested much higher. The yield response was higher than expected. But according to previous Iowa research, a response in a high-testing soil can occur with a 5 percent probability.

Table 4. Potassium fertilization effects on grain yield for the two dominant soil types in four strip trials where responses differed across soils.

			No Broadcast K		Broadcast K	
Site	Soil Type	Soil-Test K	No K	Starter K	No Starter	Starter
		ppm	----------------Grain Yield (bu/acre)---------------			
1	Zook	236	154a	180b	187b	183b
	Koszta	213	181	183	179	189
3	Clarion	145	129	132	134	134
	Webster	180	138a	135a	151b	149b
5	Floyd	149	196	200	214	210
	Tripoli	155	202a	207b	211b	202a
7	Mahaska	214	220a	231b	229b	229b
	Taintor	268	232	240	233	238

Numbers in a row followed by no letter or a similar letter do not differ (P < 0.10).

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