Corn Response to Broadcast and Starter K Fertilizers over the Landscape

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Introduction

The field trials for this on-farm project were established and harvested in 2007 and 2008, while sample and data analyses were completed during 2009. Detailed results were included in Mr. Nicolas Bergmann M.S. Thesis. This report summarizes the most important and clear results of the project without going into the details of a student Thesis or journal article.

Background

Research has shown that starter fertilizers, often N-P-K mixtures, often increases corn early growth and nutrient uptake more than similar, and sometimes higher, broadcast fertilizer rates. The growth response to starter fertilizer is larger and more frequent in conditions that limit root growth or activity, reduce the concentration in the soil of nutrient forms that plants can absorb, or slow down nutrient diffusion to the root. For example, large early corn growth responses to starter fertilizer often are observed with cold and wet soils and also when thick residue cover keeps soil cooler and wetter in early spring. Research has shown, however, that starter effects on grain yield are not as consistent. The inconsistent yield responses to starter often cannot be clearly explained, which is attributed to complex interactions between soil conditions, climate, and planting dates.

Corn responses to starter fertilizer mixtures often are explained by P in the starter (Randall and Hoeft, 1988; Bundy et al., 2005). Research also has shown that N often explains corn response to starter, however, especially in soils testing high in P. Bundy et al. (2005) concluded that responses to starter N tend to be more frequent in northern areas of the Corn Belt. Research comparing N and N-P or N-P-K starter fertilizers in eight Iowa no-till fields that tested optimum to very high in P (Bermudez and Mallarino, 2003) found that corn grain yield responses always were explained by starter N. The common use of liquid N-P or N-P-K starter mixtures precludes firm conclusions about starter K effects on corn, however. Potassium supply may explain the early corn growth and yield response to starter in low-testing soils but there is poor evidence of a true starter K effect. Iowa research with granulated P or K fertilizers broadcast or banded beside and below the seeds showed a clear effect of band P on corn growth but not of K (Bordoli and Mallarino, 1998; Mallarino et al., 1999). Iowa research with liquid 3-18-18 starter and broadcast P-K fertilization (Kaiser et al., 2005) provided no clear clues about true starter effects from K because P and K were included in the product mixture, but suggested a clear effect for P and no or little effect for K.

A more recent set of six trials conducted in Iowa during 2005 and 2006 (Mallarino and Kaiser, unpublished) compared 3-18-18 and 0-0-30 in-furrow liquid starter fertilizers for corn applied alone or after broadcast P-K fertilization. The starter rates used applied a similar amount of K (10 to 14 lb K_2O/acre) while the broadcast treatment applied the P and K needs of 2-year corn-soybean rotations (at least 100 lb of P_2O_5/acre and 120 lb of K_2O/acre). The farmers applied their normal N rate before planting corn and 50 lb N/acre were applied across all plots at planting time. Starter P-K increased early corn growth in five fields while starter K increased growth only in two fields and decreased it in three fields. Applying starter P-K in addition to broadcast P-K increased growth further in two fields, but starter K in addition to broadcast fertilizer never increased growth further and decreased it at three fields. All fertilizers increased plant P and K concentration in all fields. Starter P-K alone increased K uptake in five fields, but starter K alone increased uptake only in one field and decreased in another. Starter P-K applied in addition to broadcast P-K increased K uptake further at three fields, but starter K decreased it at one site and increased it at one site. The starter K effects on corn early growth, K concentration, and K uptake were not related to observed grain yield responses. Therefore, these results showed that P definitely plays a major role on stimulating early growth and perhaps yield but this is not necessarily the case for K.

Review of Objectives

There is a need to investigate the corn response to in-furrow liquid starter K fertilizer without the confounding effects of other nutrients. 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 (STK) and fertilization guidelines recommend starter for these soils only under certain conditions. Another important reason is that K compounds are the most common cause of salt damage to seedlings, so some fluid fertilizers are expensive because they use low-salt K compounds to minimize seedling damage. As both fields and corn planters became larger there has been a steady change from the classic "2x2" placement method to in-furrow application. The specific objectives were (1) to evaluate corn early growth, early K uptake, and corn grain yield responses to in-furrow liquid K starter applied alone or in addition to broadcast K fertilization rates commonly used by Corn Belt farmers and to study and (2) to determine potentially differential responses to starter K for different soil types present within producers' fields.

Field Trials and Procedures

The project used an on-farm, strip-trial methodology based on GPS, yield monitors, and GIS to conduct eight field-scale trials in two years (Table 1). Treatments replicated three times were a non-fertilized control, broadcast K that supplied the average amount of K needed to maintain STK levels in 2-year corn-soybean rotations (120 lb K_2O/acre), 0-0-30 in-furrow starter that applied 15 to 22 lb K_2O/acre across fields, and broadcast K plus starter K. The size of each trial was approximately 17 to 27 acres. The treatments and replication layout followed a randomized complete block, split-plot design, with broadcast rates in large plots and starter rates in subplots. Fields 3 and 4 were managed with no-till. Corn row spacing was 30 inches. Soil samples (6-inch depth) were collected before applying K treatments from grid cells whose size varied among fields from 0.33 to 1 acre. A composite sample of the above-ground portion of ten corn plants was collected at the V5 to V7 growth stage from areas delimited by the width of a treatment strip and the length of the soil-sampling grid cell. Grain was harvested with combines equipped with calibrated yield monitors, moisture sensors, and GPS receivers with differential correction. The yield monitor spatial accuracy was checked in several field locations with a hand-held GPS receiver, and yield data were unaffected by borders because at least 120 feet at each strip end were harvested but not used. ArGIS software was used to identify common yield monitor problems (such as unplanned combine stops or effects of waterways) and to delete affected data.

The soil samples were analyzed for K and other routine tests. In this article we will use the Iowa interpretation classes to classify STK values (Sawyer et al., 2002). The boundaries are ≤ 90 ppm for Very Low, 91 to 130 ppm for Low, 131 to 170 ppm for Optimum, 171 to 200 ppm for High, and ≥ 201 ppm for

Very High. The guidelines recommend maintaining STK in the Optimum class by applying K rates similar to K removal with harvest. No K fertilizer is recommended for the high-testing classes except for a common starter mixture for corn with wet and cool soil, crop residues on the soil surface, or late planting dates with full-season hybrids. The plant-tissue samples were dried at 140 °F, weighed, and ground to pass through a 2 mm screen. The total plant P and K concentration was analyzed by an acid, wet-digestion method and measuring K by inductively-coupled plasma emission spectroscopy.

The GPS coordinates of the field layouts, boundaries of georeferenced digitized soil survey maps, and the collected data were imported into ArcGIS. We used GIS spatial analysis techniques to average yield monitor points for the whole length of each strip, for areas delimited by each strip within each soil series (from georeferenced and digitized soil survey maps), and for areas delimited by each strip and polygons corresponding to field areas testing with the Iowa STK interpretation classes (based on initial soil-test results). Analysis of variance for split-plot design with broadcast K in large plots and starter K in subplots were conducted for data collected along the entire length of the strips, for each dominant soil series, and for each STK interpretation class. The latter two analyses were performed only for soils or classes that encompassed at least two field replications.

Highlights of Results

Whole-Field Corn Responses

Potassium fertilization effects on corn early growth were significant ($P \leq 0.10$) in five fields, but the 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 K decreased growth compared with broadcast K alone. In Field 4 (the other no-till site), broadcast K did not affect growth but starter K decreased it when was applied alone or in addition to broadcast K. In Field 5 all K treatments decreased growth. In Field 8 broadcast K did not affect growth but starter K applied alone decreased it. These inconsistent early growth responses to broadcast or starter K fertilizers could not be explained by the average STK level of the fields or any other measurement. Salt effects on roots and water uptake might explain a growth reduction from applied K, although field observations showed no clear effects of either fertilizer on corn plant populations at any field. Also, the broadcast rate of 120 lb K_2O/acre did not decrease early growth at the no-till fields and 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 a rates of 15 to 22 lb K_2O/acre did not result in obvious salt effect symptoms at any field. 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 variation in other growth factors. The results of previous small-plot studies (Mallarino and Kaiser, unpublished) also showed infrequent and inconsistent effects of starter K on early corn growth.

In contrast to results for early growth, starter or broadcast K fertilization increased plant K concentration at four fields and seldom decreased it (Table 3). Either fertilizer applied alone increased plant K concentration in Fields 3 and 6 with the increase being largest for broadcast K in Field 3. In Fields 5 and 7 broadcast K increased concentrations but starter K did not. Applying starter K in addition to broadcast K increased plant K concentrations further in three of these four fields but decreased it slightly in Field 8. It is interesting that increases in plant K concentration sometimes were observed when fertilization decreased or increased early plant growth. Early corn K uptake responses (Table 3) reflected mainly the K effects on plant growth and, therefore, effects were infrequent and inconsistent across fertilizers and fields. Only starter K increased K uptake at Field 2, both fertilizers increased it at Field 3 but the increase was largest for broadcast K, and at Field 8 broadcast K did not affect uptake but starter K decreased it. These results for starter K effects on early corn K concentration and uptake are in agreement with results from previous research comparing P-K and K starter fertilizers (Mallarino and Kaiser, unpublished).

Potassium fertilization effects on corn grain yield were significant in three fields, where broadcast K and starter K each applied alone increased yield (Table 4). In Field 1 broadcast K alone increased yield more than starter K and the increases over the control were 11 bu/acre for starter and 21 bu/acre for broadcast. In Field 4 the effects on yield were statistically similar for both fertilizers, but the increase seemed greater for starter K than for broadcast K (6 bu greater). In Field 6 the effects of broadcast K alone and starter K alone on yield also were statistically similar, but the increase seemed greater for broadcast K than for starter K (7 bu greater). Starter K applied in addition to broadcast K did not increase yield further at any field. An important result was that there was no yield response to K fertilizer at fields where some treatments increased early plant growth or early K uptake.

The average STK values for these responsive fields (Table 1) and current STK interpretations in Iowa explained the yield responses only partially. A small or no yield increase was expected in Field 1 because mean STK was borderline between High and Very High, but values across the field ranged from Low to Very High. A yield increase was expected in Field 4 because mean STK 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 STK 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 STK was Optimum. The unexpected yield response (in Field 1) or lack of response (in Field 2) might be explained by variation in STK or soil types within the fields.

Corn Responses by Soil Type within Fields

There were two soil types encompassing large areas in seven fields (there was only one soil type in Field 4), 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 5 and discuss only results for grain yield for the four fields 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 (Table 5). On average STK 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/acre compared with the control, but starter K did not increase yield. We cannot explain the lack of response to starter K. Although STK was similar (Optimum) for both soils, other soil properties may explain a yield 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. The magnitude of the yield increase was even larger for areas of Floyd, although STK was similar (Optimum) for both soils. Therefore, the statistically significant response 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/acre compared with the control. A larger response for the Mahaska soil is reasonable because STK 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% probability.

Data in Fig. 1 shows the average relative effects of starter and broadcast K fertilization on early corn growth, early K concentration and uptake, and grain yield across all soils that showed a grain yield response to at least one fertilizer. These averages include Field 4 (Lester soil), both dominant soils in Field 6, and also data for the soils Zook in Field 1, Webster in Field 3, Tripoli in Field 5, and Mahaska in Field 7. It is very obvious from this figure that on average K fertilization did not affect significantly or decreased early plant growth in soils where a grain yield response was observed. On the other hand, early plant K concentration was increased in these responsive soils, but this was also observed with approximate similar magnitude and frequency in non-responsive soils.

Corn Response for Field Areas Testing in Different Soil-Test K Interpretation Classes

The STK level may vary within a field and this variation should influence the corn response to K fertilization and perhaps differences between broadcast and starter fertilization. In this report we show and discuss in detail only fertilizer effects on early plant growth and grain yield because of their relevance to understand starter effects and because early K uptake followed mainly trends for early growth. The fertilizer effects increasing early K concentration were as frequent as for analyses by field and soil series, while effects on early K uptake were inconsistent because of highly inconsistent effects on early growth.

Broadcast and starter K application did not affect, increased, or decreased early growth with approximately equal frequency no matter the STK interpretation class (Table 6). One or both fertilizers affected growth only in three instances of six field areas testing Very Low (at one field) or Low (at five fields). Starter K alone did not affect growth once, increased it once, and decreased it once while broadcast K alone increased growth in one instance and decreased it in two instances. One or both fertilizers affected growth in four of seven fields with areas testing Optimum. Starter K alone did not affect growth in two fields, increased it in one field, and decreased it in the other field while broadcast K alone did not increase growth in one field, increased it in two fields, and decreased it in one field. One or both fertilizers affected growth in eight instances of ten field areas testing High (at five fields) or Very High (also at five fields). Starter K alone did not affect growth in two instances, increased it in three instances, and decreased it in three instances while broadcast K alone did not affect growth in four instances, increased it in two instances, and decreased it two instances. Application of starter K in addition to broadcast K seldom increased growth compared with broadcast K alone and usually did not affect it or decreased it with approximately equal frequency. Therefore, these results indicate that early corn growth response to starter or broadcast K fertilization was very inconsistent across a wide range of STK values, which also was observed for the whole-strip analysis and the analysis by soil series.

Table 7 shows grain yield data for field areas with STK testing within several Iowa STK interpretation classes. Based on previous Iowa research we expected large and frequent responses to K fertilization for the two low-testing STK classes, small and less frequent responses for the Optimum class, and both small and infrequent responses for the high-testing classes. Our results indicate that the frequency and magnitude of yield responses tended to decrease from the Very Low to the Very High classes, but the frequency of the response for each class departed significantly from the expected frequency. Data and statistics from Table 7 indicate that the frequency of a yield response to one or more treatments was 100, 60, 57, 60, and 60% for the classes Very Low, Low, Optimum, High, and Very High, respectively. This should not be surprising, however, because the previous STK calibration research was based on many trials over many years, and the number of field areas testing within the five interpretation classes in our study was not as large as to be able to establish probabilities of response. Therefore, according to the main objectives of this study, in this section we emphasize the comparison of responses to broadcast and starter K for the different STK interpretation classes present in the fields.

Both starter K and broadcast K applied alone increased grain yield in four of six field areas testing Very Low (at one field) or Low (at five fields). Contrary to expectations, the increases were statistically similar in one instance and starter K increased yield slightly more than broadcast K rate in the other three instances. Application of both fertilizers increased yield further only in one instance. Broadcast K alone increased yield in four of seven field areas testing Optimum but starter K alone increased yield in three fields. The yield increases by the fertilizers were similar in two fields but were higher for broadcast K in the other two fields, and application of both fertilizers did not increase yield further in three fields but reduce it in one field. Starter or broadcast K fertilizer applied alone increased yield in four of ten field areas testing High (at five fields) or Very High (also at five fields), while starter increased it in one other field and broadcast increased it in a different field. The yield increases were similar in two fields, were higher for starter K in two fields, and were higher for broadcast K in one field. Application of both fertilizers did not increase yield further in three fields, increased it in one field and decreased in another field. Therefore, an important result of the study was that the small starter K rate used often resulted in similar yield increases than the much higher broadcast K application rate designed to maintain STK, but this was not clearly related to the STK level.

Summary and Conclusions

Analysis of data averages for the entire length of the strips showed that K fertilization increased corn grain yield at three of eight fields. At two fields broadcast K increased yield more than starter K and at one field both fertilizers increased yield similarly. Seven fields had large areas with two different soil series, and analyses of yield responses for each soil showed differential yield responses to K fertilization in four of the fields. The reason for a differential response between soils within a field sometimes was not clear, but yield responses tended to exist or were larger in soils with lower STK levels and/or a combination of poor internal drainage and fine texture. However, there were no clear or consistent differences between soil series concerning relative differences between broadcast and starter K fertilization. Analysis of yield data for field areas initially testing within different STK interpretation classes also showed that the responses to K were explained not just by STK levels but also by soil properties, and there were no consistent differences between starter and broadcast K fertilization. Unexpected small to moderate yield responses in high-testing areas of some fields occurred mainly with soils with poor drainage and the finer textures. A consistent result across most soil series and STK interpretation classes was, however, that starter K in addition to broadcast K did not increase grain yield further.

Broadcast or starter K fertilization effects on corn early growth and K uptake were inconsistent for analyses of data by field, soil series, and STK interpretations classes. Early plant K concentration usually was increased by fertilization, however, and the increase tended to be larger for the broadcast fertilizer probably because the amount of K applied was much larger. However, early plant growth was not affected, increased, or decreased by K application with about similar magnitude and frequency, and there were no consistent differences between broadcast and starter K fertilizers. Moreover, the few instances with early plant growth or K uptake increases did not correlate with soil series or STK values and usually did not result in grain yield increases.

Therefore, we conclude that there is little or no true starter effect from K for corn. Starter K applied at rates that do not damage seedling or reduce corn stands may increase early growth and yield in low-testing soils. However, K does not have the clear role that both N and P have at stimulating early corn growth and grain yield, sometimes even in high-testing soils or after broadcasting fertilizers using small or moderate application rates.

References Cited

Bermudez, M., and A.P. Mallarino. 2003. Does N or P starter fertilizer increase yield of no-till corn in high-testing soils? *In* Abstracts [CD-ROM]. ASA, CSSA, and SSSA, Madison. WI.

Bordoli, J.M., and A.P. Mallarino. 1998. Deep and shallow banding of phosphorus and potassium as alternatives to broadcast fertilization for no-till corn. Agron. J. 90:27-33.

Bundy, L.G., H. Tunney, and A.D. Halvorson. 2005. Agronomic aspects of phosphorous management. p. 685-727. *In* T. Sims et al. (eds). Phosphorus: Agriculture and the Environment. Agronomy Series 46. ASA, CSSA, SSSAJ, Madison, WI.

Kaiser, D. E., A.P. Mallarino, and M. Bermudez. 2005. Corn grain yield, early growth, and early nutrient uptake as affected by broadcast and in-furrow starter fertilization. Agron. J. 97:620-626.

Mallarino, A.P., J.M. Bordoli, and R. Borges. 1999. Phosphorus and potassium placement effect on early growth and nutrient uptake of no-till corn and relationship with grain yield. Agron. J. 91:37-45.

Randall, G.W., and R.G. Hoeft. 1988. Placement methods for improved efficiency of P and K fertilizers: A review. J. Prod. Agric. 1:70-79.

Sawyer, J.E., A.P. Mallarino, R. Killorn, and S.K. Barnhart. 2002. A general guide for crop nutrient and limestone recommendations in Iowa. Publ. Pm-1688 (Rev.). Iowa State Univ. Ext., Ames.

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Table 1. Strip trials locations, years, and summary field information.

Year	Field	Soil Series	Planting Date	Corn Hybrid	Soil-Test Values † Soil-Test K Min	Avg	Max	pH	OM
					------- ppm -------				
2007	1	Zook, Koszta	1 May	P 34A12	116	214	283	7.4	5.9
	2	Readlyn, Kenyon	5 May	DK C58-13	111	156	229	6.5	3.8
	3	Clarion, Webster	14 May	NT 2503HX	124	175	251	6.5	4.6
2008	4	Lester	19 May	Crows 4940 T	71	102	133	5.7	2.7
	5	Floyd, Tripoli	15 May	DK 61-69	113	180	213	6.6	4.9
	6	Koszta, Wiota	2 May	P 33F12	91	130	197	7.0	7.1
	7	Mahaska, Taintor	8 May	DK 61-69	132	220	433	7.4	4.6
	8	Mahaska, Otley	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.

Table 2. Potassium fertilization effects on early corn growth (V5-V7 growth stage) for eight strip trials.

Field	No Broadcast K No Starter	Starter K	Broadcast K No Starter	Starter K
	---------------- 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

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

Table 3. Potassium fertilization effects on corn early K concentration and K uptake (V5-V7 growth stage) for eight strip trials.

	No Broadcast K		Broadcast K	
Field	No Starter	Starter K	No Starter	Starter K
	---------------- 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	3.7b
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

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

Table 4. Potassium fertilization effects on corn grain yield for eight trials.

	No Broadcast K		Broadcast K	
Field	No Starter	Starter K	No Starter	Starter K
	--------------------------- 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 5. 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	
Field	Soil Type	Soil-Test K	No Starter	Starter K	No Starter	Starter K
		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 ($P < 0.10$).

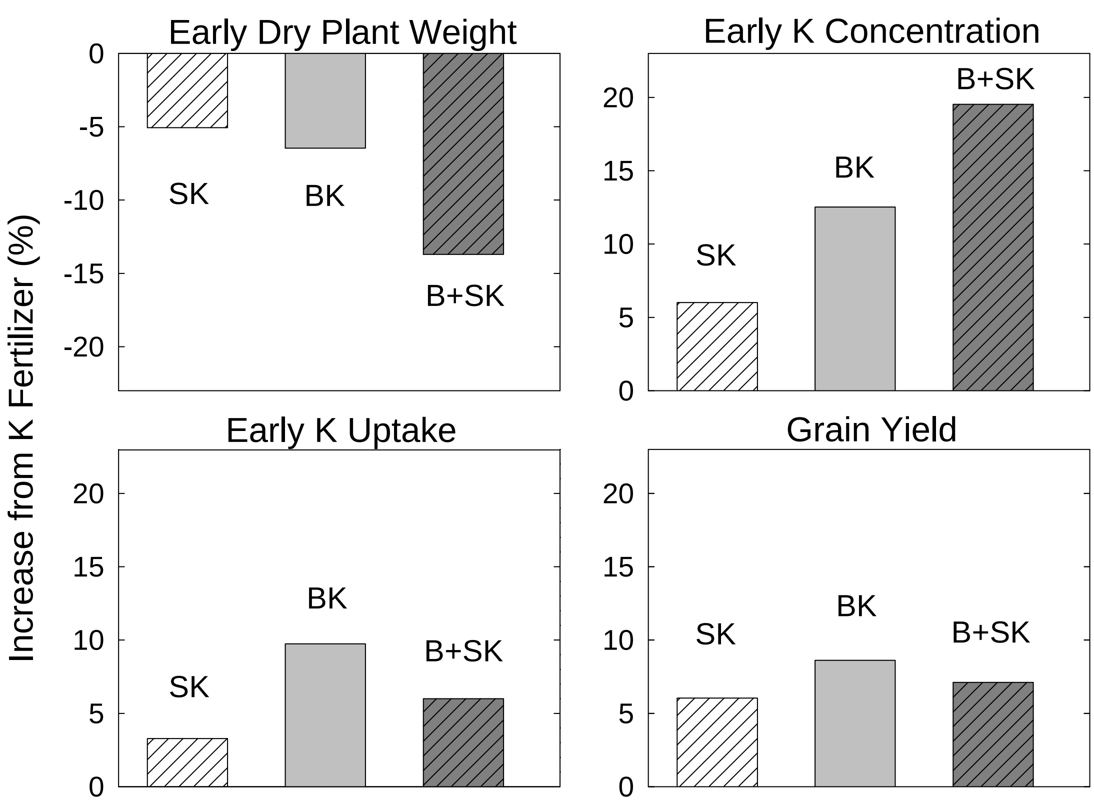

Fig. 1. Relative effect of K fertilization on early corn growth, early K concentration and uptake, and grain yield across all fields or soils showing a yield response to K (SK, starter K; BK, broadcast K).

Table 6. Potassium fertilization effects on early corn growth (V5-V7 stage) for field areas testing within different soil-test K interpretation classes.

		No Broadcast K		Broadcast K	
Field	STK class	No starter	Starter	No starter	Starter
		----------- Plant Dry Weight (g/plant) ----------			
1	Optimum	11.4	11.0	11.6	10.1
	Very high	10.8b	10.5b	11.2b	10.0a
2	Low	4.0b	4.1b	3.3a	3.4a
	Optimum	4.2a	4.6b	3.9a	3.9a
	High	3.9b	4.2c	3.1a	4.3c
	Very high	3.4a	4.2b	2.6a	4.1b
3	Low	3.5a	4.5c	3.9b	3.6a
	Optimum	3.6a	3.6a	4.8c	4.0a
	High	3.5a	3.5a	4.0b	4.1b
	Very high	3.5	3.9	4.1	3.7
4	Very low	6.2	6.0	6.0	5.6
	Low	6.7	6.4	6.8	6.2
5	Optimum	15.1b	12.5a	11.7a	11.5a
	High	14.1b	13.7b	12.4b	10.3a
6	Low	11.2d	10.3c	8.4b	7.6a
	Optimum	10.1	9.9	10.3	10.4
7	Optimum	3.6	3.1	2.5	3.3
	High	2.9	2.9	3.2	2.6
	Very high	4.2a	4.9c	4.6b	4.3a
8	Low	5.0	4.4	4.9	6.4
	Optimum	5.4a	5.3a	6.7c	6.3b
	High	6.6b	5.6a	6.7b	6.0a
	Very high	7.4c	6.2a	7.5c	6.9b

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

Table 7. Potassium fertilization effects on corn grain yield for field areas testing within different soil-test K interpretation classes.

Field	STK class	No Broadcast K		Broadcast K	
		No starter	Starter	No starter	Starter
		---------------------- bu/acre ---------------------			
1	Optimum	191	194	206	203
	Very high	167a	184b	193b	188b
2	Low	148	148	143	145
	Optimum	149	152	148	148
	High	151a	152a	162c	155b
	Very high	152	154	157	154
3	Low	131	134	136	134
	Optimum	132a	127a	145b	143b
	High	135a	140b	136a	143b
	Very high	134	137	140	140
4	Very low	179a	195c	189b	184b
	Low	170a	187c	181b	179b
5	Optimum	194a	200b	208c	200b
	High	206a	210b	220b	210b
6	Low	212a	228b	230b	226b
	Optimum	207	215	225	224
7	Optimum	202a	223b	222b	213b
	High	211	215	223	224
	Very high	227a	237c	232b	234b
8	Low	219a	227c	223b	233d
	Optimum	213a	221b	219b	226b
	High	222	219	221	220
	Very high	221	223	223	224

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