CORN AND SOYBEAN RESPONSE TO POTASSIUM FERTILIZATION AND PLACEMENT [1]

Antonio P. Mallarino, Rogerio Borges, and David Wittry [2]
Department of Agronomy, Iowa State University, Ames, Iowa

Introduction

Increased adoption of conservation tillage, evidence of large within-field nutrient variability, and an apparent increase in the frequency of crop potassium (K) deficiency symptoms in Iowa and other states have prompted questions about the effectiveness of current soil-test K interpretations and fertilizer recommendations. These questions relate to fertilizer placement and management of within-field nutrient variability. Broadcast placements are less costly than banded placements but they seem inefficient for reduced tillage (mainly with no-till and ridge-till). With reduced tillage, fertilizers are not incorporated (such as in no-till) or are incorporated in a way that may not optimize crop nutrient uptake (such as in ridge-till). Because of limited movement of K through the soil, continued broadcast or planter-band fertilization and K recycling with crop residues result in K accumulation at or near the soil surface. Although increased residue cover in conservation tillage improves water relations and root efficiency in shallow soil layers, nutrient stratification could result in reduced K uptake when the topsoil is dry. Observation of large nutrient variability and patchy crop K deficiency symptoms in many Iowa fields suggests K deficient areas resulting from uneven fertilization or soil properties that induce K deficiency. New intensive soil sampling and fertilization methods that involve global positioning systems (GPS) and variable-rate technology should improve nutrient management and ultimately the fertilizer use efficiency. Use of these technologies usually increases costs, however, and research is needed to learn in what conditions they are more effective.

The information that will be presented here summarizes ongoing research to identify more effective K soil-test interpretations and fertilization methods for corn and soybeans. The discussion will focus on results from research on K fertilizer placement methods and on-farm strip trials that assessed within-field variation of crop response to K fertilization.

Summary of Methods

Conventional fertilizer placement trials and strip response trials were conducted in Iowa for corn and soybean crops. The placement trials were established at various Iowa State University (ISU) research farms and in farmers' fields since 1994. Five long-term studies were conducted at five research farms to study placement strategies for the corn-soybean rotation. Identical experimental designs were used to study fertilization effects in both crops each year. Twenty-six short-term trials with corn and 24 short-term trials with soybeans were established on farmers' fields having long histories of no-till or ridge-till management.

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[1] Presented at the North Central Extension-Industry Soil Fertility Conference. November 14-15, 2001, Des Moines, IA.
[2] Associate Professor, Adjunct Assistant Professor, and Graduate Research Associate, Dep. of Agronomy, Iowa State Univ., Ames, IA 50011.

Treatments at the research farms were placements and rates of K fertilizers (dry potassium chloride), which were replicated three times. Treatments included rates ranging from 0 to 140 lb K_2O/acre that were applied broadcast, deep banded, and banded with the planter. Only the lower rates (35 to 70 lb K_2O/acre) were applied with the planter. The broadcast and deep banded fertilizers were applied in the fall. Coulters and knives of the deep bander were setup to apply fertilizer to a 6-7 inch depth and at a spacing that coincided with the corn row spacing (30 or 38 inches). The planter-banded fertilizer applied at research farms was banded 2 inches beside and 2 inches below the seeds. There were two controls at all trials. One was an absolute control and the other was a control that received an "empty coulter-knife" deep-band pass to assess any physical effects of the coulter-knife pass. At farmers' fields, the fertilizer rates used were similar but only the broadcast and deep-band placements were evaluated. At the deep-band plots, crop rows were placed on top (within 4 to 5 inches) of the fall-applied knife tracks, except at the soybean on-farm trials because a narrow row spacing was used.

Seven two-year on-farm strip response trials with the corn-soybean rotation were conducted at farmers' fields since 1999 (data for the 2001 growing season have not been processed yet). A strip-trial methodology, GPS, variable-rate technology, and grain yield monitors were used to evaluate a check and a fixed K rate in all fields, and a variable K rate at some fields. Current ISU soil-test K interpretations and fertilizer recommendations for the two-year corn-soybean rotation were used starting with either corn or soybeans. Treatments were applied to strips 60-foot wide and as long as the fields, and were replicated three to four times. Responses to variable-rate fertilization will not be discussed in this presentation. Fertilizer (dry potassium chloride) was broadcast for either corn or soybeans using commercial fertilizer spreaders equipped with GPS receivers and controllers. Soil samples were collected using a 0.75-acre grid-point soil sampling scheme, in which each composite sample (12 cores, 6-inch depth) was collected from area approximately 900 sq. ft. in size at the center of each cell. This sampling method is more intensive than any grid sampling method being used by Midwestern producers. The fixed rate was uniform within a field but varied between fields because average soil-test values and yield potential differed among fields. Following ISU fertilizer recommendations, a fertilizer rate approximately similar to estimated crop removal was applied when the average soil-test K value was within the Optimum range, but also when it was within the High or Very High classes (to test potential response within these ranges). Grain yields were harvested and recorded with combines equipped with yield monitors and real-time GPS receivers and differential signal correction. The procedures used minimized errors due to borders, yield monitor calibration, waterways or grass strips, and others. At some fields, grain from each strip was weighed and there was little or no difference with the yield monitor estimates. The impact of the treatments on soil and crop responses were assessed with geographical information systems (GIS) and spatial statistics methods.

Impact of Potassium Placement on Crop Yield

The fertilizer placement studies encompassed a wide variety of growing conditions and average yields across sites ranged from approximately 100 to 210 bu/acre of corn and 30 to 70 bu/acre of soybeans. Potassium fertilization increased corn and soybean yields at many sites, although statistically maximum yields were achieved with the lowest rate used (35 lb K_2O/acre) at most sites. Thus, to simplify the presentation of data, only average responses to fertilization and placement will be discussed in this report. Large or widespread responses of corn or soybeans to K were not expected because with the exception of two soils that had soil-test K within the upper Low ISU interpretation class (60 to 90 ppm, ammonium acetate test), all the soils tested Optimum (90 to 130 ppm) or higher (the High class is 131 to 170 ppm and the Very High class is more than 170 ppm). Although usually crops did not respond to K when soil-test K was Very High, responses were not significantly related to soil-test K values ranging from the upper Low to the upper High classes. This result is one of the most important results from these studies, and introduced doubts about current interpretations and K fertilizer recommendations for the current Optimum and High classes. Extensive soil-test calibration research with various soil-test methods is being conducted at this time to revise current Iowa recommendations.

Crop response to the K placement methods varied markedly between crops and tillage systems. Figure 1 summarizes data for chisel-disk and no-till trials at research farms, and Fig. 2 summarizes data for the ridge-till fields. The deep-band placement was better than the broadcast and planter-band placement methods at many cornfields. Responses to deep-band K were larger and more consistent for ridge-tillage, although responses varied markedly across sites and cannot be appreciated in the averages shown in the figures. The placement differences were smaller for soybeans. The two band placements usually did not differ, and differences between band and broadcast placements were statistically significant only in few sites. Across all fields and years, the corn yield advantage of deep-band K over the other two placement methods was about 8 bu/acre for ridge-till, 4 to 5 bu/acre for no-till (including data from producers' fields not shown in Fig. 1), and about 2 bu/acre for the chisel-disk tillage. In several ridge-till fields the corn response to deep-band K was large, and high rates of broadcast K did not increase yield over the control. In no-till fields, the results show that deep band K helps reduce the yield gap between the no-till and chisel-disk tillage.

Comparisons of the yield of the absolute check and the check with a deep coulter-knife pass showed that the response to deep-band K was not explained by physical effects of the coulter-knife pass for any tillage system. Similar experiments conducted for no-till corn with various P fertilizer rates that are not discussed here showed that the coulter-knife pass by itself had a variable yield advantage over the absolute check mainly when no P was applied (a high rate of broadcast P fertilizer was uniformly applied across all K plots). Responses frequently were observed in high-testing soils and could not be solely explained by K stratification. The sites in which the response to K placement was largest did not have the largest soil K stratification (on average, the no-till sites had 40% higher K in the 0-3 inch soil depth than in the 3-6 inch depth). Rainfall data suggest that the magnitude of responses to deep-band K were related to deficient rainfall (soil moisture was not measured) during June and early July. It is likely that plant K uptake from shallow soil layers was reduced by dry conditions during this growth period, and that a deep-band K placement alleviated the problem. Observation of corn early vegetative growth (V5 to V6 stages) responses and visual evaluations of K deficiency symptoms (not presented) showed that the deep-band K placement sometimes increased early growth and reduced deficiency symptoms more than the broadcast or planter-band K placements. However, corn at sites with large grain yield response to deep-band K sometimes showed no K deficiency symptoms.

Within-Field Variation of the Crop Response to Potassium

There was high soil-test K variation in most fields, and values encompassed several soil-test interpretation classes. According to Iowa research conducted during the 1970s and 1980s, corn and soybean responses to K should be large and likely in the Very Low and Low classes, small and less likely in the Optimum class, and unlikely in the High or Very High classes. Ranges of soil-test K values and field-average corn and soybean responses to K fertilization are shown in Table 1. The corn response (either as first or second crop after applying two-year fertilization rates) was large in three fields (9.3 to 23.1 bu/acre), small in one field (4.4 bu/acre), and was not significant in two fields (2.3 and 3.9 bu/acre). The field-average soil-test K ranged from Low to Optimum in fields with large responses, was in the lower part of the High class in the field with a small response, and was borderline between the High and Very High classes in fields with smaller nonsignificant responses. The field-average soybean response was moderate in two fields (2.0 and 2.5 bu/acre) and not significant in the other fields. The average soil-test K was Low or Optimum in the responsive fields, and ranged from a value borderline between the Low and Optimum classes to values borderline between the High and Very High classes in the other fields.

One advantage of on-farm strip trials with GPS, intensive soil sampling, and yield monitors is the possibility for studying yield responses for areas within a field with contrasting soils or soil-test values. Statistical and GIS analyses of treatment effects for areas within each field with different soil-test K values showed that, as expected, the yield response usually was higher when soil-test K was within the Very Low or Low interpretation classes compared with that for the Optimum class. Data in Fig. 3 (for corn) and Fig. 4 (for soybeans) show yield responses for field areas that tested within current ISU soil-test K interpretation classes. In these figures, data for soil test interpretation classes with less than two 0.75-acre cells were not included because results would be unreliable. Also, responses for the Very High class were agronomically and statistically insignificant and are not shown. An interesting and unexpected result, which coincide with results from the placement trials discussed previously, was the occurrence in several fields of moderate responses (about 5 to 6 bu/acre for corn) in areas testing High in soil-test K, which were approximately similar to responses observed in the Optimum class. No K fertilization is recommended for the High class by current ISU soil-test interpretations. Thus, two important aspects can be concluded from these strip trials. One is a need for revising current Iowa K soil test interpretations. The other is that large within-field variability in both soil-test K values and crop response to K fertilization suggests that variable-rate fertilization can potentially improve K fertilizer management. Ongoing research is investigating the cost-effectiveness of variable-rate K fertilization using alternative intensive soil sampling schemes.

General Conclusions

The results suggest three major areas for potential improvement of K management practices. Larger than expected grain yield responses (mainly of corn) in soils testing Optimum and High in K according to current Iowa soil test interpretations suggest the need for changes to these interpretations. Variation across soils suggests that a simple change in the boundaries of the interpretation classes is not possible. Current research is focusing on calibrating various soil tests for K for corn and soybeans for contrasting soil associations. Another area relates to fertilizer placement methods. The deep-band K placement was more efficient than broadcast or planter-band placements for ridge-till and no-till corn. Advantages of this placement method were much smaller or nonexisting for corn managed with chisel-disk tillage, and were smaller and less consistent for soybeans managed with any tillage. Large variation in the corn response to deep-band K seemed more related to soil moisture in late spring and early summer than to soil-test K stratification, and responses tended to be larger with deficient rainfall. Finally, large within-field variability in soil-test K values and crop response to fertilization suggest that variable-rate fertilization can potentially improve K fertilizer management. Ongoing research is investigating the cost-effectiveness of variable-rate K fertilization using alternative intensive soil sampling schemes.

Table 1. Soil-test K ranges and field-average grain yield response to K fertilization for several strip trials with the corn-soybean rotation.

			Soil-Test K			Fertilized	Yield Increase	
Year	Field	Predominant Soil	Min	Mean	Max	crop	1st Crop	2nd Crop
			---------- ppm ---------				------- bu/acre -----	
							Corn	Soybeans
1999	1	Tama	70	129	276	Corn	18.1	2.5
	2	Kenyon, Dinsdale	132	172	219	Corn	2.3	0.7
	3	Kenyon, Floyd	47	88	161	Corn	23.1	2.0
2000	4	Clarion, Webster	85	165	369	Corn	3.9	na †
							Soybeans	Corn
1999	5	Kenyon, Dinsdale	117	140	221	Soybeans	-0.2	4.4
	6	Kenyon, Floyd	56	89	136	Soybeans	0.8	9.3
2000	7	Klinger, Dinsdale	84	133	194	Soybeans	0.7	na

† na = yield data for the 2001 growing season have not been processed.

Figure 1. Response of Corn and Soybean Managed with No-Till or Chisel-Disk Tillage to Potassium Placement.

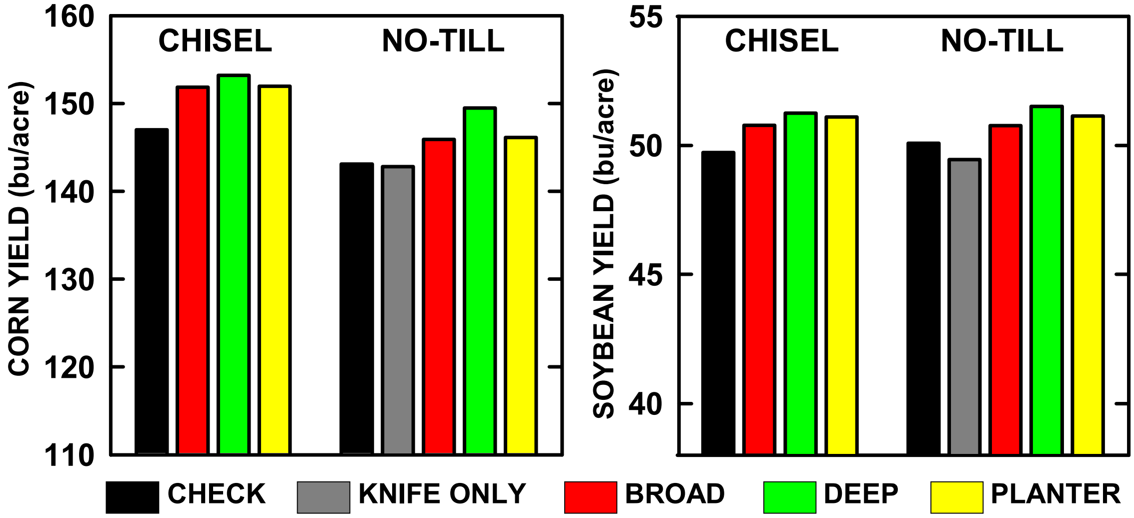

Figure 2. Response of Corn and Soybean Managed with Ridge-Tillage to Potassium Placement.

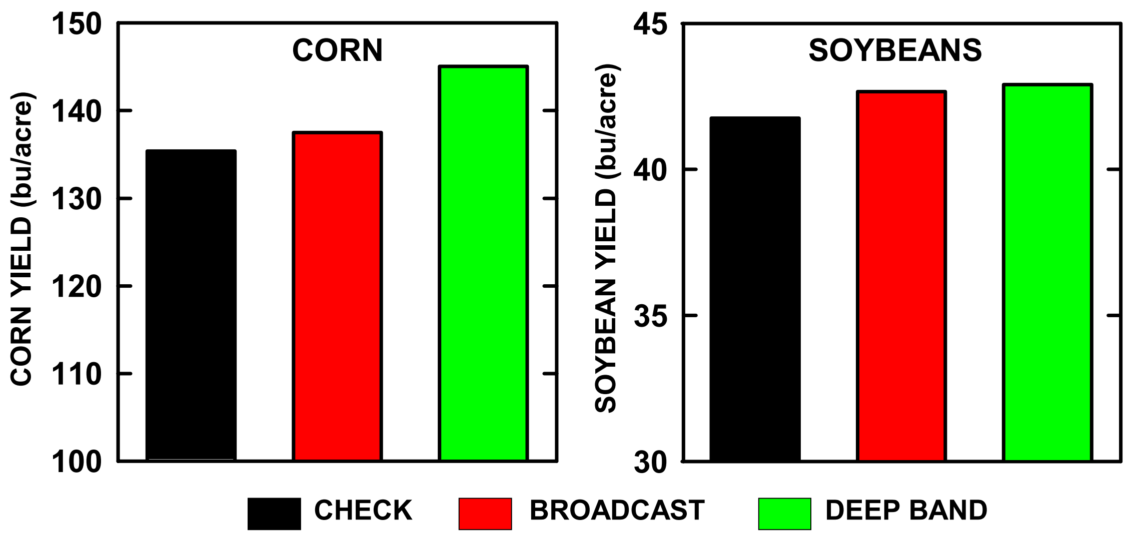

Figure 3. Within-Field Corn Yield Response According to Soil-Test Potassium

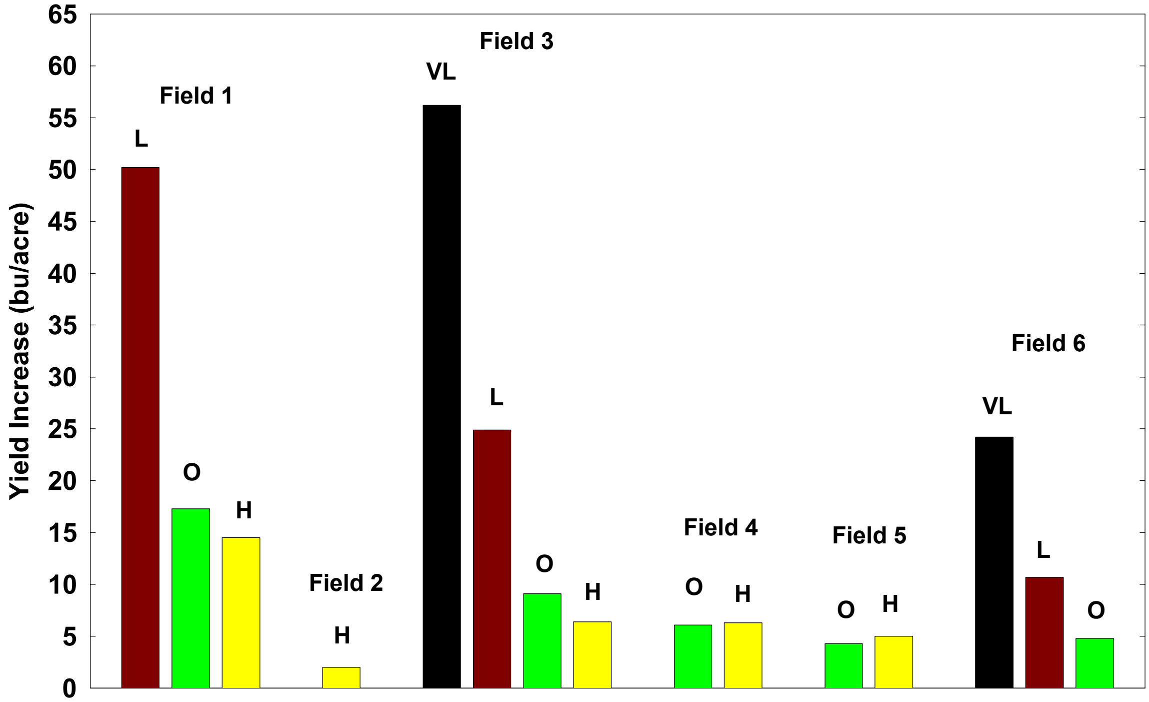

Figure 4. Within-Field Soybean Response According to Soil-Test Potassium