TILLAGE AND FERTILIZER PLACEMENT FOR THE CORN-SOYBEAN ROTATION

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Introduction

The information presented is part of ongoing research to identify effective conservation tillage systems and phosphorus (P) and potassium (K) fertilizer placements for corn and soybeans. The rate of adoption of the no-till system by Iowa producers has decreased after a marked increase during the late 80s and early 90s. Actually, the area of no-till corn has decreased slightly since 1994. Several aspects could explain this trend but slow early growth in spring, a perception of lower corn yields, less yield stability over time, and concerns about appropriate fertilizer management are major factors. Although the increased residue cover usually improves moisture availability, root growth, and nutrient uptake efficiency at shallow soil layers. However, it may also reduce soil temperature in spring, delay planting, and reduce early growth. Broadcast fertilizer placements are less costly than banded placements but they seem inefficient for no-till fields because fertilizers are not incorporated. Because of the reduced movement of P and K in soils and nutrient cycling with residues, broadcast applications result in P and K stratification and accumulation within the top 2 or 3 inches of soils. The stratification could result in lower total P and K uptake by plants especially when topsoil is dry. Another related aspect is that producers are uncertain about the value of soil testing in conservation tillage because of the large variability and lack of knowledge concerning techniques for collection of samples.

A large research project was initiated in 1994 to address these questions with the support of the Iowa Soybean Promotion Board, the Leopold Center for Sustainable Agriculture, Practical Farmers of Iowa, the Iowa State University Outlying Research Centers, and numerous Iowa producers. Ten long-term trials with the corn-soybean rotation were established on five Iowa State University research farms in 1994 and continue to be evaluated. These experiments evaluate chisel-disk, no-till, and fall strip-tillage (with no-till) in combination with various P and K fertilizer placements. Fifty-five additional short-term trials were established since 1994 at producers' fields managed with no-till and ridge-till. This presentation summarizes results from the tillage-placement trials at the research farms with the corn-soybean rotation and no-till short-term trials at producers' fields.

Fields and Experiments

Ten long-term trials with the corn-soybean rotation were established on five Iowa State University research farms in 1994. The experimental areas were subdivided for separate P and K trials and for corn and soybean crops. The rotation was established by rotating crops over time (both crops were grown each year). Thus, 80 site-years were harvested from 1994 to 1997. In 1994, the fields had from one to three years of no-till management. Soil-tests (0 to 6 inch depth) were very low to very high for P (6-35 ppm, Bray-1) and optimum to very high for K (90-250 ppm, ammonium acetate). Soils were Webster-Canisteo, Marshall, Galva, Kenyon-Clyde, and other major Iowa soils. Treatments were tillage systems, and placements and rates of P and K fertilizers (dry granulated fertilizers), which were replicated three times. The tillage systems were chisel-disk and no-till. One treatment within the no-till plots evaluated a fall strip tillage, which was made with the same coulter-knife combination used to apply deep-banded fertilizer.

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Granulated fertilizers were applied broadcast, deep-banded at 5 to 8-inch depth, or planter-banded (or starter) 2 inches beside and below the seed. Rates ranged from 0 to 112 lb P_2O_5/acre and 0 to 140 lb K_2O/acre. Row distance and deep-band spacing was 30 inches for both crops. In deep-band plots, the rows were located on top of the residue-free knife tracks. Fertilizers were applied every year to corn and soybean in the rotation, except for one treatment (a doble maintenance rate) that was applied every other year. The broadcast and deep banded fertilizers were applied in the fall for all trials, except for the first (1994) growing season. Planting dates and plant stands were similar for the two tillage systems for each crop at each location. At producers' fields (15 site-years for corn and 15 for soybeans), the methods used were similar except that the only tillage treatment evaluated was the strip-tillage, there was an additional P-K mixture treatment, only the broadcast and deep banded placements evaluated, and soybeans were drilled in narrow rows. Early growth of both crops was measured by weighing plants at the V5 to V6 growth stage. Grain yields were adjusted to 15.5% (corn) or 13% (soybeans) moisture content. In this article, each site-year of data for each crop and nutrient (a total of 110) is referred to as "a site".

Summary of Results

The study encompassed a wide variety of growing conditions and mean yields across sites ranged from 95 to 205 bu/acre of corn and 30 to 65 bu/acre of soybeans. Because of the large data set collected in the study, detailed information for each site and experiment cannot practically be shown in this summary presentation. Thus, averages over sites or responsive sites will be shown as appropriate and comments will be made concerning the variation in responses across sites. The study of early growth and grain yield showed that any response to P fertilization and placement was statistically similar for the chisel-disk and no-till systems. This is a very important result. It suggests that different stratification (which was more marked for no-till) and mixing of fertilizer with soil (which was more complete for chisel-disk) between tillage systems was not a factor in the crop response to placement. Because of this reason, results presented for tillage treatments are averages over all fertilized treatments. Also, although the figures that show response to fertilization and placement will show data separately for the two tillage systems, the discussion will make distinction between tillage systems.

Tillage Effects on Crop Early Growth and Grain Yield

Data of long-term trials that compared tillage systems showed that early growth and grain yield of corn managed with the chisel-disk tillage usually was higher than for corn managed with no-till. The differences were statistically significant in about 60 % of the site-years for early growth and 40% of the site-years for grain yield but the differences usually were always present. The data for soybeans showed that early growth usually was larger for the chisel-disk tillage but grain yields usually did not differ and occasionally either the chisel-disk or the no-till tillage produced larger plants. Data in Fig. 1 shows average effects for the four years of data at each of five Iowa locations. Study of rainfall and air temperatures at each location not always explained the differences in response to tillage across locations and years. In general, as expected, differences in growth and grain yield of corn in favor of the chisel-disk tillage were larger when spring weather was cold and wet. The lack of high correlation between tillage differences and these measurements suggests that other factors, perhaps tillage effects in several soil properties, have a strong influence in the yield differences.

The study of fall strip-tillage in no-till cornfields showed that although this practice usually increased early growth of corn its effects on grain yields were inconsistent. Data in Fig. 2 show yield results for 22 fields (data for adjacent P and K trials within a field were averaged) and early growth data for seven fields (plant weights were not collected at other fields). The fields had varied histories of no-till management (three to 14 years). Statistical analyses showed that the strip tillage usually did not influence yield, it increased yield at four fields, and decreased at two fields. Overall 22 fields, the average yield increase due to fall strip-tillage was only 1.5%. Moreover, the largest increases in early growth not always coincided with the largest increases in grain yield. This result shows that obvious effects of the fall strip tillage on early growth not necessarily result in higher yields. Because of crop response to deep-band fertilizer that will be discussed below, the results also suggest that fall strip tillage will be a reliable and cost-effective practice only when it is used in combination with deep fertilizer placement. Additional trials are being conducted at a field scale to obtain more information.

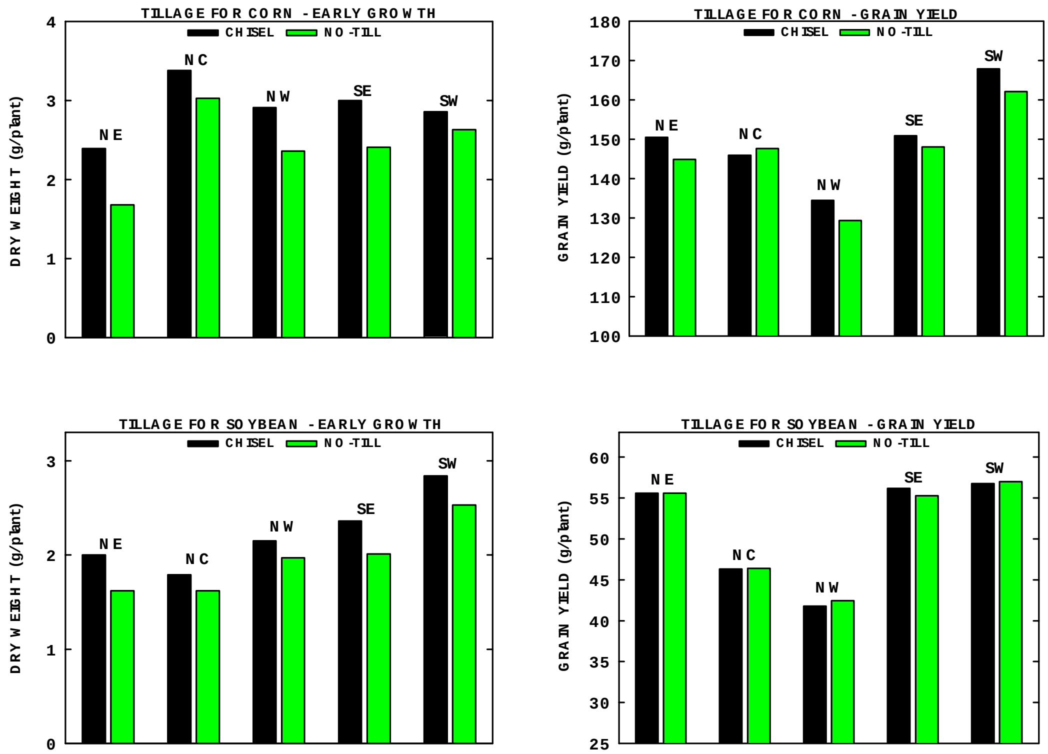

Fig. 1. Four-year average effects of tillage (chisel-disk and no-till) on early growth and grain yield of corn and soybean in five Iowa locations (NE = northeast, NC = northcentral, NW = northwest, SE = southeast, and SW = southwest).

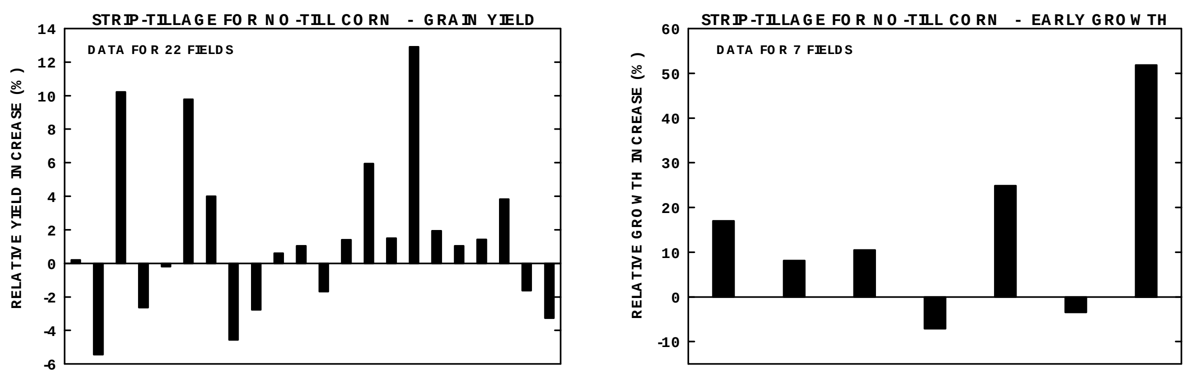

Fig. 2. Variation across fields of the effect of fall strip-tillage on early growth and grain yield of no-till corn (growth was measured at seven sites, which correspond to the first sites of the yield graph).

Fertilization Effects on Early Growth and Grain Yield.

Study of yield responses of either crop at research farms or producers' fields showed no statistically significant differences between the P fertilization rates and the K fertilization rates except at one of the sites that tested vary low in P. Even at this very low site, any response to P or K placement was similar for all rates used. This finding (no difference between placement effects for the fertilizer rates used) has a major significance. It shows that, contrary to expectations by many producers, P and K fertilizer rates needed to achieve optimum yields of corn or soybean cannot be reduced by banding. Because of these results, and to simplify the presentation and discussion of data, only average responses to fertilization and placement will be discussed in this report.

Fertilizer placement for corn.

Phosphorus fertilization increased corn grain yield at several sites that tested very low or low in soil-test P (0-6 inch depth) but at no site that tested optimum or above. Statistically maximum yields were achieved with the lowest rate used (28 lb P_2O_5/acre) at all sites and for all placements. The lowest soil-test P value observed across sites was 5 ppm and the highest was 35 ppm. The boundaries of Iowa State University interpretation classes (Bray-1 test) very low, low, optimum, high, and very high are 8, 16, 20, and 30 ppm, respectively. The placements did not differ statistically at any trial, although in a few trials the band treatments produced slightly higher yields. The upper two graphs in Fig. 3 show the average responses to P placement of the group of sites where fertilization increased yield. The lack of difference between the broadcast and deep-band placements was consistent at research farms and producers' fields (the planter-band P placement was not evaluated at producers' fields) so only data for the research farms are shown. Contrary to results for grain yield, early growth of corn was greatly increased by P fertilizer applications. This response occurred even in high-testing soils, although it tended to be larger in soils that tested below optimum in P. Responses almost always were larger for the planter-band placement (starter), less for the deep-band placement, and even less for the broadcast placement. The combination of responses in grain yield and early growth shows that obvious effects of banded P on early growth not necessarily translate into higher grain yields. The P effects on early growth usually are explained by high P needs during periods of rapid cell multiplication and colder soil temperatures. These results suggest that plants often can compensate for slower early growth.

Potassium fertilization increased corn grain yield at several sites, although statistically maximum yields were always achieved with the lowest rate used (35 lb K_2O/acre). These responses were not expected because all soils tested optimum or higher in soil-test K. The lowest soil-test K value observed was 92 ppm and the highest was 262 ppm. The boundaries of Iowa State University interpretation classes (ammonium acetate test) very low, low, optimum, high, and very high are 60, 90, 130, and 170 ppm, respectively. The K placements differed statistically at only four sites, and at both sites the deep-band placement produced higher yields than other placements. When data from all sites were combined, however, responses to both K fertilization and deep-band placement were significant. This result is explained by small but frequent advantage for the deep-band placement at many sites. The lower two graphs in Fig. 3 show the average responses to K placement of the group of sites where K fertilizer increased yields. The advantage of the deep-band placement over the broadcast placement was consistent at research farms and producers' fields so only data for the research farms (which included all placements) are shown. Potassium fertilization and placement seldom influenced early growth of corn. This result is in sharp contrast effects of P placement on early growth and of K placement on grain yield. It coincides with the well known fact crop responses to starter fertilizer usually are explained by N or P. It also could be explained by the usually high levels of soil K at the fields.

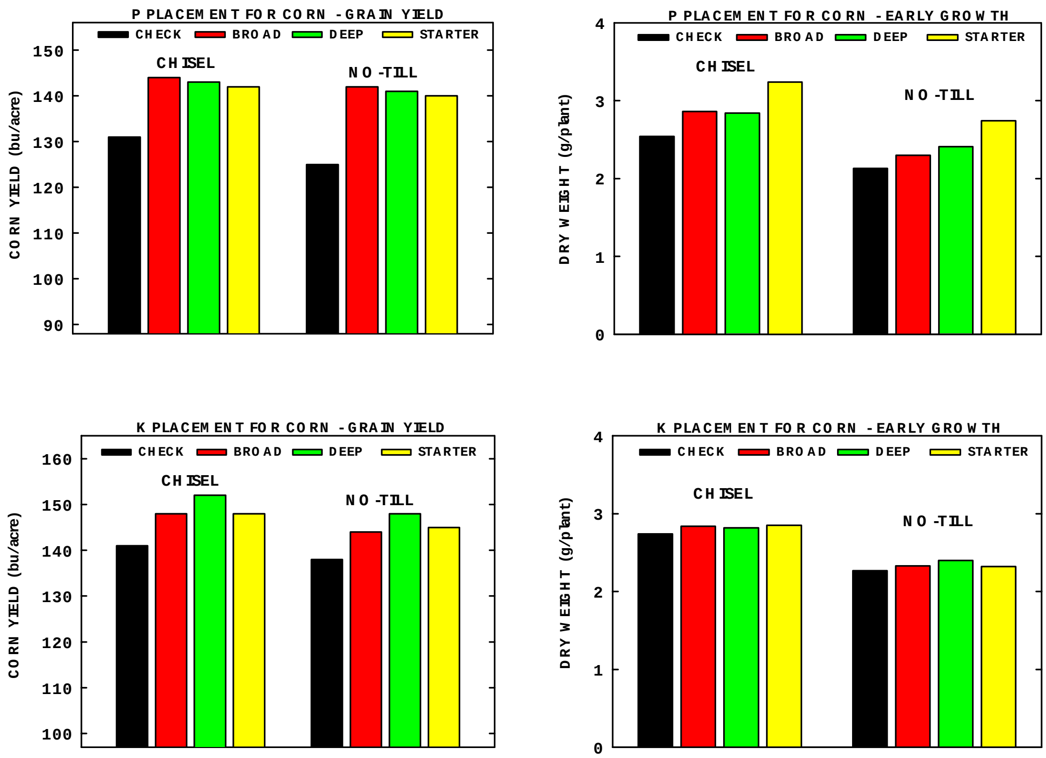

Fig. 3. Average effects of P and K fertilization and placement on early growth and grain yield of corn managed with chisel-disk and no-till tillage for fields that responded to P fertilization.

The lack of major grain yield response to P fertilizer when soil-test P was optimum or above coincides with previous results for Iowa fields managed with chisel-plow or ridge tillage and broadcast fertilization. The soils differed in the stratification of soil-test P, which reflected the differences in histories of no-till management and P fertilization. On average, the soils had 75% more soil-test P in the 0-3 in. depth than in the 3-6 in. depth and ranged from about 10 to 200% across sites. Responses to P placement, however, were not observed even in soils with high stratification. The results suggest that soil-test P stratification, placement methods, and sampling depth for P are not major issues for no-till Iowa soils and weather conditions similar to those included in this study. The shallow soil sampling was a better predictor of yield responses only in very few instances. Several considerations are important when interpreting the lack of response to P placement and comparing it with results for other regions. Aspects that may explain a lack of response to P placement include the moderate P fixation capacity of Iowa soils, the lack of extremely deficient soils, the fall broadcast fertilization in no-till, and the usually good soil physical properties for root growth (as compared with soils of other regions). Thus, the results do not exclude the possibility of benefits of P banding in Iowa under special conditions such as in highly calcareous soils and in soils very deficient in P and/or with less favorable physical properties.

The small but frequent significant grain yield response to deep-band K fertilization in soils that tested optimum or above in soil test K contrast with previous research on Iowa soils managed with conventional tillage and broadcast fertilization. Although responses to deep-banded K usually were small, they occurred at many sites. Although a small part of the response could be due to the strip-tillage effect, this is not likely because this response was not observed for deep-banded P. Also, results not shown for trials at producers' fields showed that crops respond to deep-band K even two years after the application. The yield responses and soil K at various depths were not significantly correlated, although it must be remembered that all fields tested optimum or above in K. Also, sites in which the response to K placement was largest did not have the largest soil K stratification. Although the K stratification in these soils was less than for P, in average the soils had 40% higher K in the 0-3 in. depth than in the 3-6 in. depth. It is likely that the responses to deep-banded K were related with weather conditions, particularly soil moisture in late spring or early summer. The yield response to deep-banded K relative to the response to broadcast K decreased with increasing June or early July rainfall. These correlations suggest that responses to deep-banded K are greater when there is little rainfall during the period of fastest corn growth. It is likely that plant K uptake from shallow soil layers is reduced by dry topsoil and that the deep-banded K alleviates the problem.

Fertilizer placement for soybeans.

Phosphorus fertilization increased soybean grain yields in soils that tested very low or low soil test P, although responses did not occur at all low-testing soils. The P placement method influenced yields significantly at one site, in which the two banded placements did not differ and produced higher yields than the broadcast placement. The analysis of means over all sites that responded to P fertilization showed no P placement effects. Data in Fig. 4 show the average responses to P placement for the responsive sites at research farms (there was no response to P placement at the producers' fields).

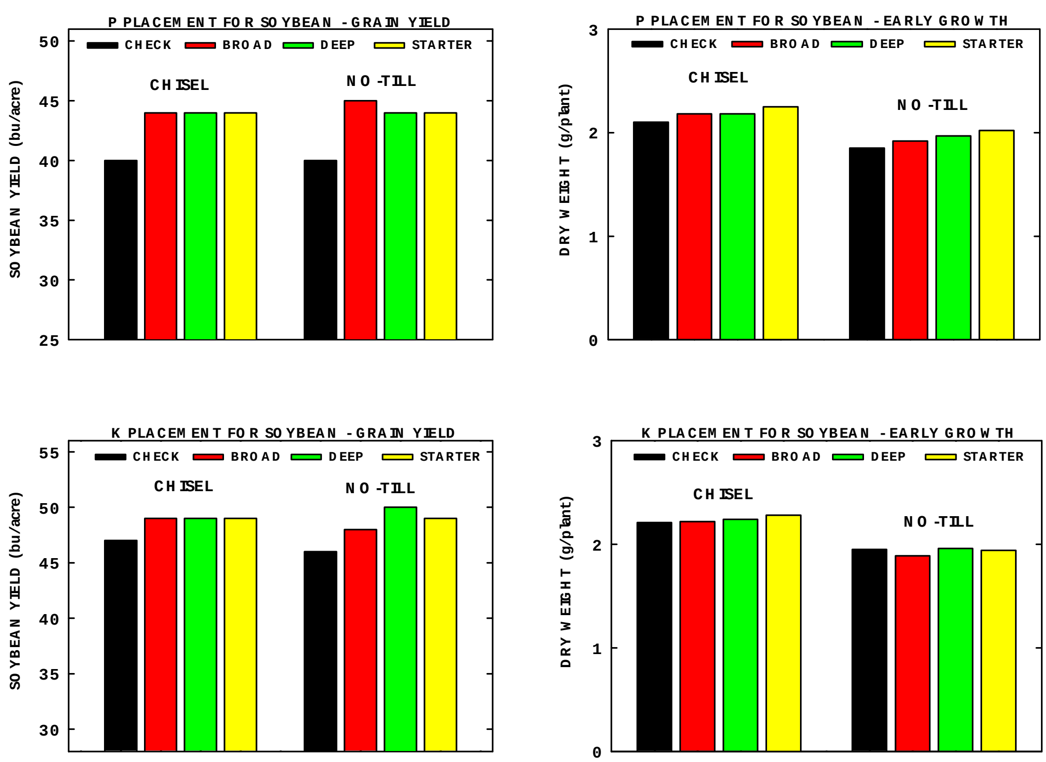

Fig. 4. Average effects of P and K fertilization and placement on early growth and grain yield of soybeans managed with chisel-disk and no-till tillage for fields that responded to P fertilization.

Early growth of soybeans usually was increased by P fertilizer applications, although differences usually were smaller than for corn. Also, the response occurred even in high-testing soils, although it tended to be larger in soils that tested below optimum in P. Similarly to results for corn, responses almost always were larger for the planter-band placement (starter), less for the deep-band placement, and even less for the broadcast placement. The combination of responses in grain yield and early growth shows that small effects of banded P fertilizer on early growth do not translate into higher soybean yield.

Potassium fertilization increased soybean grain yields significantly at several sites. Similar to results for corn, these responses were not expected because most soils tested optimum or higher in soil test K. Although statistical analysis confirmed an influence of the K placement method only at few sites, an analysis of averages across all sites showed a significant placement difference for no-till soybeans. This is the only instance in which the tillage made a difference in the response to fertilizer placement. Yields for the two banded placements did not differ statistically and were higher than yields for the broadcast placement. Data in Fig. 4 shows these average responses. A similar small advantage for the deep-band placement over the broadcast placement was observed at producers' fields (not shown). High rates of broadcast K did not offset the advantage of deep-banded or planter-banded K. The responses of soybeans to the band placements, were not clearly related with deficient rainfall in late spring and early summer or with soil test K. Potassium fertilization and placement seldom influenced early growth of soybeans. This result is in contrast to effects of P placement on early growth and of K placement on grain yield. This result coincides with the rare responses of soybeans to starter fertilizer.

Conclusions

Grain yields of corn often were significantly lower for no-till at many fields. The average yield difference across all fields and years was only 3.5 bu/acre but was as high as 12 bu/acre in some fields. Differences were larger after many years of no-till and with wet and cold spring weather. Tillage did not affect soybean yield. Planting on top of a fall-applied tilled strip often increased early corn growth but had inconsistent effects on grain yield. Most often it did not increase yields and sometimes it increased or decreased yields.

The results showed that P fertilization increased yields of no-till corn and soybeans in soils testing very low and low and that there were no differences among P placements. Any of the placements evaluated are effective to alleviate P deficiencies in low-testing soils. In contrast, the banded P placements almost always enhanced early corn growth. This enhanced early growth, however, never translated into higher grain yields. Deep-banded P greatly reduced the accumulation of P near the soil surface of no-till soils, which could be of significance for the conservation of the quality of surface water supplies.

Deep-band K fertilization increased grain yields of corn managed with no-till or chisel-disk tillage and yields of soybeans managed with no-tillage. The responses were not expected because the soils tested optimum or above in soil-test K. The responses tended to be larger for no-till corn and, although they were fairly consistent, were small in several fields. The average yield increase over the broadcast or planter-band placements across all fields was 3 bu/acre. The largest responses seemed more related with deficient rainfall in late spring and early summer than with soil test K (the study included no low-testing soils) or soil K stratification. In contrast to results for P, banded K did not enhance early growth of corn or soybeans.

Because the yield responses to deep-banded K usually were small, the cost-effectiveness of this placement will be largely affected by differences in the costs of application and by soil moisture conditions in late spring or summer that cannot be predicted in advance. The results suggest that crops respond to deep-band K even two years after the application. Thus, infrequent deep banding (every three or four years) could still increase yields and increase the profitability of this practice.