PHOSPHORUS AND POTASSIUM PLACEMENT METHODS FOR CORN AND SOYBEAN: AN IOWA PERSPECTIVE

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Introduction

Increasing fertilizer prices and awareness of potential impacts of excessive or badly applied nutrients on water quality has renewed interest in fertilizer management strategies that reduce nutrient inputs or improve efficacy. Fertilizer recommendations for phosphorus (P) and potassium (K) in Iowa and most states of the Corn Belt are based on soil testing and maintenance of desirable soil-test values by applying amounts removed with crop harvest. The typical Iowa farmer applies before planting corn the P and K fertilizer needed for corn-soybean rotations. A few farmers, mainly in the northern regions of the state and those using no-till management, also apply starter fertilizer for corn. Iowa research during the 1960s and 1970s showed that application of P and K fertilizer at rates of 20 lb P_2O_5 or K_2O/acre or higher rates applied with planter attachment besides and below the seeds (commonly referred to as the 2x2 method) seldom was more efficient than similar amounts applied broadcast and seldom increased yield significantly in high-testing soils. Corn response to N-P-K starter was more likely for very early planting dates with wet and cold soil and/or high residue cover. Reports of corn responses to starter have been more frequent in northern regions of the Corn Belt, such as in Minnesota and Wisconsin.

New developments since the early 1990s have determined a need for further research on P and K fertilizer methods, however. Adoption of chisel-plow, no-till, and strip-till management has increased steadily in Iowa and the Corn Belt (little or no moldboard plowing is used anymore). With no-till or chisel-plow tillage, crop residues and broadcast fertilizers are not incorporated or are partially incorporated into the most shallow soil layers. These practices result in significant residue, P, and K accumulation at or near the soil surface and also in both cooler and wetter soils in early spring. These conditions may reduce early crop growth and nutrient uptake by crops, although residue cover improves water availability and root efficiency in shallow soil layers during summer. At the same time there has been a steady increase in the width of planters that has discouraged use of 2x2 fertilizer attachments. Few Iowa farmers have fertilizer attachments and a few apply in-furrow liquid starter.

Therefore, several Iowa long-term research projects began studying broadcast, 2x2 band, and deep-band placement methods for granulated P and K fertilizers for corn and soybean and also liquid P-K starter for corn using 2x2 or in-furrow application methods. This article briefly summarizes the most relevant results of these projects. Readers must understand that results and recommendations for prevailing soil and climate conditions in Iowa should not be directly extrapolated to other regions.

Placement Methods for Primary Phosphorus and Potassium Fertilization

Ten long-term Iowa studies have assessed P and K placement methods for the corn-soybean rotation under chisel-plow/disk or no-till management since 1994. Until 2001, treatments included several rates of granulated fertilizers broadcast (in the fall), deep banded (in the fall), and banded with the planter (2x2 method). The broadcast and 2x2 methods continue being evaluated today. More than 30 additional short-term trials were established on farmers' fields managed with no-tillage to further evaluate the broadcast and deep-band methods. Fields tested from very low to very high in P and K according to Iowa interpretations, soil pH varied from acid to calcareous (up to pH 8.2), and the

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texture of the surface soil layer ranged from loam to clay-loam and silty-clay-loam. The deep bands were applied at a 5-7 inch depth and at a spacing that coincided with the corn row spacing (usually 30 inches), and planter-applied bands were placed 2 inches beside and below the seeds. At most sites the coulter-knife used to place the deep bands also tilled the soil along a narrow swath.

The results of these studies were consistent with studies conducted decades ago in Iowa concerning little and inconsistent crop response to P placement methods for any tillage system or region. Results also showed no differences among K placement methods for crops managed with chisel-plow/disk tillage. Such a lack of response to P banding was observed even with significant soil-test P stratification. However, the results for no-till crops indicated that deep-band K application often was more efficient than either broadcast or planter-band methods. Additional yield increases due to deep placed K were larger and more consistent for corn than for soybean. Data in Fig. 1 summarize results for long-term experiments at five Iowa State University research farms that compared the three placement methods for the two nutrients. The advantage for deep-band K was even higher in fields managed with permanent large ridges (not shown) than for no-till. The figure shows averages for rates of 28 and 56 lb P_2O_5/acre or 35 and 70 lb K_2O/acre because results were similar for the two rates. It is important to note that banding of P or K did not reduce the amount of fertilizer needed to achieve a certain level of yield.

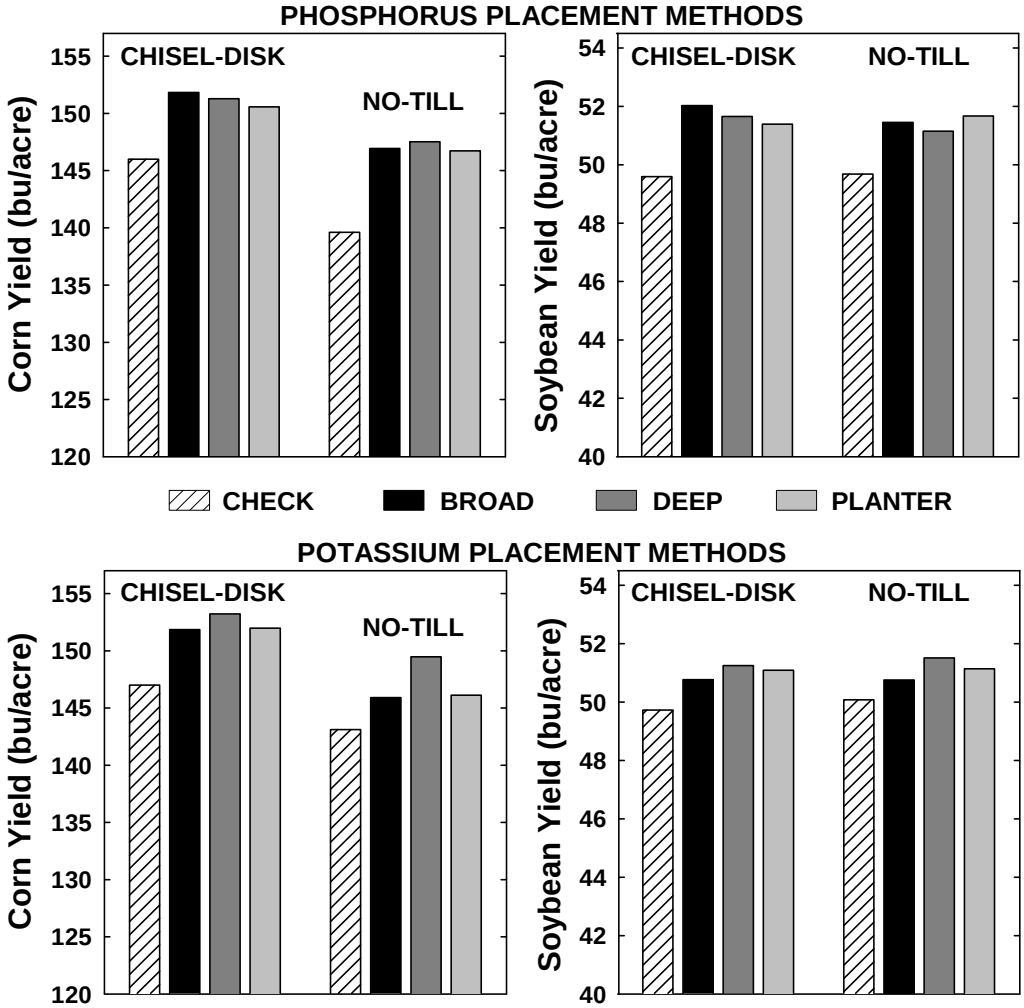

Fig. 1. Average corn and soybean yield response to P and K fertilizer placement methods across five Iowa long-term field trials and rates of 28 to 56 lb P_2O_5/acre and 35 to 70 lb K_2O/acre.

Results of evaluations of plant early growth and nutrient uptake showed very contrasting results, however. Data summarized in Fig. 2 show that banded P greatly increased early plant growth more than broadcast P, but this was not observed for K fertilizer.

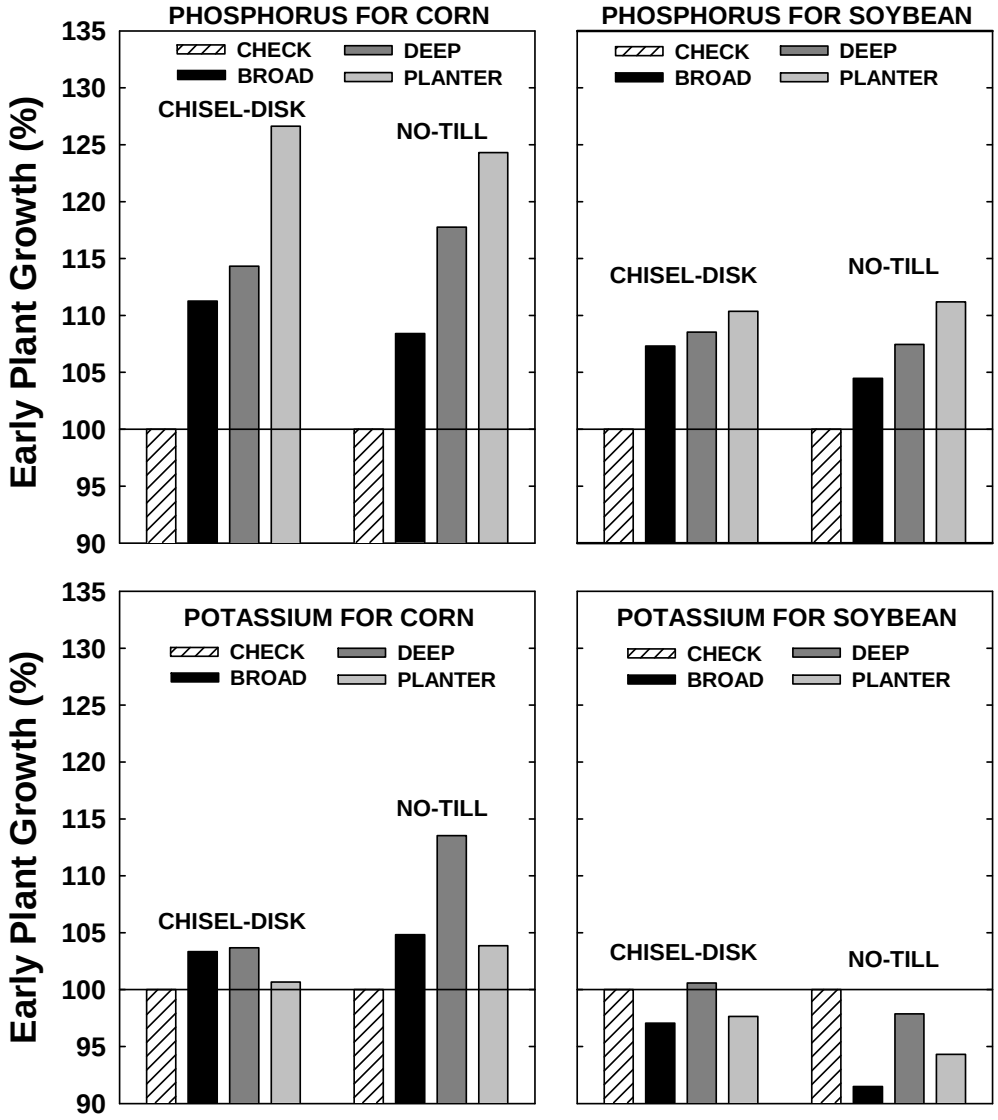

Fig. 2. Average corn and soybean early plant growth response to P and K fertilizer placement methods across five Iowa long-term field trials and rates of 28 to 56 lb P_2O_5/acre and 35 to 70 lb K_2O/acre.

Based on these results, current Iowa fertilizer recommendations do not include guidelines for P fertilizer placement methods, except for suggesting starter fertilizer under specific conditions, but recommend deep-band K for no-till and ridge-till systems. This research evaluated application rates of 28 lb P_2O_5/acre or 35 lb K_2O/acre and higher rates. Therefore, results do not exclude the possibility of placement methods differences for P or even larger for K when lower fertilizer rates are applied to soils testing very low in P or K, where the planter-band placement method may be more effective. However, in practice few farmers would broadcast very low P and K fertilizer rates. Because the average magnitude of the yield increase for deep-band K in no-till fields was variable and it does not determine a significantly lower application rate than with the broadcast method, deep K banding often

may not offset increased application costs. Large variation in the no-till corn response to deep-band K was more related to deficient soil moisture in late spring and early summer than to soil-test K stratification. Therefore, conditions for large yield responses that offset costs are difficult to predict.

Liquid Starter Fertilization for Corn

Application of commercial liquid N, N-P, or N-P-K starter was tested at more than 50 trials conducted in Iowa producers' fields. All fields were managed with corn-soybean rotations and with no-till, ridge-till, or chisel-plow/disk tillage. The research was developed with different objectives using two different sets of field trials. In one set of trials, the objective was to assess corn response to P and K starter with and without the broadcast P-K rates recommended to supply the need of 2-year corn-soybean rotations applied once before corn (which ranged from 100 to 160 lb P_2O_5/acre and 100 to 180 K_2O/acre). A maintenance rate based on crop removal was also applied to high-testing soils, although this is not recommended in Iowa. In this set of trials, N fertilizer was applied across all treatments by injecting 120 to 160 lb N/acre before planting corn plus 50 to 60 lb N/acre broadcast immediately after planting. The liquid starter was applied to the seed furrow or with 2x2 planter attachments, but the two methods of application were not compared. The starter products used varied across fields and included 3-18-18 (low salt), 6-18-6, 7-21-7, or 9-18-9, and applied rates of 5 to 25 lb P_2O_5 and K_2O/acre.

This set of trials resulted in very significant outcomes. One result was that P-K starter fertilization in low-testing soils resulted in large corn yield increases but the higher broadcast rates recommended for these soils increased yield further. Other important yield results were that P-K starter never increased corn yield further when it was applied after applying the recommended broadcast P-K rates for 2-year corn-soybean rotations, and that in soils testing optimum or higher in P or K the responses were similar for starter fertilizer and the much higher broadcast rates designed to maintain soil-test values over time. Furthermore, results showed that similarly to findings with granulated fertilizers, starter P increased early corn growth in fields testing very low to very high and that this effect was greater with no-till management.

Data in Fig. 3 summarize corn early growth and grain yield responses for starter P-K, broadcast P-K, and both starter and broadcast fertilization according to the initial soil-test P level of 31 field trials that used approximately similar methods. As expected, the yield response decreased as the soil-test P level increased. Results also show that broadcast fertilizer increased grain yield more than the starter in low-testing soils, the starter in addition to broadcast fertilizer did not increase yield further, and the response to both sources was approximately similar in soils testing more than about 20 ppm Bray-1 P. The data must be interpreted with care because P and K were applied together and soil-test K varied mostly from low to very high across most soil-test P ranges, although it was also high or very high when soil-test P was high. Analysis of the data for each site (not shown) indicated little or no response to starter or broadcast fertilization when both soil P and K were high. In contrast to results for grain yield, starter P-K fertilizer almost always increased early corn growth more than the broadcast fertilizer and often increased early growth after having applied broadcast fertilizer, even in high-testing soils. Results of plant analyses (not shown) suggested that this plant growth response usually was due to starter P and sometimes due to starter N. The plant analyses suggested that in some fields the high N fertilizer rate applied uniformly across all treatment did not completely eliminate a starter N effect in some fields.

The observed similar responses to starter or broadcast P-K in soils testing medium or high should not be confused with a placement method difference. Iowa research has shown that the probability of a crop yield response is about 25% in soils testing 16 to 20 ppm P (Bray-1 method) or 130 to 170 ppm K (ammonium acetate method) to a 6-inch soil depth. Fertilization based on P and K

removed with harvest is recommended for these soil-test ranges with the objective of catching any possible crop response and to maintain soil-test values over time for long-term profitability and reduced risk of yield loss. Therefore, lower fertilizer rates, even as low as starter rates, could result in maximum yield of a first crop. However, such small fertilizer rates will not maintain soil-test values over time and higher rates may have to be applied for future crops. No fertilizer is recommended for soils testing higher in P and K, except for conditions of limited soil drainage, early planting dates with cold and wet soil, or very high residue cover.

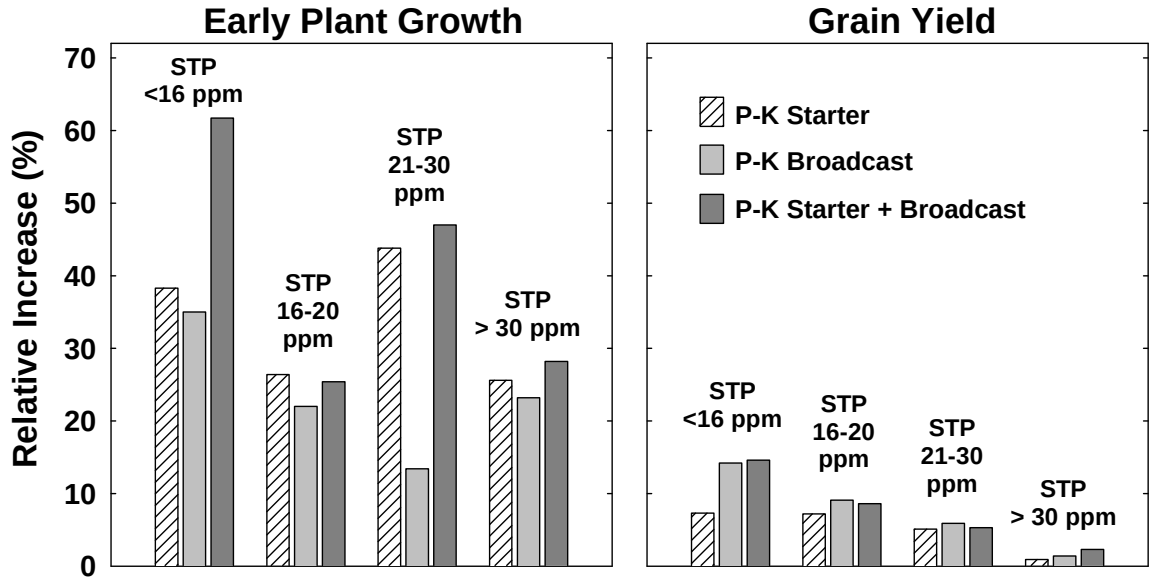

Fig. 3. Average corn early growth and yield responses to starter P and K fertilizer (5 to 25 lbP_2O_5 and K_2O/acre) and broadcast fertilizer (100 to 160 lb P_2O_5/acre and 100 to 180 K_2O/acre) across 31 Iowa trials in fields managed with no-till or chisel-plow/disk tillage.

Research involving a second set of eight replicated strip trials trials focused on determining if the occasional corn response to starter observed in Iowa high-testing soils managed with no-tillage is due to N, P, or P-K in the starter. Four replicated treatments in this set of trials were a check; commercial liquid starter N-P or N-P-K to supply 5-10, 15-25, and 0-7 lb N, P_2O_5, and K_2O, respectively (depending on the product and field); the commercial starter rate plus 28% or 32% urea-ammonium nitrate solution (UAN) to a total of 23 to 30 lb N/acre; and starter N (UAN) to supply 23 to 30 lb N/acre. All fertilizers were applied beside and below the seeds with 2x2 planter attachments. No broadcast P or K was applied because the fields tested high to very high in P and K. However, UAN or anhydrous ammonia N fertilizer was injected across the entire experimental areas at rates ranging from 110 to 160 lb N/acre in spring before planting corn in one field and sidedressed at the V4 to V6 corn growth stage in the other fields.

Figure 4 summarizes the results of these trials for both corn grain yield and early plant growth. In these eight high-testing fields, the response to starter was always due to starter N. The average grain yield increase across all fields was about 5 bu/acre, although increases at each field ranged from 0 to 9 bu/acre. There was no response to starter N (or to any starter treatment) in the field where the uniform primary N fertilization was applied in spring before planting corn. Therefore, the results from this set of trials confirmed indications from results of the other trials in that that starter N usually explains the corn yield response to starter in Iowa high-testing soils managed with no-tillage, at least when the primary N fertilization is done after planting corn.

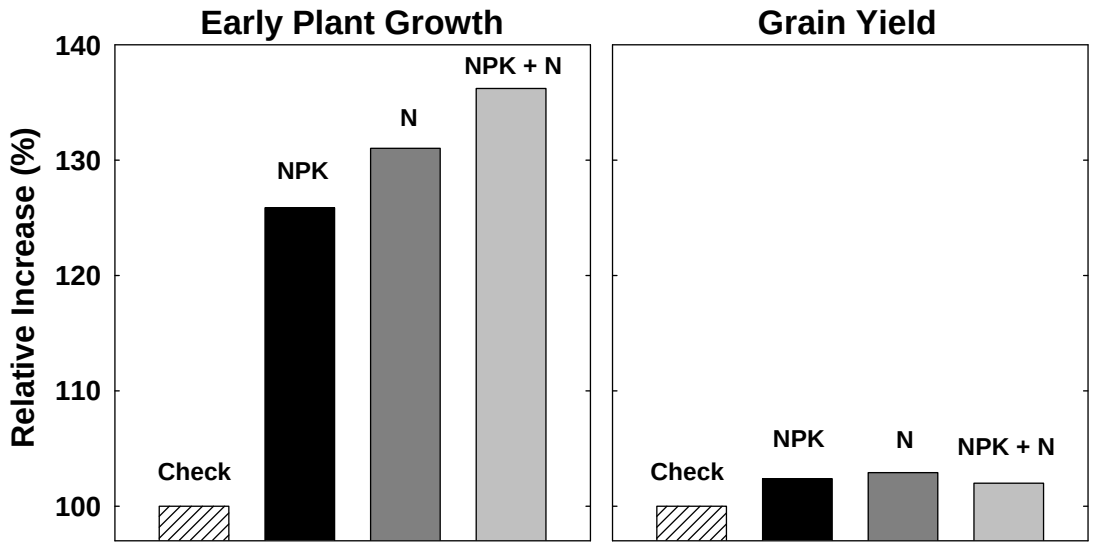

Fig. 4. Average corn early growth and yield responses to liquid starter N-P or N-P-K (5-10, 15-25, and 0-7 lb N, P_2O_5, and K_2O/acre), starter mixed with UAN (to supply a total of 23 to 30 lb N/acre), and starter N (UAN to supply 23 to 30 lb N/acre) across eight trials in Iowa high-testing fields managed with no-tillage.

Summary and Conclusions

Theoretical considerations and results of research in other regions suggest that banding the primary P and K fertilization needs of crops may be better than broadcast fertilization in some soils. Also, other considerations suggest that starter fertilization of corn can effectively supplement the primary broadcast fertilization program with certain soil and climate conditions. The Iowa experience provided useful results for Iowa crop producers, and combined with local research also may be useful for regions of neighboring states with similar soils, climate, and crop production systems.

A humid climate and medium-textured soils with properties that result in good water holding capacity and root growth determine little or no advantage of band P placement for corn and soybean in Iowa. Although shallow or deep banding of P almost always increases early crop growth, especially with no-till management, it seldom results in higher grain yield than with broadcast fertilization and does not reduce the amount of P needed for maximum yield. Research did indicate, however, that deep placement of K fertilizer often, but not always, is better than broadcast fertilization with no-till and ridge-till management. The benefit of deep K banding is poorly related to soil-test K stratification and is better related to below-normal late-spring or early summer rainfall. The research also showed that in soils having near optimum P and K levels starter fertilization and larger broadcast rates designed to maintain soil-test values over time often result in a similar yield response. This result confirms a known fact, which is that P and K rates smaller than rates designed to maintain soil-test P and K values often maximize the yield of one crop and in the short term are more profitable. The results indicated that occasional responses to starter fertilizer in Iowa high-testing no-till soils usually are explained by starter N mainly when the primary N fertilization is applied in the fall or sidedressed after planting corn, and seldom to starter P as many believe. Research results do not support using starter or broadcast fertilization across all conditions in high-testing soils. The research did indicate, however, that small starter fertilizer rates provide an economical and environmentally sound way of applying additional N, P, and K cast when producers are concerned about reduced early corn growth and yield in high-testing soils.

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