STARTER AND FOLIAR FERTILIZATION: ARE THEY NEEDED TO SUPPLEMENT PRIMARY FERTILIZATION?

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Introduction

Many Iowa fields require nitrogen (N), phosphorus (P), and potassium (K) fertilization for optimum crop production. Crops remove large amounts of these nutrients from the soil, and large amounts of fertilizers often need to be applied. Fertilizer application methods and application equipment commonly used to supply these nutrients are adapted to large fertilizer application rates. These methods include broadcast application of granulated or fluid fertilizers with or without incorporation into the soil with tillage, injection of fluid fertilizers into the soil, or deep banding of granulated fertilizers. The P and K fertilizers usually are applied before planting crops, while N fertilizers for corn are applied before and (or) after planting the crop. Also, most producers apply once before planting corn the P and K fertilization rates recommended for the 2-year corn-soybean rotation.

Other methods of fertilizer application can be used to supplement the primary fertilization with N, P, K, sulfur (S), or micronutrients. These methods include spraying fluid fertilizers over crop canopy and application of starter fertilizer mixtures with the planters. Few farmers use these supplemental fertilization methods. Foliar fertilization is used mainly for soybeans, while starter fertilization is used mainly for corn. Research with foliar fertilization of corn or starter fertilization for soybeans is scarce. The results have shown no yield increases, and will not be discussed. This presentation will briefly summarize results of research for foliar fertilization of soybeans and starter fertilization for corn, and will discuss the conditions in which these practices could be profitable for Iowa producers.

Foliar Fertilization of Soybeans

Fertilization at reproductive growth stages.
Numerous field experiments conducted during the 1970s and 1980s in Iowa and other regions investigated foliar fertilization of soybeans at reproductive stages. The soybean plant is characterized by a sharp decline of root activity during late seed development stages and increased translocation of nutrients from leaves and pods into the seed. Researchers theorized that if nutrients were applied directly to the foliage at this time, leaf senescence could be delayed and grain yields might be increased. Iowa research during the early to middle 1970s seemed to confirm this hypothesis. A few experiments showed that spraying soybean canopy with a 10-1-3-0.5 N-P-K-S nutrient mixture between the R5 and R6 growth stages could increase yields by 7 to 8 bu/acre. However, many other on-farm trials showed that foliar fertilization at late reproductive stages produces inconsistent results and usually does not influence yield or reduces yield. For example, results of research conducted during the middle to late 1970s in more than 200 fields across 28 states showed that yield responses varied from a maximum increase of about 1 bu/acre to a yield decrease of 6 bu/acre. More recent work in Iowa and neighboring states under rain-fed conditions showed similar inconsistent responses. These results have discouraged further research or widespread adoption of foliar fertilization of soybeans at late growth stages.

Fertilization at early growth stages.
Little effort was dedicated until the middle 1990s to study foliar fertilization of soybeans during early vegetative stages. Field observations and research with P and K in Iowa suggested that nutrient deficiencies may occur during early growth of soybeans, even in fields that have been fertilized. Deficiencies have been partly explained by inhibited activity of roots when the topsoil is dry, reduced early nutrient uptake because excessively wet and cold soil, and other factors resulting in reduced early root growth. In these conditions, supplemental foliar fertilization could result in increased growth and higher yield. Small amounts of N, P, and (or) K applied at early critical periods could be effective if foliar fertilization is viewed as a complement for soil P and K fertilization and symbiotic atmospheric N fixation.

Approximately 100 replicated field trials have been conducted at Iowa producers' fields since 1994 to evaluate the effect of foliar fertilization of soybean at early growth stages with various commercial fluid fertilizers. The fields were managed with no-till, ridge-till, or chisel-plow tillage. Because the majority of Iowa soybean fields test optimum or higher in soil-test P or K, only a handful of fields tested below optimum. Treatments changed over time. The mixtures used (N-P-K-S) included 3-18-18-0, 3-18-18-1, 10-10-10-0, 10-10-10-1, 8-0-8-0, and some of these same mixtures with the addition of various micronutrients. Treatments involved single or double applications (spaced 10 days) of 2 to 4 gal./acre sprayed with 10 gal./acre of water during the V5 to V7 growth stages.

Figure 1 summarizes results across fields and years for 66 experiments that compared different sets of six treatments. Results of other trials are not shown because fewer treatments were compared and the general results were similar. Each graph shows results across all fields and for fields where at least one treatment was statistically different from the check. Foliar fertilization increased yield in 15 to 30% of the fields depending on the year. Only the higher rates of 10-10-10 and 8-0-8 fertilizers (with or without S) reduced yield in a few fields (obvious leaf burn was observed). Differences between treatments were not consistent across the responsive fields, and could not be explained with certainty. However, yield responses were more consistent for a rate of 3 gal./acre of 3-18-18 fertilizer. Adding S or micronutrients did not produce higher yield. Although double applications sometimes were better than single applications, the yield responses usually were statistically similar and yield differences seldom offset increased application costs. It is important to remember that most fields tested optimum or higher in P and K, and that responses were observed in low-testing fields and also in many high-testing fields.

The conditions in which foliar fertilization would increase yield are difficult to predict. The relationship between yield response and site variables (such as soil-test values, soil type, tillage system, nutrient uptake at early vegetative growth stages or at early reproductive stages, rainfall, temperature, planting date, etc.) was studied by multivariate statistical analyses. The results did not support strong and clear conclusions, but suggested conditions in which a response to foliar fertilization is more likely.

In some years, responses were higher and more frequent in ridge-till and no-till fields compared with chisel-plow tillage. The result is reasonable because foliar fertilization could alleviate early nutrient deficiencies that sometimes occur in fields managed with these systems. In some years yield responses were higher or more frequent when early plant growth and P or K uptake

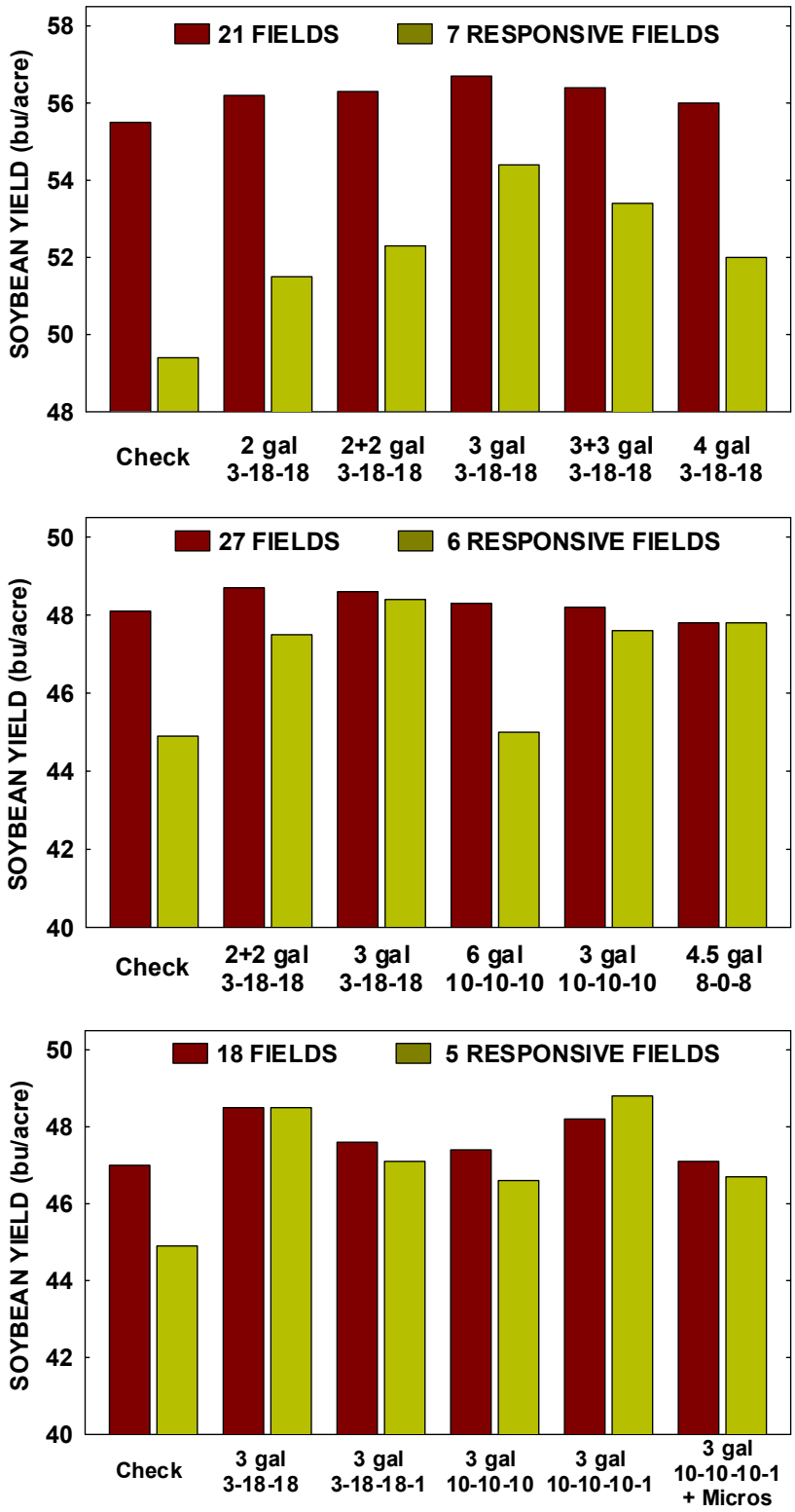

Fig. 1. Soybean yield response to foliar fertilization at early growth stages for three sets of on-farm trials conducted in Iowa (soil-test P and K was optimum or higher in most fields).

were low because of a variety of conditions (such as nutrient deficiencies, cool temperatures, and either low or excessive rainfall). Thus, growth factors that inhibit growth and nutrient uptake early during the growing season increase the likelihood of positive responses to foliar fertilization.

Starter Fertilization for Corn

Many studies have shown that starter fertilization can increase early plant growth, nutrient uptake, and grain yield of corn. Research has also shown that band application of small amounts of P and K fertilizer applied to the seed furrow or beside and below the seed (commonly referred to as the 2 x 2 method) is more efficient than similar amounts applied broadcast. However, little research has focused on studying how small starter P and K rates can supplement primary fertilization programs that involve large broadcast fertilization rates. Most Iowa farmers apply once before planting corn the P and K fertilizer recommendations for the 2-year corn-soybean rotation. Many farmers question the need of starter fertilization when maintenance fertilization based on these broadcast fertilization rates is being used. Observations of early corn growth suggest that starter application could still be needed, especially for no-till or ridge-till corn. Also, research is needed to better understand the reason for occasional corn responses to N-P or N-P-K starter fertilization in soils testing high in P and K.

The response of corn to commercial liquid N, N-P, or NPK starter was tested at more than 50 trials conducted in Iowa producers' fields since 1994. All fields were managed with a corn-soybean rotation and most with no-tillage or ridge-tillage. The trials can be grouped into three sets of experiments. For Set 1, treatments were a check and N-P or N-P-K starter with or without a broadcast P-K rate to supply the need of a 2-year corn-soybean rotation (100 to 140 lb P_2O_5 and K_2O). Nitrogen was applied across all treatments by injecting 120 to 160 lb N/acre before planting and broadcasting 60 lb N/acre immediately after planting. For Set 2, only a check and starter fertilizer were compared, no preplant P or K was applied, and the farmers used their normal N fertilization practices. For these two sets, the starter was applied to the seed furrow or with the 2 x 2 method (the two methods of application were not compared). The starter products used varied across fields and usually were 3-18-18, 6-18-6, 7-21-7, 9-18-9, or 10-34-0 applied at a rate of 5 to 6 gal./acre. For Set 3, treatments were a check, starter N, and starter N-P or N-P-K applied with the 2 x 2 method to fields testing high or very high in P and K. No broadcast P or K was applied, and a rate of 110 to 160 lb N/acre was sidedressed (injected) across all treatments at the V5 to V6 corn growth stage. Grain yield and early corn growth (at the V5 to V6 stage) were measured in all trials.

These studies showed that starter fertilization in low-testing soils produces large corn yield increases, but higher broadcast rates are needed to maximize yield and build-up soil test values. In low-testing soils, both P and K in the starter mixture explained the yield response to starter (without preplant P and K application). However, in soils testing Optimum or higher, or when starter is applied after preplant P-K fertilization, the corn response to starter usually was explained by the P or N in the mixture. Study of responses to starter across many fields showed a significant relationship with soil test P but not with soil-test K. Figure 2, which summarizes data for the Sets 1 and 2 of experiments describe above, shows that the corn yield response to starter is large in low-testing soils but sharply decreases at high soil-test P values. The small

response found in soils that tested high in P seldom was statistically significant. The response in high-testing soils sometimes was agronomically important, however, and was observed only in no-till and ridge-till fields. The methods used for these experiments do not allow for conclusive explanation of this response, but results of plant analyses (not shown) suggested that it could be due to either N or P in the mixture.

Comparisons of yield responses to starter N or starter N-P-K conducted in no-till soils that tested high in P and K confirmed that the N often explains the yield response to starter in these soils. Figure 3 summarizes the results of these experiments for both grain yield and early growth. In these eight high-testing fields, the response to starter was always due to starter N probably because the primary N fertilization was applied sidedressed. Starter N may not be needed when the primary N fertilization is applied in spring before planting, but could be needed when it is applied in the fall and N has been lost from the top few inches of soil.

Studies of corn response to P-K starter fertilization with and without commonly used broadcast P-K fertilization rates showed that in soils testing Optimum or higher in P (and presumably with non-limiting N) these methods usually produced similar yield levels. Figure 4 shows corn yield response to both methods across fields ranging from low to high in soil-test P. The observed response in fields testing Optimum is reasonable because Iowa research has shown up to 25% probability of a small yield response in this soil P class. Results for the high-testing soils showed a much smaller response to either fertilization method that seldom was statistically significant even in fields managed with no-tillage or ridge-tillage. Although the response to starter or broadcast fertilization was similar in high-testing soils, the starter applied only a fraction of the 2-year P-K maintenance fertilizer rate. However, ongoing long-term research indicates that continued use of small starter rates results in declining soil-test P and K values and higher rates are needed to maintain optimum soil-test levels. Results do not support using starter or broadcast fertilization across all conditions in high-testing soil. Additional fertilization is occasionally needed in no-till and ridge-till fields, mainly under conditions of limited soil drainage, cool soil, high residue cover, or late planting dates with full-season hybrids.

Another important result from all the studies is that starter and broadcast fertilization have very different effects on grain yield and early corn growth. Figures 3 and 4 show that both fertilization methods increase early corn growth much more than grain yield. Moreover, fertilization increases early growth markedly even in high-testing soils when yield is not increased. The small amount of nutrients applied with the starter always produces significantly more early growth than much larger broadcast application rates. However, this extra growth does not result in increased grain yield. The data in Fig. 4 shows that the N in the starter has a large effect in early corn growth.

An interesting additional result from experiments comparing starter N and starter N-P-K is that delaying the primary N fertilizer application for no-till corn until sidedress time may result in a yield reduction. The averages across eight sites shown in Fig. 4 indicate that starter N increased grain yield by about 5 bu/acre, even though N fertilizer at rates of 110 to 160 lb N/acre were sidedressed (injected) across all treatments. Results for each trial showed that this difference ranged from 0 to 9 bu/acre across fields and years.

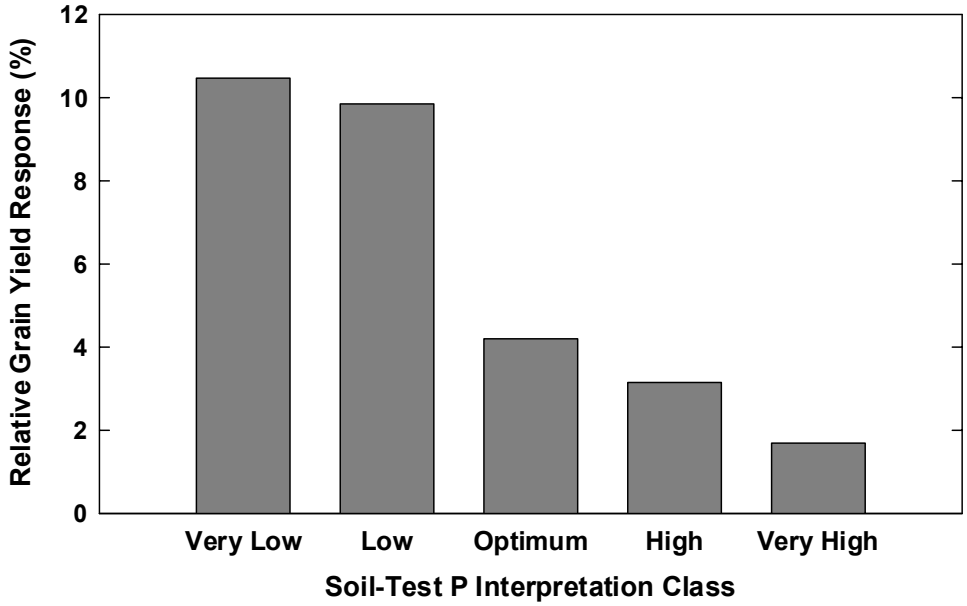

Fig. 2. Relationship between the corn yield response to starter fertilization and soil-test P. No preplant P or K was applied, and soil-test K ranged form Very Low to Very High across all P classes.

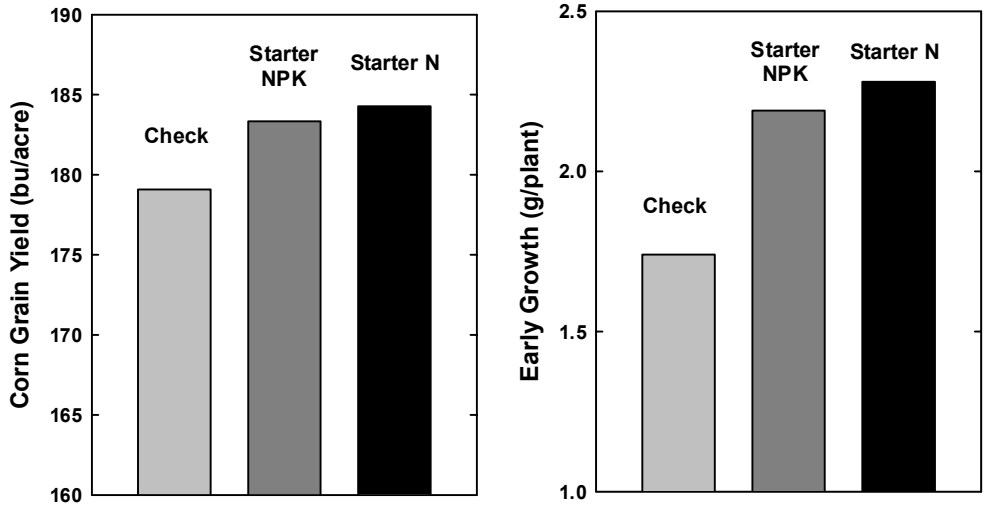

Fig. 3. Effect of starter NPK and starter N on grain yield and early growth of no-till corn in high-testing soils (averages for eight fields). No preplant N, P, or K was applied, and 110 to 160 lb N/acre were sidedressed (injected) across all treatments.

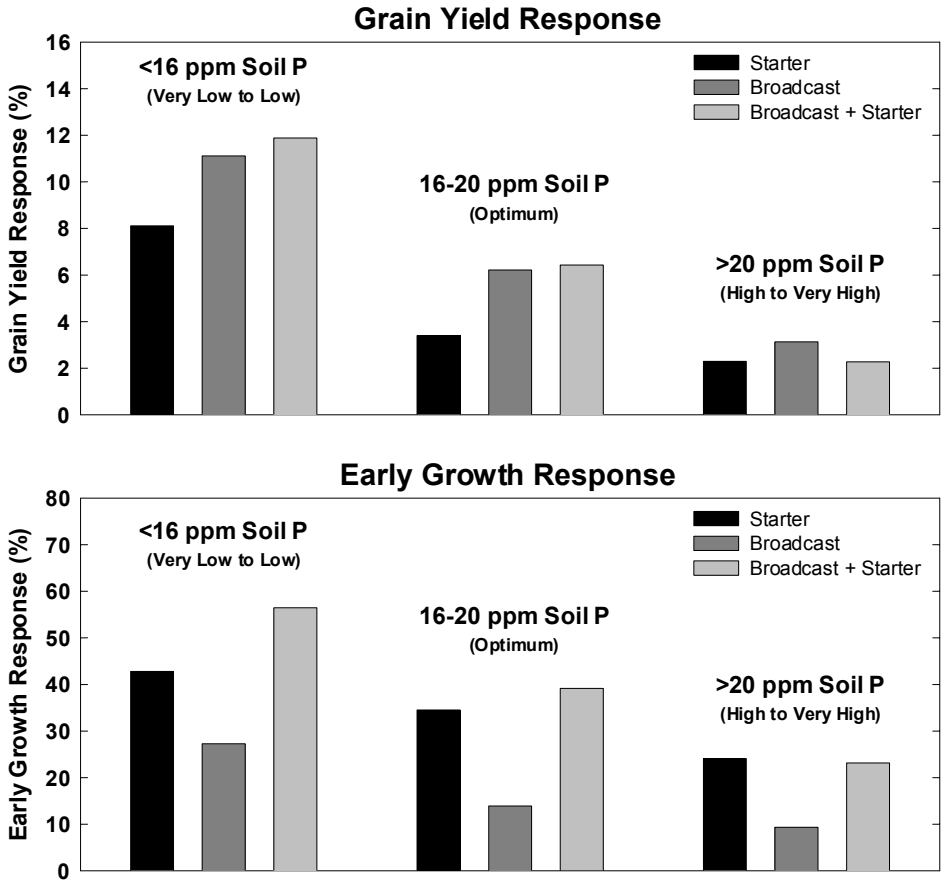

Fig. 4. Comparison of corn yield and early growth response to starter and broadcast P-K fertilization for various ranges of soil-test P values. Soil-test K ranged from low to very high values across all soil-test P ranges.

Summary and Conclusions

Both foliar fertilization of soybeans and starter fertilization of corn can effectively supplement the primary fertilization programs for these crops in some conditions. However, these practices across all production conditions will not be economically effective for producers.

Foliar fertilization of soybeans with macronutrients at early vegetative stages is likely to increase yields in 15 to 20% of Iowa production conditions, even in high testing soils. The research results have shown no consistent differences between products, rates, or frequencies of application tested. However, a single application of 3 gal./acre of 3-18-18 (which never caused leaf burn) usually produced the highest and more consistent yield responses. Although no simple set of measurements can be used to predict a response to foliar fertilization, a response will be more likely when low nutrient availability (which does not necessarily mean low soil-

test values) and/or climatic factors limit plant growth in late spring and early summer. In these instances, responses as high as 10 bu/acre are possible, even in high testing soils. Across all conditions, the expected average response is about 1 bu/acre.

A small amount of starter fertilizer can produce corn yield similar to yields produced by much larger broadcast rates, except in low-testing soils. Starter fertilization in addition to broadcast rates commonly applied before planting corn for the 2-year corn-soybean rotation to maintain optimum or higher soil-test P and K values does not increase yield further. However, starter fertilization produces the same yield level with only a small fraction of the nutrient applied with broadcast fertilization. Moreover, research shows that the N in the starter, especially in no-till fields, often explains corn yield response to starter in high-testing soils when the primary N fertilization is sidedressed. Research results do not support using starter or broadcast fertilization across all conditions in high-testing soils. Additional fertilization is occasionally needed in fields managed with no-till or ridge-till tillage, mainly under conditions of limited soil drainage, cool soil, high residue cover, or late planting dates with full-season hybrids. Thus, starter fertilizer provides an economical and environmentally sound way of applying N, P, and K when farmers are concerned about reduced early corn growth and yield in high-testing soils under some conditions.