Improving Corn and Soybean Yields with Starter and Foliar Fluid Fertilizers

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ABSTRACT

Micronutrient fertilizer can be applied during planting with N-P-K starter fertilizers or during foliar applications on corn (Zea mays L.) and soybean [Glycine max (L.) Merr.]. Six sites for each crop were established to evaluate combinations (factorial arrangement) of liquid starter and foliar fertilizers that contain N-P-K with and without a blend of micronutrients (Fe, Mn, Zn, Cu, and B) under irrigated conditions. Starter fertilizer treatments included: control; N-P-K fertilizer at 4–15, 10, and 10 lbs acre-1 of N, P2O5, and K2O; and N-P-K plus 0.5 lbs acre-1 of each micronutrient. Foliar fertilizer treatments included: control; N-P-K fertilizer at 2, 2, and 2 lbs acre-1 of N, P2O5, and K2O; and N-P-K plus 0.2 lbs acre-1 of each micronutrient. Foliar applications were made at the R2 and V6–V8 growth stages in soybean and corn, respectively. No early growth increases were attributed to the micronutrient blend in corn. Grain yield was increased at one site with sandy soil and low organic matter. Across six site-years, there was an increase over the control in soybean height (8 cm) and yield (4.5 bu acre-1) with starter N-P-K plus micronutrients. Starter N-P-K plus micronutrients decreased soybean trifoliolate leaf Mn concentration at all site-years with the use of chelated EDTA micronutrients. This response was attributed to the formation of FeEDTA and increased Fe supply that reduced root Mn absorption and translocation to leaves. Foliar fertilization did not increase yield in corn or soybean. Starter fertilizers showed more tendencies to increase yield than foliar fertilization in corn and soybean.

INTRODUCTION

A relatively small increase in yield may be sufficient to return a profit with micronutrient fertilization, especially when commodity prices are high. As a result, there in an increasing interest in applying micronutrients in geographic regions without a history of micronutrient deficiencies. Starter and foliar fertilization of macronutrients (N, P, and K) and secondary nutrients such as S are usually a supplement to higher rates of nutrient applications made during a separate field pass. However, micronutrients are needed by plants in relative small amounts that could be exclusively applied during planting with N-P or N-P-K starter fertilizers or during foliar applications, which minimizes any additional application cost.

Starter and foliar fertilization of corn and soybean have been evaluated with varying levels of success in increasing yield. Starter fertilization with N and P often increases corn early growth and early N and P uptake more frequently than is does grain yield (Kaiser et al., 2005; Wortmann et al., 2006; Mallarino et al., 2011). Probability of a yield response with N-P-K starter fertilizer is higher when soil test P (STP) or K (STK) is low (Kaiser et al., 2005; Wortmann et al., 2006, Mallarino et al., 2011). Starter fertilizers often include N-P or N-P-K mixtures making it difficult to attribute the response to a single nutrient (Bermudez and Mallarino, 2003). Based on our current knowledge of nutrient deficiencies and frequency of occurrence in the Great Plains region of the USA, the likelihood of increasing corn yield with micronutrient fertilizer is higher for Zn, Cl, and Fe and lower for B, Mn, Cu, Mo, and Ni. Soil DTPA (diethylene triamine pentaacetic acid)-Zn at less than 1 mg kg-1 has been used as indicator of potential corn yield response (Liekam et al, 2003).

An increase in early growth and yield from starter N fertilization of soybean has been successful in the northern Great Plains (Osborne and Riedell, 2006). Research on soybean response to starter fertilization including P has been shown to increase plant height (Ham et al., 1973) and yields (Ham et al., 1973; Bauh et al., 2000) when STP is low. Preplant and foliar K applications can be effective at increasing soybean height and yield on low STK soils (Nelson et al., 2005). Further, leaf area index can be increased with P and K fertilization as early at the V2 growth stage (Farmaha et al., 2012). Foliar N-P-K fertilization of soybean had led to only small and inconsistent yield increases where STP and STK are optimum to very high (Haq and Mallarino, 2000; Mallarino et al., 2001). Mallarino et al. (2001) found no additional yield increase with micronutrients (B, Fe, and Zn) added to an N-P-K foliar fertilization. However, a positive yield response from the use of N-P-K foliar fertilizer was measured over 18 site-years by Mallarino et al. (2001). Further, foliar B application has increased soybean yield where rice (Oryza sativa L.) is produced in the rotation (Ross et al., 2006).

Iron and Zn applications may result in more frequent soybean yield response in the Great Plains region. Soil DTPA-Zn has been proven to be a useful indicator of potential soybean yield response, but soil DTPA-Fe has been less effective. Plant nutrient analysis in combination with soil analysis has been used to diagnose and monitor plant nutrient status to correct or prevent deficiencies. There is an increasing interest in using plant analysis as a monitoring and quality assurance tool. For monitoring plant nutrient status, specific plant parts at particular growth stages are needed to compare to established nutrient sufficiency ranges (NSRs). Jones (1967) determined the soybean NSRs based on the youngest uppermost mature trifoliolate leaf without the petiole during blooming prior to pod set (R1 to R2 growth stage). Mills and Jones (1996) published a set of NSRs that included only small changes since the 1960s set was available. Those changes were adding the NSR for S and adjusting the lower end of the NSR for N from 4.5 to 4.0 % N. Given the growing interest and use of plant analysis to make fertilizer recommendations, ongoing research is needed to confirm that the corn and soybean NSRs are robust across time, environments, and genetics (soybean varieties and corn hybrids).

The overall purpose of this study was to evaluate corn and soybean response (growth, plant nutrition, and yield) to combinations of starter and foliar fertilization that contain N-P-K with and without a blend of micronutrients (Fe, Mn, Zn, Cu, and B) and to determine which combination of starter and foliar fertilization increases yield under irrigated conditions in Kansas.

MATERIALS AND METHODS

Studies were conducted from 2010-2012 for corn and soybean. Sites had no history of visible micronutrient deficiency symptoms. All sites were irrigated with pivot sprinkler irrigation systems in corn-soybean rotations. Irrigation was applied as needed during the growing season. The corn N fertilizer rates varied from 150-250 lbs acre-1 depending on the site. Plot size was 30 or 50 ft in length and 10 or 15 ft in width, with row-spacing of 30 in, except for soybean row spacing was 15 in at once site.

The experimental design was a factorial arrangement in a randomized complete block design with three replications. The starter fertilizer factor consisted of three treatments: control, N-P-K, and N-P-K plus a micronutrient blend of Fe, Mn, Zn, Cu, and B (referred hereafter as N-P-K-M). The rates were 4, 10, and 10 lbs acre-1 of N, P_2O_5, and K_2O. The micronutrient mix contained B derived from boric acid, CuEDTA (ethylenediamine tetraacetic acid), MnEDTA, ZnEDTA, and FeHEDTA (N-hydroxyethyl-ethylenediamine triacetic acid) at rates of 0.5 lbs acre-1 for each micronutrient. Starter fertilizer was surface dribbled over the row.

The foliar fertilizer factor consisted of same three treatments: control, N-P-K, and N-P-K-M. The factorial arrangement resulted in nine treatment combinations between starter and foliar. The foliar fertilizer was applied at the V6–V8 corn growth stage (Abendroth et al., 2011) and at the R2 soybean growth stage (Ritchie et al., 1997). The rates were 2, 2, and 2 lbs acre-1of N, P_2O_5, and K_2O using a 10-10-10, (N-P_2O_5-K_2O) fertilizer formulation. The foliar micronutrient blend contained the same products utilized for starter at rates of 0.2 lbs acre-1 for each micronutrient. Foliar fertilizer was applied using a CO_2 pressurized backpack sprayer adjusted to 0.14 MPa and diluted into 20 gal acre-1 of water.

Composite soil samples were collected from each small plot from the 0- to 6-in depth prior to planting. Soils were oven dried, crushed to pass through a 2 mm sieve. Soil samples were analyzed for pH (1:1 soil:water), P by Mehlich-3 colorimetric method (Frank et al., 1998), K by ammonium acetate (Warncke and Brown, 1998), organic matter (OM) by weight loss-on ignition or Walkley-Black method (Combs and Nathan, 1998), cation exchange capacity (CEC) by summation (Warncke and Brown, 1998), Fe, Mn, Zn, and Cu by DTPA (Whitney, 1998), and B by hot water (Watson, 1998).

Corn samples consisted of five or ten aboveground whole corn plants collected at the V6–V8 growth stage from each small plot prior to foliar application. Plant samples for soybeans consisted of 30 of the uppermost fully-expanded trifoliolate leaves without petioles at the R2 growth stage from each small plot prior to the foliar fertilizer treatment application. Post foliar fertilization plant analysis was conducted on 15 corn ear leaves at the R1 growth stage and 30 soybean trifoliolates at the R3 growth stage. Plant samples were oven-dried at 65°C for 3–5 days, weighed, and ground to pass a 2 mm screen. After digesting with HNO_3 and 30% H_2O_2, the concentration in plant samples for P, K, Ca, Mg, S, Cu, Fe, Mn, Zn, and B were determined by inductively coupled plasma atomic emission spectroscopy (ICP-AES). Total N for plant samples was determined by dry combustion using a LECO FP-528 Nitrogen Analyzer (LECO Co., St Joseph, MI). Soybean plant height was recorded at full maturity (R8 growth stage). Grain yield was determined from the center 2 or 4 rows of each small plot and adjusted to 130 and 155 g kg-1 moisture for soybean and corn, respectively.

Data were analyzed with the MIXED procedure in SAS 9.2 (SAS Institute, 2010) with blocks as a random factor. For analysis across sites, both site-year and block within site-year were considered as random factors. Statistical significance was determined at $\alpha = 0.10$.

RESULTS AND DISCUSSION

Corn early growth (V6) was significantly increased with starter fertilizers (Fig 1). However the addition of micronutrients with the starter (Zn, Mn, Fe, Cu, B) did not contribute to additional plant growth at this stage. Increase in corn plant early growth with starter fertilizers are attributed primarily to N and P fertilizer, and secondary and micronutrients would not be expected to increase early growth. Micronutrient uptake at V6 growth stage followed a similar tendency as plant growth (Fig 2). This suggests that increase in plant growth contributed to nutrient uptake in greater extent compared to tissue nutrient concentration. However, some micronutrients such as Zn and Cu tissue concentration were increase with the addition of fertilizer micronutrients in the starter.

Corn grain yield was increased across locations with starter fertilizer treatments. However no additional grain yield increase with micronutrients in the starter fertilizer (Fig 3). One location in 2012 showed a significant increase to starter fertilizer (N, P, K) and additional grain yield increase with the addition of micronutrients (Fig. 4). The soil at this location was sandy (80% sand) and very low OM content (0.9%). Is likely that these soil conditions are contributing to the grain yield response to micronutrient application.

Soybean yield was increased with starter fertilizers; however yield increase with micronutrients was not statistically significant despite an average increase in yield across locations (Fig 5).

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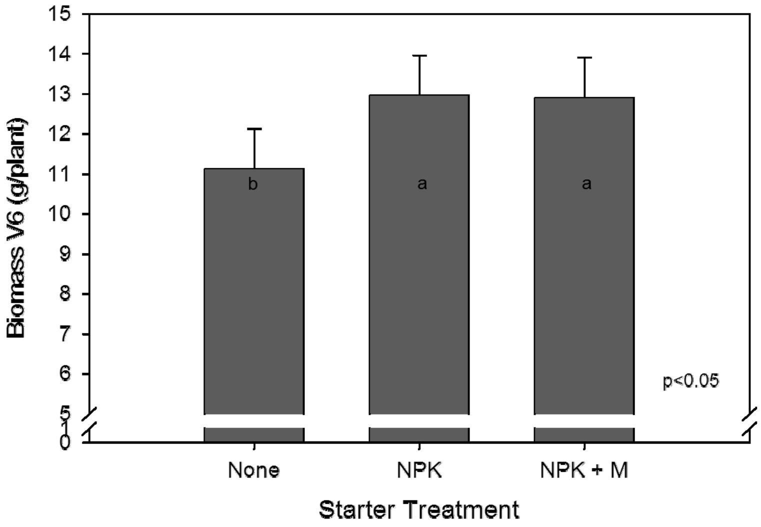

Figure 1. Effect of starter fertilizer application on corn biomass at V6. Letters indicate statistically significant difference between treatments at $p \leq 0.05$

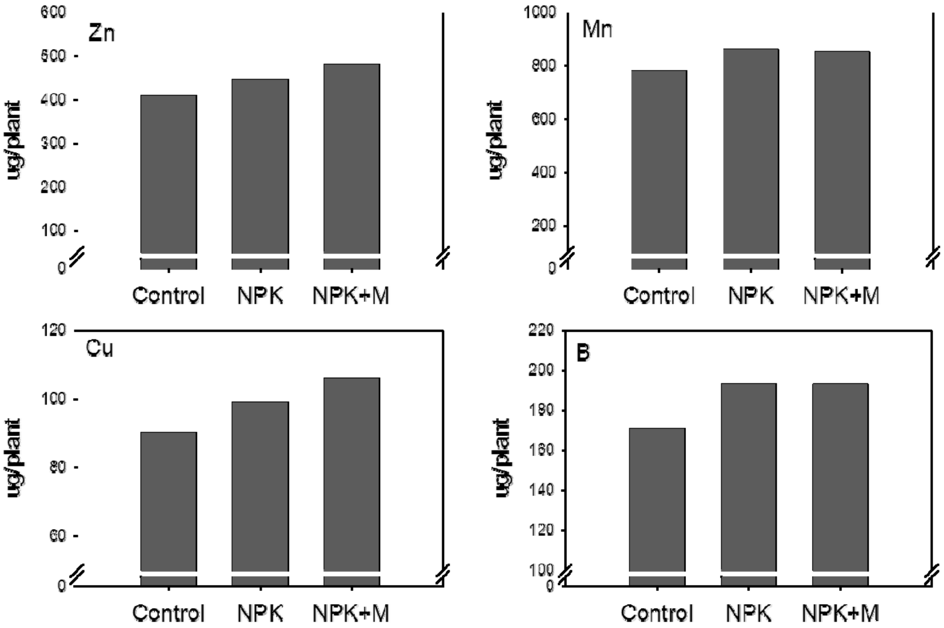

Figure 2. Effect of starter fertilizers with and without micronutrient application on corn tissue nutrient concentration at V6.

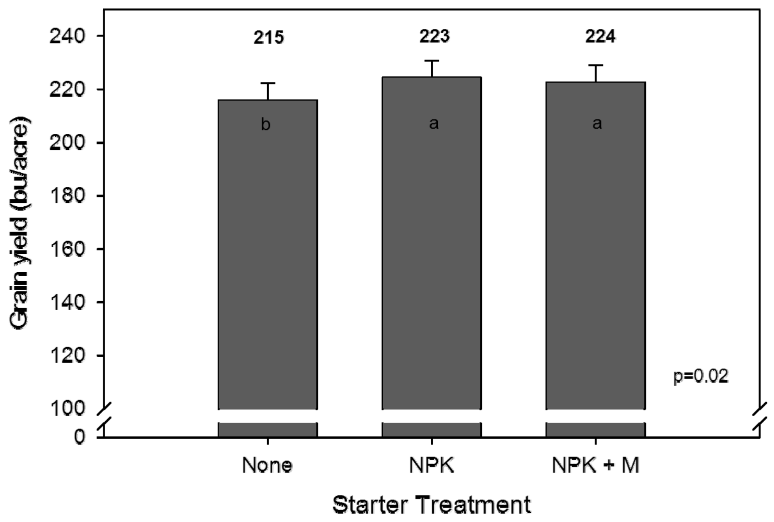

Figure 3. Effect of starter fertilizer application on corn grain yield. Letters indicate statistically significant difference between treatments at $p \leq 0.05$

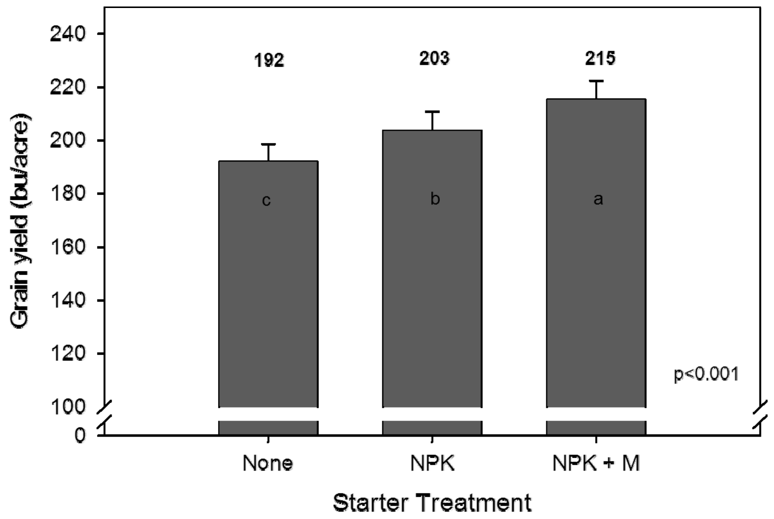

Figure 4. Corn grain yield response for one responsive location in 2012 (Rossville). This location was sandy with low organic matter content. Letters indicates statistically significant difference.

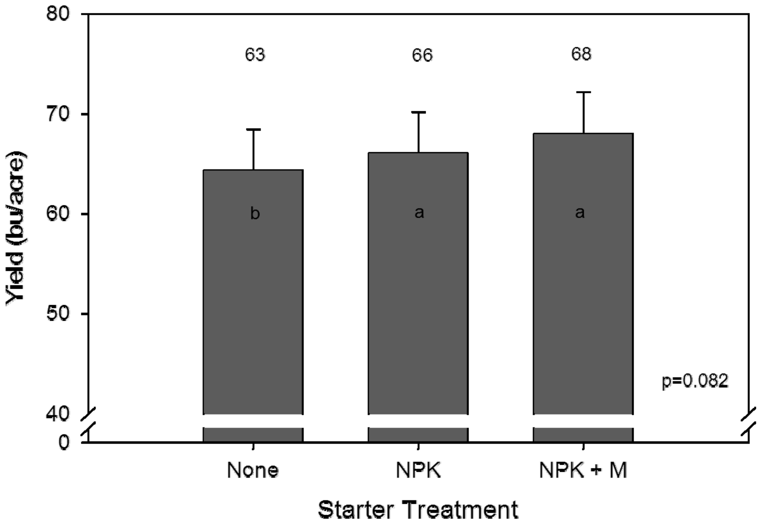

Figure 5. Soybean yield response to starter fertilizer application with or without micronutrients.

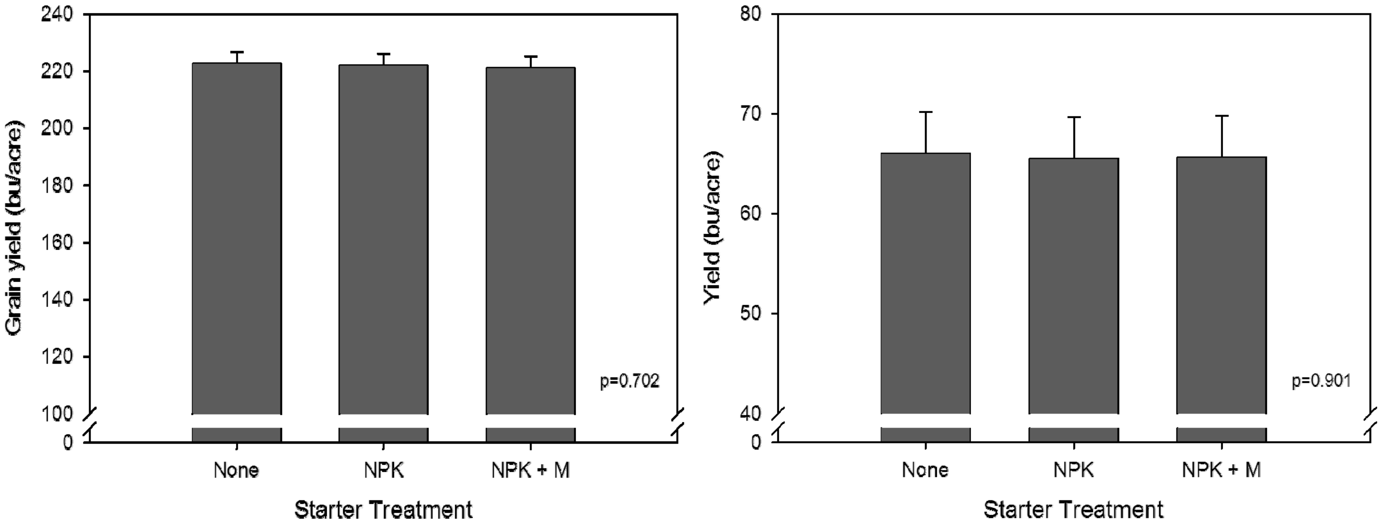

Figure 6. Corn and soybean yield response to foliar fertilizer application with or without micronutrients.