# Nitrogen and Potassium Interactions in Corn

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## ABSTRACT

Extensive research in the North Central region has investigated separately nitrogen (N) and potassium (K) fertilizer management for corn. However, there is scarce information available about how N and K interactions affect corn grain yield and nutrient uptake. The objective of this study was to evaluate the effects of various combinations of N and K rates on corn yield, N and K tissue concentrations, and N and K removed with grain harvest. Two trials with continuous corn were conducted from 2013 to 2016 at fields with Webster (northern Iowa) or Mahaska (southeast Iowa) soils, which were managed with chisel-plow/disk tillage. Annual treatments replicated three times were the combinations of five N rates (0 to 300 lb N/acre) and four K rates (0 to 72 lb $K_2O$/acre). Granulated urea was broadcast and incorporated into the soil in the spring at one site and urea ammonium nitrate solution was injected at the V4 to V5 growth stage at the other site. Potassium chloride (KCl) was broadcasted and incorporated into the soil in the spring at both sites. Leaves opposite and below the primary ear were sampled at the R1 growth stage and grain was sampled at harvest. The tissue samples were analyzed for total N and K concentrations. Fertilization with N increased leaf and grain tissue N concentrations, and fertilization with K increased the K concentration of both tissues. Potassium fertilization had no clear effect on leaf and grain tissue N concentrations. Nitrogen fertilization decreased or did not affect leaf and grain K concentrations when K was not applied and the soil K supply limited yield. Potassium fertilization alleviated or offset the effect of N application at reducing tissue K concentrations. There was a large grain yield response to N fertilizer and a smaller response to K fertilizer at both sites, and there were significant N by K interactions. Corn yield and the yield response to N were higher with adequate K supply compared with K deficient treatments. Similar interactions were observed for N and K removed with grain harvest. The study demonstrated that K deficiency not only limits corn yield, but also limits its capacity to respond to N fertilization.

## INTRODUCTION

Fertilization of corn with nitrogen (N) and potassium (K) fertilizers is needed in the vast majority of soils and cropping systems of the North Central region of the U.S.A. Considerable research has been conducted in the region on optimum N fertilization rates in different soils, areas, and cropping systems. Extensive research also has been conducted to investigate how soil-test K levels and K removal with harvest influences the K fertilization rates for corn. However, scarce research has investigated possible interactions between N and K fertilization in corn. Plant nutrient interactions often occur and are known to impact crop yield. The concept of an interaction between plant growth factors has been defined in different ways. From a fertilization rates perspective, an interaction exists when the plant response to application rates of one nutrient is affected by the rate or the soil-test level of another nutrient. The yield increase from different rates of a nutrient and/or the rate that produces the maximum yield could change. Nutrient interactions can be evaluated by including several rates of two or more nutrients and measuring grain yield or tissue nutrient concentrations or uptake. This is seldom done, however, due to the high cost of several such trials over several sites or years. The majority of experiments conducted to study the crop response to one nutrient include application of non-limiting but not excessive levels of others. Experiments including two or more nutrients with several application rates are important to understand how nutrients interact for expressing a crop yield potential.

Research summarized in reviews has shown that N uptake and utilization with adequate K supply leads to more efficient N use and increases yield of several crops and that the N form supplied or absorbed by plants may affect the crop response to applied K (Dibb and Thompson, 1985; Pinney et al., 2005). However, field studies to investigate N by K interactions in corn are scarce. An Iowa long-term study with continuous corn evaluating several combinations of N, K, phosphorus (P), and lime showed a positive interaction between N and K but not among the other nutrients (Mallarino and Rueber, 2003). In this study, the corn yield response to N fertilization and the N rate needed to maximize yield were greater with adequate K supply than with a deficient K supply. Potassium applications that increased soil-test K levels above recommended levels for corn did not affect corn yield and the response to N fertilizer. The scarce information available especially for soils of the region suggested a need for additional study of N and K interactions in corn. Therefore, the objective of this study was to evaluate the effects of various combinations of N and K rates on corn grain yield, N and K tissue concentrations, and N and K removed with grain harvest.

## SUMMARY OF PROCEDURES

Two trials with continuous corn were established in 2013 and were evaluated until 2016. One trial was located at the Northern Iowa Research Farm (NIRF) near Kanawha on an area with Webster soil series. The other trial was located at the Southeast Iowa Research Farm (SERF) near Crawfordsville on an area with Mahaska soil series. The plots of each site were managed with chisel-plow/disk tillage and a 30-inch row spacing. Target corn populations were 34,000 to 35,000 plants/acre. Annual fertilization treatments replicated three times at both sites included the factorial combinations of five N rates (0, 75, 150, 225, and 300 lb N/acre) and four K rates (0, 24, 48, 72 lb $K_2O$/acre). At SERF, all plots were subdivided to apply 0 or 50 lb S/acre using gypsum. Since there was no yield response to S in any year of the study, only results for N and K are summarized in this article. Treatments and replications were arranged as a completely randomized design at NIRF and as a randomized complete block design at SERF. The N fertilizer source at NIRF was granulated urea, which was broadcast and incorporated into the soil in the spring before planting corn. The N source at SERF was urea ammonium nitrate solution (UAN) that was injected between the corn rows at the V4 to V5 growth stages. The K source at both sites was potassium chloride (KCl), which was broadcast in the spring before the last disking or field cultivation prior to planting corn. At both sites, blades of leaves opposite and below the primary ear were sampled at the R1 growth stage (silking) and grain was sampled at harvest. Leaf and grain samples were analyzed for total N and K concentrations. Grain yield from both sites was adjusted to 15.5% moisture.

**HIGHLIGHTS OF RESULTS**

The most relevant results are summarized by showing averages across years at each site. The corn grain yield varied across the evaluation years, mainly in response to weather conditions. At NIRF, the average yield for the two highest N rates and plots receiving K fertilizer was 181, 158, 202, and 217 bu/acre in 2013, 2014, 2015, and 2016, respectively.. Excessive rainfall limited yield below its potential in 2013 and 2014. At SERF, the average yield for the two highest N rates and plots receiving K fertilizer was 128, 206, 228, and 211 bu/acre in 2013, 2014, 2015, and 2016, respectively. The very low yield in 2013 was due to excessive spring rainfall, which also caused very large variability among the replications. Therefore, the 2013 results for the SERF site are not included and three-year averages are shown.

Results of chemical analyses of ear leaves and grain showed that N fertilization increased tissue N concentrations and K fertilization increased K concentrations at both sites. Potassium fertilization did not affect ($P \leq 0.05$) the N concentration of either tissue at any site (not shown). However, data in Figs. 1 and 2 show that N and K fertilization interacted, affecting the K concentrations of both tissues at both sites. At NIRF, N fertilization significantly decreased the ear-leaf K concentration when K was not applied and the soil K supply limited yield ($P \leq 0.05$), but did not affect K concentrations when K was applied (Fig. 1). Nitrogen fertilization slightly decreased the grain K concentration with or without K fertilization. At SERF, N fertilization did not affect the ear-leaf K concentration when K was not applied ($P \leq 0.05$) but increased it when K was applied (Fig. 2). At this site, N fertilization decreased the grain K concentration with or without K application, but the decrease was less pronounced when K was applied.

There were large grain yield increases from N fertilization every year at both sites. At NIRF, there were small to moderate yield increases from K fertilization each year that did not differ statistically ($P \leq 0.05$) for the annual rates of 24, 48, or 72 lb $K_2O$/acre. At SERF, there was a larger yield response to K fertilization, which on average across the three years occurred up to the 48-lb application rate ($P \leq 0.05$). Initial soil-test K levels (6-inch depth) at both sites were within the Low soil-test interpretation category according to Iowa State University soil-test interpretations (Mallarino et al., 2013). Soil-test K values 121-160 and 51-85 ppm are considered Low by the dry or field-moist testing procedures, respectively, when using the ammonium-acetate or Mehlich-3 methods. By fall 2016, the soil-test levels of plots at both sites that received no K had decreased to the Very Low category.

Figures 3 and 4 show the average grain yield and N or K removed with grain harvest for both sites. The figure for NIRF (Fig. 3) shows the yield response to N fertilizer for plots that received no K and the average N response from plots that received K since there were no statistical K rate differences. The figure for SERF (Fig. 4) shows the yield response to N fertilizer for plots that received no K and the average N response from plots that received the 48- and 72-lb K rates because these rates produced yield higher than the 24-lb rate. The results from both sites show a very large response to N with or without K applied and a smaller response to K. There were significant interactions ($P \leq 0.05$) at both sites, however. The corn yield and the response to N was higher when K was applied. At NIRF (Fig. 3), the 225-lb N rate maximized yield without K but with K applied the highest N rate applied (300 lb/acre) increased yield further, and seems a higher N rate would have produced even higher yield. The response to K was very small and not statistically significant for N rates of 225 lb or less, but the combination of K with the 300-lb N rate produced the highest yield. At SERF (Fig. 4), K fertilization did not clearly affect the N rate needed to maximize yield but for the three highest N rates yield with K application was much higher than without K. The fertilization effects on N and K removed with grain harvest were approximately similar to results observed for yield, although at SERF (Fig. 4) the interaction was more pronounced for the K removed than for yield.

The yields for the 48- and 72-lb annual K rates did not differ at any site, and by the end of the study, the 72-lb rate had increased soil-test K above the Optimum soil-test category at both sites. Therefore, the observed N by K interaction, larger corn yield and nutrient removal responses with applied K than with deficient K, does not imply that excess K is needed to allow corn to express all its potential capacity to respond to N fertilization.

## CONCLUSIONS

The study confirmed that adequate fertilization with both N and K are needed to maximize corn grain yield. It also demonstrated that K deficiency not only limits corn yield, but also limits its capacity to respond to N fertilization.

## ACKNOWLEDGEMENTS

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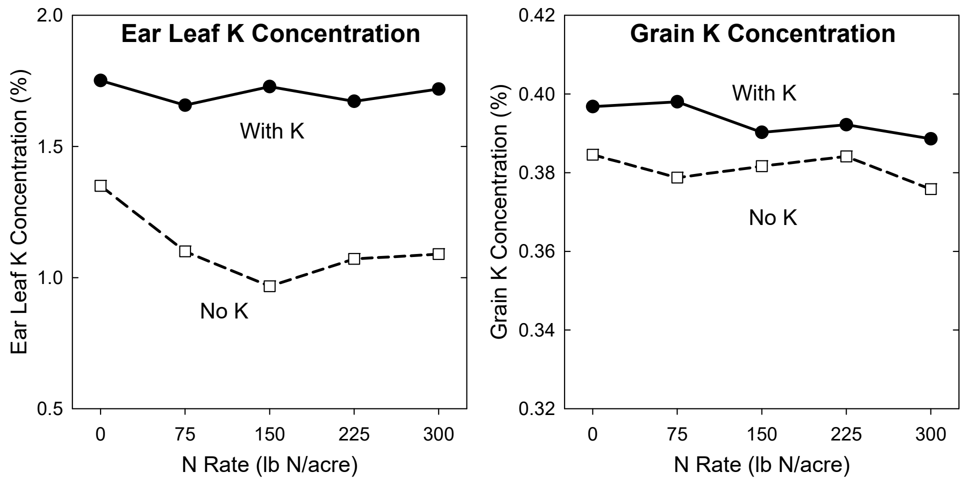


Fig 1. Nitrogen fertilization effects on corn ear-leaf and grain concentrations as affected by K fertilization at NIRF (averages across 4 years).

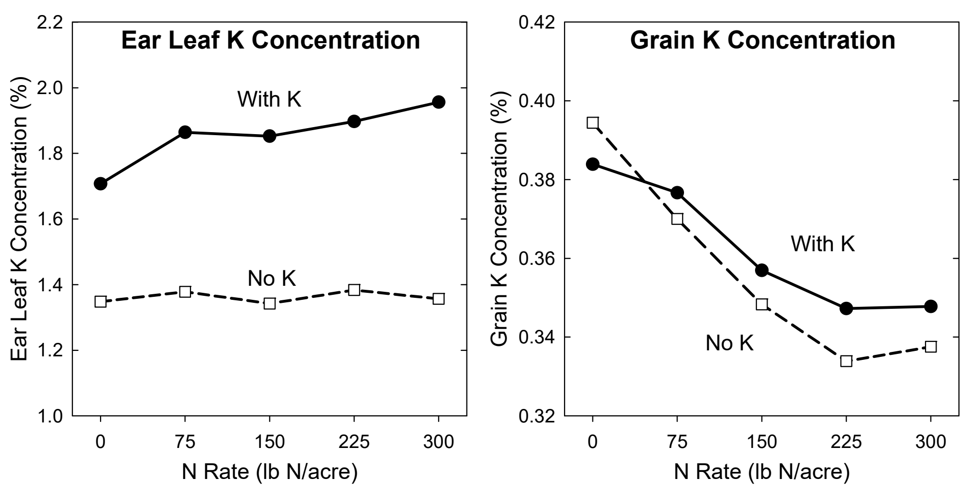


Fig 2. Nitrogen fertilization effects on corn ear-leaf and grain concentrations as affected by K fertilization at SERF (averages across 3 years).

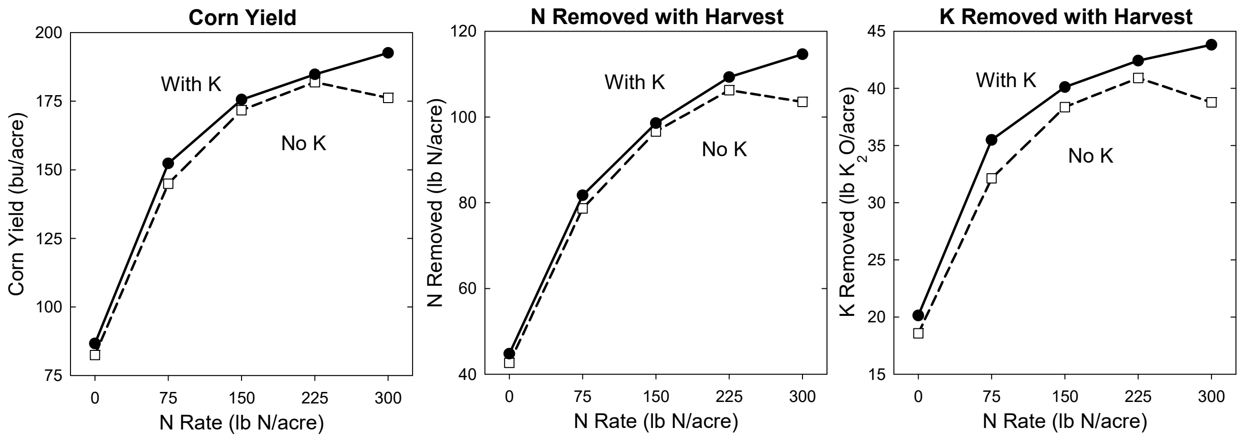


Figure 3. Nitrogen fertilization effects on corn grain yield and on N and K removed with grain harvest as affected by K fertilization at NIRF (averages across 4 years).

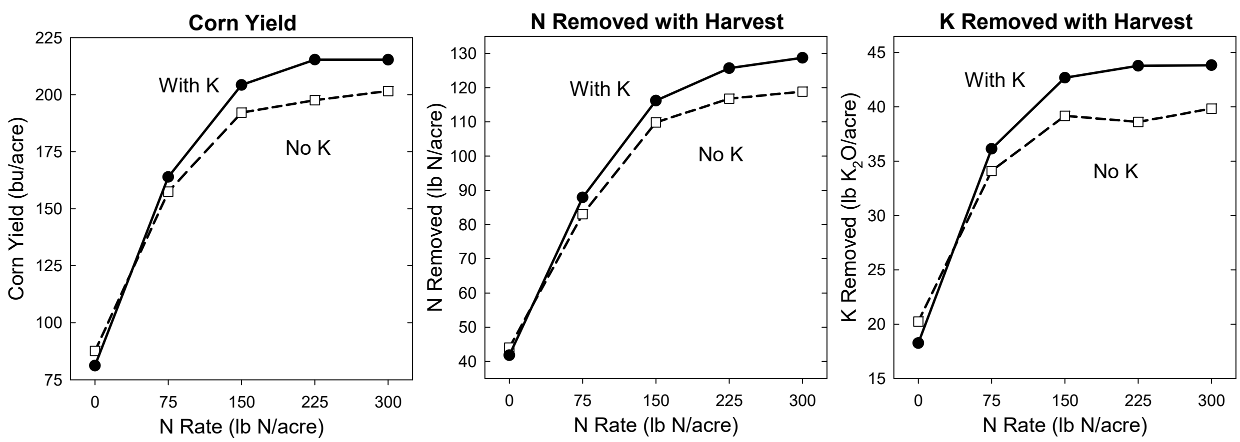


Figure 4. Nitrogen fertilization effects on corn grain yield and on N and K removed with grain harvest as affected by K fertilization at SERF (averages across 3 years).