CORN AND SOYBEAN GRAIN YIELD AND CONCENTRATION OF POTASSIUM IN PLANT TISSUES AND SOIL AS AFFECTED BY POTASSIUM FERTILIZATION

M.W. Clover, A.P. Mallarino, and P.A. Barbagelata
Department of Agronomy, Iowa State University, Ames

Introduction

Research in the Midwest has shown that K fertilization tends to increase plant K uptake by corn and soybean and the K concentration of vegetative tissues. Several studies found that K fertilization usually increases the K concentration of vegetative plant parts, often regardless of the soil-test K (STK) level and grain yield response (Mallarino et al., 1999; Borges and Mallarino, 2000; Yin and Vyn, 2002a, 2002b; Borges and Mallarino, 2003; Yin and Vyn, 2003). It is well known that the K concentration in soybean grain is much higher than in corn grain, and that at prevailing yield levels the amount of K removed is greater for soybean. However, comparatively scarcer research has shown that K fertilization effects on grain K concentration are lesser than for vegetative tissues and less consistent. For example several studies (Higashi, 1991; Yin and Vyn, 2002a, 2003; Mallarino and Valadez-Ramirez, 2005) have shown that the K concentration in corn and soybean grain vary significantly across years, sites, tillage systems, and other management practices but K fertilizer and STK effects on grain K concentration are relatively smaller and inconsistent and, as a consequence, the yield level variation has the most predictable impact on K removal. This is important because STK and K removal with harvest are used to determine K fertilization rates for crops. These studies and others suggested a need for more research to better understand the magnitude of fertilization effects on grain yield, K uptake, K concentration in plant parts, and K removal. Therefore, the objectives of this study were to evaluate the relative magnitude of K fertilization effects on corn and soybean grain yield; young plants, leaves, and grain K concentrations; K removal, and post-harvest STK.

Materials and Methods

Eighteen conventional plot trials with corn and soybean were established in Iowa from 2003 to 2005. Treatments were five K fertilizer (KCl) rates consisting of 0, 30, 60, 120, and 180 lbs K_2O/acre broadcast before tillage. All sites had been managed with corn-soybean rotations. Sites with corn residue were chisel plowed in the fall and disked in spring while sites with soybean residue were disked in spring. Each treatment plot measured 40 to 60 ft in length and 30 to 40 ft in width depending on the site. The treatments and four replications were arranged as a randomized complete-block design in all trials. Soil-test P was maintained at optimum or higher levels while a rate of 150 to 180 lb N acre^{-1} was applied for corn in spring.

Soil samples (12 cores, 15-cm depth) were taken from each plot before K fertilizer application and again following crop harvest. Soil samples were analyzed for K by the ammonium-acetate test on samples dried at 35 to 40 °C (Warncke and Brown, 1998). The aboveground portion of 10 plants was sampled at the V5 to V6 growth stage to assess early growth (dry weight), total K concentration, and total K uptake per plant. Leaf K concentration was measured by sampling and analyzing the blade portion of corn leaves opposite and below the ear from 10 plants at the

60 to 80% silking stage and the three top, fully mature triofoliolate leaves of 10 soybean plants at the R2 growth stage. Grain yield was adjusted to 15.5 and 13.0 % moisture for corn and soybean, respectively. Plant tissue was dried at 65 °C, weighed (except the leaves), and analyzed for total K by an acid digestion method and emission or inductively-coupled plasma.

Analysis of variance was conducted on grain yield for each corn and soybean site to determine whether or not there was a response ($P \leq 0.1$) to K. The sites were classified as yield responsive or non-responsive based on this analysis. Data for sites within each of four resulting groups of sites (responsive or non-responsive corn and soybean sites) were averaged to describe the average response of early plant weight, plant K concentration, plant K uptake, leaf K concentration, grain K concentration, K removal, and post-harvest STK according to the grain yield response to K fertilizer. Linear, linear-plateau, and quadratic-plateau models were used to describe grain yield responses, and the best model was chosen based on study of statistical significance and coefficients of determination. Linear and quadratic models were fit to the other crop and soil measurements, and quadratic models are shown only when the quadratic term contributed significantly after the linear term ($P \leq 0.1$). Relative responses to K fertilizer were calculated to compare responses of the different measurements using comparable units.

Results

Table 1 shows summary information about site location, soil series, initial STK, and the statistical significance of the grain yield response ($P \leq 0.1$). Grain yield and plant responses for each site are not shown in this summary article. One site tested Low according to Iowa State University STK interpretations (Sawyer et al., 2002), 12 tested Optimum, and the others tested High or Very High. Previous research indicates that the probability of a yield response within each category is 80% for Very Low, 65% for low, 25% for optimum, 5% for high, and <1% for Very High. The Iowa interpretation categories differ according to subsoil K concentration, and the Optimum category is 90 to 130 ppm (6-inch soil samples) when subsoil K is 50 ppm or less (most soils in Iowa and in the study) and 111 to 151 ppm when subsoil K is higher. Potassium fertilization increased grain yield ($P \leq 0.1$) at seven sites. All seven sites tested Optimum in STK. There was no yield response at the low-testing site (Site 4), at six other sites testing Optimum, and at any site testing High or Very High. Potassium fertilization significantly increased early plant K concentration, early plant K uptake, and leaf K concentration at most sites (12, 10, and 17 sites, respectively). These responses were not related to STK or grain yield responses. On the other hand, responses of early plant growth, grain K concentration, and K removal to K fertilization were infrequent (2, 6, and 7 sites, respectively).

The average corn and soybean grain yields across sites with statistically significant or non-significant yield responses are shown in Fig. 1. Data for the non-responsive are shown because they show an interesting result. On average the yield level was significantly greater for non-responsive sites compared with the responsive sites. Information of growing conditions at each site that is being analyzed at this time may explain this result. The average response trend across responsive sites followed a linear-plateau trend for both crops. Calculations based on the response models indicated that on average for these sites, corn grain yield responded linearly up to 122 lb K_2O/acre while soybean yield responded up to 106 lb K_2O/acre. For comparison, current Iowa guidelines suggest 90 lb K_2O/acre for both corn and soybean in soils testing Low, and K fertilizer rates based on K removal for soils testing Optimum.

Figure 2 compares the relative responses to K fertilization across yield responsive or non-responsive corn and soybean sites for grain yield, early plant K concentration, leaf K concentration, grain K concentration, and K removal. These responses were calculated relative to the grain yield, tissue K concentration, or K removal for the highest K fertilizer rate used for each yield response group and crop. Potassium fertilization did not increase ($P \leq 0.1$) early growth of either crop regardless of the grain yield response and data are not shown. However, K fertilization significantly increased early plant K concentration, early plant K uptake, and leaf K concentration for both crops regardless of the grain yield response. The responses of early plant K uptake followed closely the responses of early plant K concentration and are not shown. The tissue K increasing rate per unit of K applied differed little between yield responsive and non-yield responsive groups within each tissue. The response trends sometimes were linear and sometimes curvilinear but quadratic coefficients usually were small and trends were almost linear. The only exception was soybean early K concentration, which showed a sharp curvilinear trend with a plateau after the 120-lb K rate. This result suggests a lower limit for K uptake in young soybean tissue compared with mature leaves or corn tissue.

In contrast to responses of K content of vegetative tissue, data in Fig. 2 show that K fertilization had no effect ($P \leq 0.1$) on corn grain K concentration regardless of the grain yield response. In soybean, however, there was a small grain K concentration response for both yield responsive and no-responsive sites. The response was very small but linear for sites without yield response, and was larger and slightly curvilinear for the yield responsive sites. These results coincide with greater K concentration in soybean grain than in corn grain, and indicate a greater capacity for K accumulation in grain by soybean. Because the K fertilization effect on grain K concentration was small, K removal responses followed closely yield response trends for both crops, although the yield plateau at high K rates was not evident for K removal by corn. Potassium fertilization increased grain K removal for both crops in yield responsive sites but did not affect ($P \leq 0.1$) grain K removal in non-responsive sites.

Post-harvest STK was increased linearly by K fertilization for the previous corn or soybean crops regardless of the grain yield response (Fig. 3). The soil samples were taken in the fall, one to 4 weeks after harvest. These STK values are the net result of several processes that include effects of fertilization, crop K uptake, and K reactions in soils. Average post-harvest STK of yield responsive sites was below the initial STK values for both crops and all K fertilization rates. In the non-responsive sites, however, a K rate of about 120 lb K_2O/acre maintained initial STK. These are averages across sites, and there was much variation across sites in both yield levels and STK. The average results were surprising, however, because the K rate needed to maintain initial STK was much higher than usually assumed K rates and K removed with grain harvest, especially for corn. Figure 4 shows the average amount K removed with grain harvest as affected by K fertilization, and obviously K removal alone cannot explain the STK trends shown in Fig. 3. Previous Iowa research based on five long-term experiments showed very poor relationships between P or K removed, pre-harvest, and post-harvest soil-test P or K values in the same year (Mallarino and Valadez-Ramirez, 2005; Prater and Mallarino, 2006). However, the same studies showed that P and K fertilization based on currently assumed grain P and K concentrations approximately maintained soil-test values over several years when assumed yield levels represented the actual yield levels. The results of this study and poor relationships between yield, K removal, and STK in the short term may be explained by interactions between K uptake and removal, K recycling in crop residues, K equilibria in soils, and sampling depth.

Conclusions

Potassium fertilization seldom increased early growth of either crop at yield responsive or non-responsive sites, but often increased significantly the K concentration of corn and soybean young plants and mature leaves regardless of the grain yield response and STK. Potassium fertilization did not affect on the K concentration of corn grain and had a small effect on the K concentration of soybean grain. As a result, grain K removal was increased significantly by K fertilization only in yield responsive corn and soybean sites. Potassium fertilization affected post-harvest STK significantly in these one-year trials. However, the amount of K needed to maintain STK was much greater than expected, and differences were not explained solely by grain K removal. Further research is being conducted at these and other sites to be able to explain the unexpected short-term relationships observed between K fertilization, K removal with harvest, and STK.

References

Borges, R., and A.P. Mallarino. 2000. Grain yield, early growth, and nutrient uptake of no-till soybean as affected by the phosphorus and potassium placement. Agron. J. 92:380-388.

Borges, R., and A.P. Mallarino. 2003. Broadcast and deep-band placement of phosphorus and potassium for soybean managed with ridge tillage. Soil Sci. Soc. Am. J. 67:1920-1927.

Higashi, S.L. 1991. Tissue tests for evaluating the potassium status of corn. M.S. Thesis. Library. Iowa State University. Ames, Iowa.

Mallarino, A.P., and M. Valadez-Ramirez. 2005. Relationships between soil-test potassium, grain yield, and potassium removal in corn-soybean rotations. Agron. Abs. CD-ROM. ASA-CSSA-SSSA. Madison, WI.

Mallarino, A.P., J.M. Bordoli, and R. Borges. 1999. Phosphorus and potassium placement effects on early growth and nutrient uptake of no-till corn and relationships with grain yield. Agron. J. 91:37-45.

Prater, J., and A.P. Mallarino. 2006. Soil phosphorus, grain yield, and phosphorus removal during twelve years of phosphorus management for corn-soybean rotations. Agron. Abs. CD-ROM. ASA-CSSA-SSSA. Madison, WI.

Sawyer, J.E., A.P. Mallarino, R. Killorn, and S.K. Barnhart. 2002. General guide for crop nutrient recommendations in Iowa. Publ. Pm-1688 (Rev.). Iowa State. Univ. Extension.

Warncke, D., and J.R. Brown. 1998. Potassium and other basic cations. p 31-33. *In* J. L. Brown (ed.). Recommended chemical soil test procedures for the North Central region. North Central Region Publ. No. 221 (Rev.) Missouri Exp. Stn. Publ. SB 1001. Columbia, MO.

Yin, X., and T.J. Vyn. 2002a. Residual effects of potassium placement and tillage systems for corn on subsequent no-till soybean. Agron. J. 94:1112-1119.

Yin, X., and T.J. Vyn. 2002b. Soybean responses to potassium placement and tillage alternatives following no-till. Agron. J. 94:1367-1374.

Yin, X., and T.J. Vyn. 2003. Potassium placement effects on yield and seed composition of no-till soybean seeded in alternate row widths. Agron. J. 95:126-132.

Table 1. Summary information for 18 K response field trials.

Site	Year	County	Crop	Soil Series	Soil-Test K Value	Soil-Test K Category †	Yield Response
					ppm		
1	2003	Boone	Corn	Webster	133	Opt	*
2	2003	O'Brien	Corn	Galva	173	High	ns
3	2003	Washington	Corn	Mahaska	141	Opt	*
4	2003	Boone	Corn	Clarion	117	Low	ns
5	2003	Boone	Soybean	Webster	153	Opt	*
6	2003	O'Brien	Soybean	Galva	154	Opt	*
7	2003	Washington	Soybean	Mahaska	130	Opt	*
8	2004	Floyd	Corn	Clyde	196	High	ns
9	2004	Hancock	Corn	Nicollet	162	Opt	ns
10	2004	Floyd	Soybean	Kenyon	170	Opt	ns
11	2004	Hancock	Soybean	Canisteo	138	Opt	ns
12	2005	Boone	Corn	Nicollet	234	V. High	ns
13	2005	O'Brien	Corn	Primghar	170	Opt	*
14	2005	Washington	Corn	Taintor	134	Opt	ns
15	2005	Boone	Soybean	Canisteo	163	Opt	ns
16	2005	Boone	Soybean	Canisteo	139	Opt	*
17	2005	O'Brien	Soybean	Primghar	213	V. High	ns
18	2005	Washington	Soybean	Nira	148	Opt	ns

† Iowa State University soil-test K interpretation category. * Statistically significant grain yield response at $P \leq 0.10$.

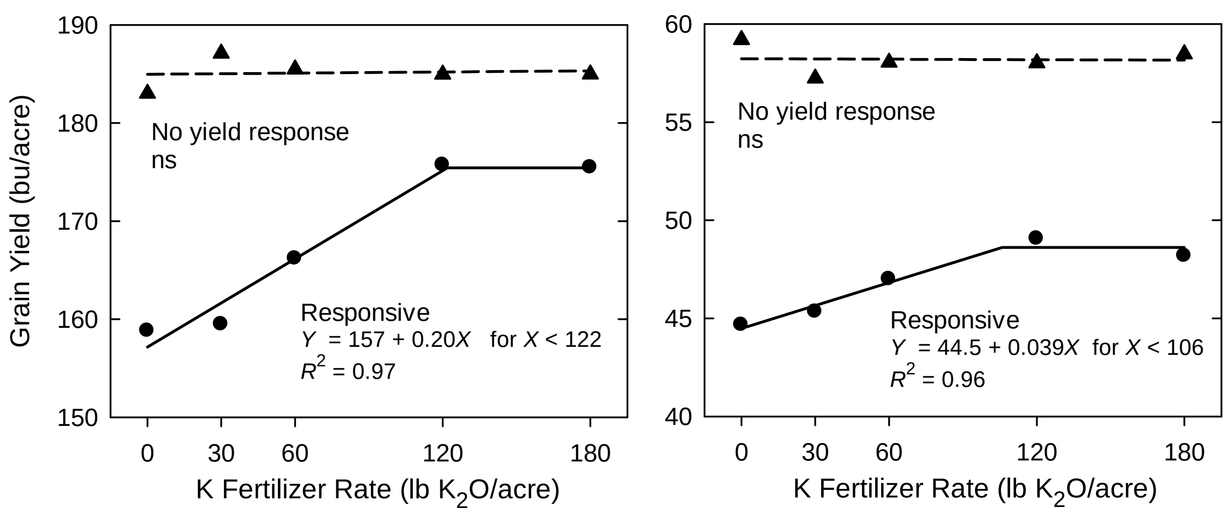

Fig. 1. Average corn and soybean grain yield for sites with and without grain yield response as affected by K fertilization.

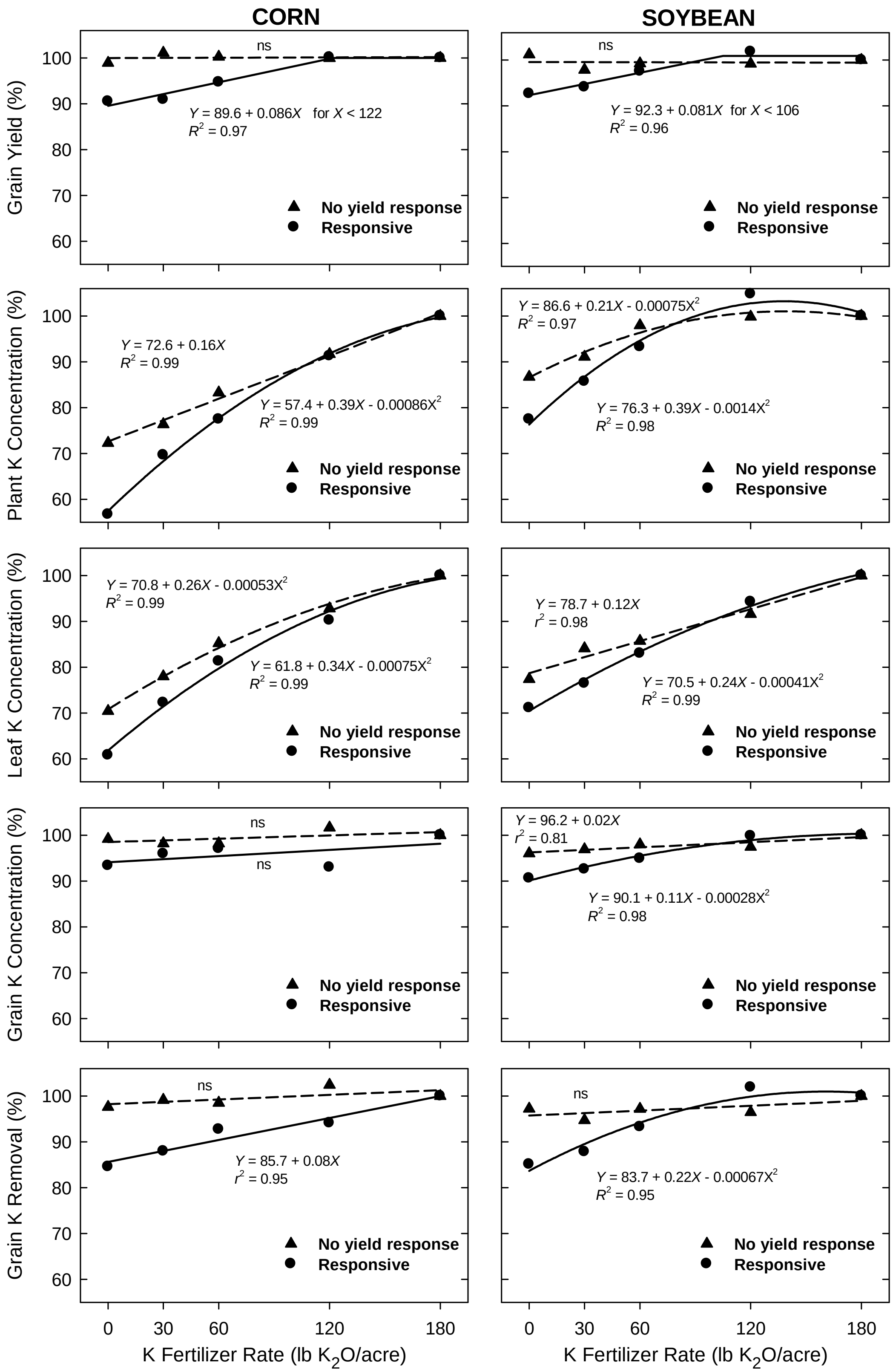

Fig. 2. Relative corn and soybean grain yield, early plant K concentration, leaf K concentration, grain K concentration, and grain K removal as affected by K fertilization for sites with and without grain yield response.

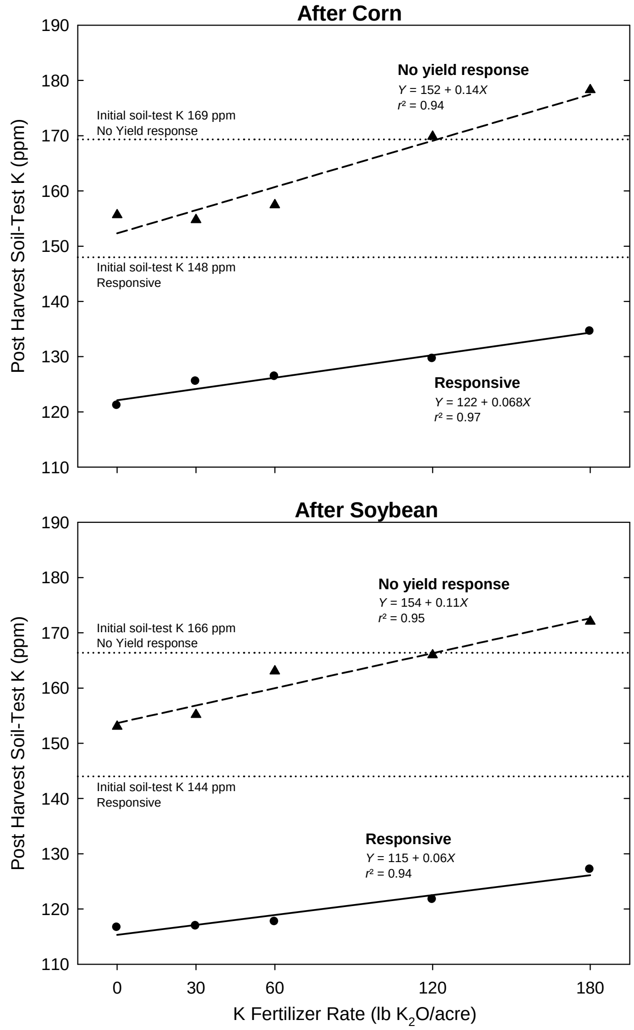

Fig. 3. Effect of K fertilization on the average post-harvest soil-test K for corn and soybean sites with or without grain yield response to K.

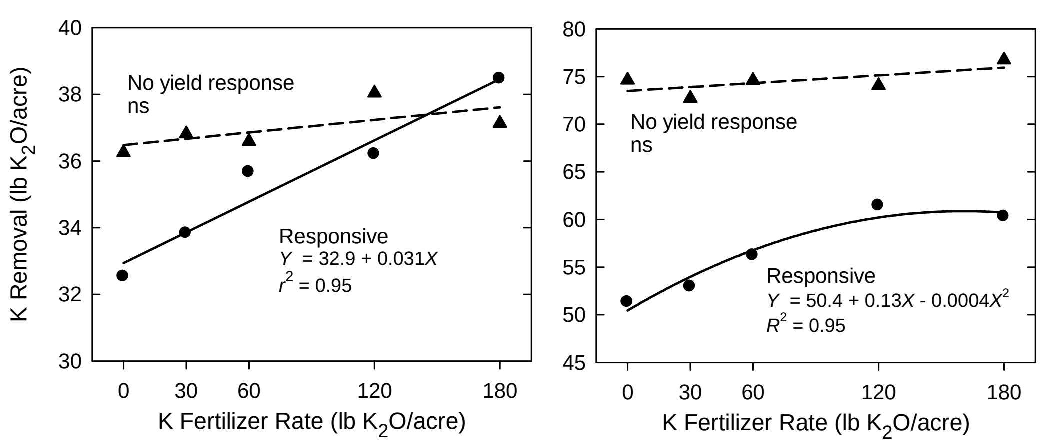

Fig. 4. Average K removed with corn and soybean grain for sites with or without grain yield response as affected by K fertilization.