NO-TILL SOYBEAN RESPONSES TO RESIDUAL FERTILIZER K AND SITE-SPECIFIC EXCHANGEABLE K ON VARIABLE SOILS

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Abstract

Because meeting the potassium (K) requirements of no-till soybean is more dependent on soil properties near the soil surface than it is in conventional soybean production, management of both tillage systems and K fertilizer application in the preceding corn crop may also be critical for the subsequent no-till soybean crop. Both stratification and spatial variability in soil exchangeable K may constrain the achievement of satisfactory yields and consistent seed quality in no-till soybean. The objective of this project was to evaluate the yield and quality responses of no-till soybean to 3 tillage systems (no-till, strip-till, and chisel) and 3 K fertilizer treatments (control, fall only, and fall plus starter) applied to previous corn. The experiment was conducted for a 3 year period in East-central Indiana. No-till soybeans were planted in 38-cm row widths. Multiple within-plot soil and grain quality samples enabled detailed analyses of soybean responses to treatments and site-specific soil properties. Soybean yields were not significantly affected by prior tillage systems or by residual K fertilizer treatments. However, there were differences in seed composition (oil, protein, and nutrient concentrations). Soybean responses to K fertility treatments in prior corn were more likely to be evident in leaf nutrient concentrations and seed composition changes (seed K content, oil) than in final yields.

Introduction

No-till soybean production acreage has increased markedly since the late 1980s and early 1990s in many Midwestern states; this progression from just a small fraction of the acreage to a majority no-till acreage in several states has raised new concerns about K fertility management. No tillage causes major changes in nutrient availability with depth, soil temperature, water content, pest incidence, and root growth and distribution. Soybean K needs in no-till, relative to conventional systems, are more dependant on soil exchangeable K concentrations, root density and soil moisture and temperature in the surface layer than K uptake in conventional tillage systems. Therefore, traditional K management recommendations designed for soybean under conventional tillage may need to be revised to ensure that K nutrition, yield and quality of soybeans will not be restricted. In addition, recent quality research (Vyn et al., 2002) confirms that higher seed K in soybeans is positively associated with high concentration of isoflavones (a nutraceutical with purported human health benefits).

Concerns about K fertility management have increased as no-till soybean acreage has increased, as dry summer and compacted soil conditions have resulted in lower levels of K uptake, as information about the extent of K stratification in no-till soils have become better known, and as the deep banding of P and K fertilizers on 30" row centers have become a more popular alternative for strip-till corn farmers. Although the 20% no-till adoption rate for corn in Indiana suggests that there is much rotational tillage taking place from year to year within fields, the soil fertility evidence also indicates that soil K stratification can be almost as pronounced after conservation practices like fall chisel plowing or shallow, single-pass cultivation as they can be after a "pure" no-till system (Holanda et al., 1998).

One essential aspect of K fertility management is to reduce the incidences of seed yield loss and inferior seed quality resulting from areas of fields with below optimum soil-test K. Improved K fertilizer recommendations for no-till soybean may be essential in order to achieve more uniform crop yield and quality.

Most of the published research has been devoted to the effects of direct K applications to soybeans, but fewer reports are available concerning the residual effects of K fertilization, K placement, and tillage system for corn on subsequent no-till soybean in corn-soybean rotations.

Materials and Methods

Field Experiments

In the spring of 2001, a field experiment was established near Farmland in East-central Indiana at the Davis Purdue Agricultural Center (DPAC) in order to evaluate the yield and quality responses of no-till soybean to conservation tillage systems and associated K fertilizer management in previous corn on soils varying in texture and soil exchangeable K (SEK). This experiment was continued during the 2002 and 2003 growing seasons.

The tillage treatments in the prior corn year were fall chisel with spring field cultivation (conventional practice in Indiana), strip tillage to a depth of 20 cm, and no-tillage. There were three K fertility sub-treatments within each of the tillage plots. These were: no K, fall broadcast or banded K at 90 kg ha-1 (Fall K), and the fall K treatment plus 50 kg ha-1 of actual K in the spring (F&S K). All sub-treatments received N and P in the starter and side-dressed N during the corn year. The residual effects of tillage and K fertility for corn were monitored in subsequent no-till soybean planted in 38 cm rows. No additional K fertilizer was applied in the soybean year. The soybean variety for all 3 years was Golden Harvest H3520 RR.

Experimental Design

A split-plot experimental design was arranged with 6 complete blocks. Tillage and K fertility treatments were randomized to whole plot and sub-plot units, respectively. Sub-plot dimensions were 4.6 meters wide by 152.5 meters long in which 12 soybean rows spaced at 38 cm were no-till planted.

Statistical analysis

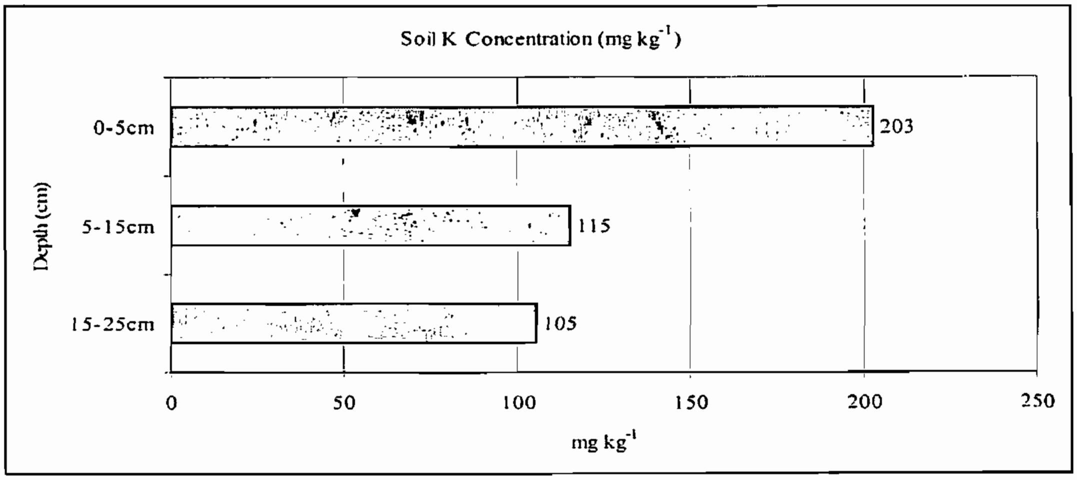
Analysis of Covariance was used to analyze the data for a split-plot experimental design with the covariate (Initial Soil K content) measured at the sub-plot level.

Results and Discussion

Soil Measurement Results

Soil samples were taken at 3 different depths (0-5 cm, 5-15 cm and 15-25cm) in each of the 3 years to determine both the initial exchangeable K status and the extent of stratification that was present in the soil. Soil K concentrations (combined for the 3 different tillage treatments and the 3 K fertility treatments) were stratified with depth. The ratios of exchangeable soil K concentration in the 0-5cm soil layer, relative to the 5-15 and the 15-25cm soil layers, averaged 1.9 to1. The average soil K concentration for the 0 to 5, 5 to 15, and 15 to 25 cm soil layers were 203 mg kg^{-1}, 115 mg kg^{-1} and 105 mg kg^{-1}, respectively (Figure 1).

Figure 1. Mean soil-test K concentrations by depth interval (mean of prior tillage and fertility treatments from 2001 to 2003)



Plant Measurement Results

Leaf K concentration at the R1 stage, seed K content and seed yield were measured in all 3 years. Tables 1, 2 and 3 show the results for years 2001, 2002 and 2003, respectively.

Table 1. Leaf and seed K concentration (%) and seed yield (bu/acre) as affected by tillage and K fertility, 2001

Tillage Treatment	No K	Fall K	F & S K	Mean
	K treatment			
	---------Leaf K conc. (%)----------			
NT	2.04	2.04	2.03	2.04
ST	1.98	2.03	2.03	2.01
FC	2.05	2.07	2.03	2.05
Mean	2.02	2.04	2.03	2.03
	---------Seed K conc. (%)----------			
NT	1.86	2.08	2.07	2.01
ST	1.89	1.98	2.07	1.98
FC	1.72	1.95	1.98	1.88
Mean	*1.82 b*	*2.00 a*	*2.04 a*	
	---------Seed yield (bu/acre)----------			
NT	55	53.5	55	54.7
ST	55	55	56.5	55
FC	59.4	55	56.5	56.5
Mean	56.5	55	56.5	55

Means within a column or a row followed by the same letter, or no letter, in each table are not statistically different according to a LSD at $\alpha = 0.05$. NT=no-till, CT=conventional tillage, ST=strip-till, No K=no K, Fall K=fall applied K, F&S K=fall and spring applied K.

Results from 2001 data collection showed that no significant tillage or K treatment effects were observed for seed yield or for leaf K content. Leaf K concentration averaged 2.03 percent, while the average of seed yield was 55 bu acre^{-1}. However, there was a significant K treatment effect on seed K content. Both fall applied K, and fall plus spring applied K, resulted in higher seed K contents than the control.

Table 2. Leaf and seed K concentration (%) and seed yield (bu/acre) as affected by tillage and K fertility, 2002

	K treatment			
Tillage Treatment	No K	Fall K	F & S K	Mean
	---------Leaf K conc. (%)----------			
NT	1.86	1.90	1.94	*1.90 a*
ST	1.79	1.79	1.77	*1.78 b*
FC	1.80	1.82	1.82	*1.81 b*
Mean	1.81	1.84	1.85	
	---------Seed K conc. (%)----------			
NT	*1.23 b*	*1.40 a*	*1.40 a*	1.35
ST	*1.28 b*	*1.42 a*	*1.41 a*	1.37
FC	*1.26 b*	*1.28 b*	*1.47 a*	1.34
Mean	1.26	1.37	1.43	
	---------Seed yield (bu/acre)----------			
NT	38.6	40.1	40.1	40.1
ST	35.7	35.7	37.2	35.7
FC	38.6	37.2	37.2	37.2
Mean	37.2	38.6	38.6	38.6

Means within a column or a row followed by the same letter, or no letter, in each table are not statistically different according to a LSD at $\alpha = 0.05$. NT=no-till, CT=conventional tillage, ST=strip-till, No K=no K, Fall K=fall applied K, F&S K=fall and spring applied K.

Results from 2002 data collection showed that no significant tillage or K treatment effects were observed for seed yield. Seed yield averaged 38.6 bu acre^{-1}. However, there was a significant tillage treatment effect on leaf K concentration and tillage by K fertility interaction effect on seed K concentration. Soybean plants that followed no-till corn had higher leaf K than those after chisel and strip-till. The fall application and the fall plus spring application resulted in higher seed K levels than the control for the no-till and the strip-till treatments. Following the chisel treatment, only the fall plus spring application resulted on higher seed K content than the control.

Table 3. Leaf and seed K concentration (%) and seed yield (bu/acre) as affected by tillage and K fertility, 2003

	K treatment			
Tillage Treatment	No K	Fall K	F & S K	Mean
	---------Leaf K conc. (%)----------			
NT	2.19	2.31	2.41	2.30
ST	2.12	2.42	2.31	2.29
FC	2.04	2.30	2.32	2.22
Mean	*2.12 b*	*2.34 a*	*2.35 a*	
	---------Seed K conc. (%)----------			
NT	1.51	1.54	1.53	1.53
ST	1.49	1.53	1.53	1.52
FC	1.52	1.52	1.54	1.52
Mean	*1.51 b*	*1.53 a*	*1.53 a*	
	---------Seed yield (bu/acre)----------			
NT	38.6	38.6	38.6	38.6
ST	37.2	38.6	38.6	38.6
FC	35.7	38.6	38.6	38.6
Mean	37.2	38.6	38.6	38.6

Means within a column or a row followed by the same letter, or no letter, in each table are not statistically different according to a LSD at $\alpha = 0.05$. NT=no-till, CT=conventional tillage, ST=strip-till, No K=no K, Fall K=fall applied K, F&S K=fall and spring applied K.

Results from 2003 data collection showed that no significant prior tillage or K treatment effects were observed for seed yield. Seed yield averaged just 38.6 bu acre^{-1}. However, there was a significant K treatment effect on both leaf and seed K concentrations. Both the fall application and the fall plus spring application treatments resulted in higher leaf and seed K than the control.

Overview

It is interesting to observe that seed K concentrations varied so much from year to year even though the same variety was grown every year. Leaf K concentrations were more consistent from year to year, and were generally in the accepted range (1.7 to 2.5 %) of critical trifoliate leaf K concentrations for the Corn-Belt states. However, these leaf K concentrations were also generally less than the 2.4% critical level recommended recently by Yin and Vyn (2004) for no-till soybean in Ontario, Canada.

Soybean yields were limited by growing season factors in 2002 (drought) and 2003 (aphids); it is also in those years that seed K concentrations were very low. Normally, soybean seed K concentrations average above 1.7% (Xinhua and Vyn, 2003, 2004).

The soybean yield and composition responses to previous fertility treatments must still be compared for various ranges in initial soil-test K. When we did so for the high oil corn that preceded the no-till soybean, the K fertility treatments were more clearly separated (Vyn et al., 2002).

Conclusions

Results from this 3-year study showed that the prior tillage system in corn had no significant impact on any of the soybean plant responses measured. Trifoliate leaf K concentrations increased with K fertility sub-treatments in 2003, but not in 2001 or 2002. Soybean yields were not significantly increased in response to the residual K fertilizer treatments in any of the years. Soybean seed K concentrations after all tillage systems were consistently (0.02 to 0.22%) higher after the fall K alone, and fall plus spring K, fertility treatments. However, the absolute seed K percentages ranged widely from year to year even though the same variety was used each year. Soybean responses to K fertility treatments in prior corn were more likely to be evident in seed composition changes (seed K content) rather than being expressed in higher yields.

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