CORN AND SOYBEAN RESPONSE TO STARTERS AFTER BROADCAST FERTILIZER APPLICATION

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Abstract

Corn response to fertilization and placement methods has always been a subject of interest and extensive research; however studies on soybean response to placement have been limited in Kansas. The objective of this study was to evaluate the effect of starter and broadcast fertilizer application on corn and soybean in a typical corn-soybean rotation in Kansas. Grain and seed yield, early growth, nutrient concentration and uptake were evaluated over eight site-years trials in Kansas for both corn and soybean during 2011 and 2012. Treatments were unfertilized control, NPK dribble starter, broadcast MAP or DAP and the combination of starter and broadcast. Soil samples and plant tissues were collected and analyzed for N, P and K concentration. Corn early growth was measured at V6 to V7 growth stages. After corn and soybean reached physiological maturity, grain yield was determined. None of the individual sites showed a significant effect of starter and broadcast treatments or an interaction between the two placements methods on corn or soybean grain yield. Corn early growth, P concentration and uptake of young corn plants were significantly increased across site-years. Broadcast increased corn plant K concentration and uptake, whereas starter increased K uptake only. Phosphorus concentration on soybean leaf was increased by broadcast application, while K concentration was decreased by starter or broadcast alone.

Introduction

Fertilizer placement and application method can substantially affect yield response and producer's profitability. Starter fertilizer is a common practice in the USA to enhance crop yield potential. Some studies reviewed the effects of placement and fertilization of P and K on different crops and have shown that starter fertilizer often increase corn grain yield compared to a control treatment with no fertilization (Bundy et al., 2005, Randall and Hoeft, 1988). This response can be explained by soils with P and/or K deficiency. Ketcheson (1968) however, indicated that soils high in nutrient level do not always supply enough quantity of nutrients to the plant during the early part of growing season given, especially when certain conditions limit the nutrient availability. Low temperature soils for example, can reduce root growth (Ching and Barber, 1979, Havlin, 2005) and nutrient uptake by plant (Mackay and Barber, 1985). In order to avoid these effects, application of starter fertilizer can have a positive effect early growth and grain yield, increasing the nutrient concentration and availability in the roots zone when cool temperatures slow root growth and nutrient diffusion (Borkert and Barber, 1985). Overall yield increases due to starter application are most frequently found on low testing soils, poorly drained soils, late planting crops, long hybrid maturity groups, and conservations tillage systems (Bundy and Andraski, 2001, Randall and Hoeft, 1988). Fertilizer application as starter, broadcast, and the combination of both has been evaluated extensively for the past few years on corn in many states of US. However, studies on soybean response to placement are limited in Kansas. The objectives of this study was to evaluate the effect of starter and broadcast fertilizer applications on corn and soybean in a typical corn-soybean rotation in Kansas, and evaluate current P and K fertilization guidelines for corn and soybean.

Material and Methods

Trials were conducted at eight site-years with corn and soybean during 2011 and 2012. Fields with corn-soybean rotation histories were selected to represent the common crop rotation in the region of study. The experiments were established at Kansas State University research farms. Table 1 shows a summary of site information. Odd sites were managed under no tillage approximately six years. Sites 2, 6 and 8 were chisel plowed in the fall and turbo-tilled in the spring just before planting. Site 4 was V-ripped (subsoiled) in the winter and field cultivated in the spring. The experimental design consisted of a factorial arrangement in a complete randomized design with four treatments and four replications. Treatments were (i) unfertilized control; (ii) NPK dribble starter; (iii) NPK dribble starter in combination with broadcast fertilizer (P and K) and (iv) broadcast NPK before planting. Starter was a mixture of commercial formula 3-18-18 and UAN 28% making a total application of 17 kg ha^{-1} of N and 24 kg ha^{-1} of each P_2O_5 and K_2O. Broadcast fertilizer was a combination of MAP (11-52-0) and KCl (0-0-62) for a total application rate of 112 kg ha^{-1} for both P_2O_5 and K_2O. The broadcast application rates can be considered commonly used rates by producers before corn in a corn-soybean rotation and intended for both crops in the rotation. Broadcast fertilizer was spread 1-4 weeks before planting at all sites. Sites 2, 4, 6 and 8, broadcast fertilizer was incorporated before planting and non-incorporated at the no-till sites (1, 3, 5, and 7). Nitrogen fertilizer was applied in spring one month prior planting injecting anhydrous ammonium at a nitrogen rate of 168 kg ha^{-1} for sites 2 and 4. At site 1 and 3 180 kg ha^{-1} of nitrogen was applied as side-dress urea before the V5 corn growth stage. Trials located in Shawnee County were irrigated with center pivot sprinkler irrigation systems and irrigation was applied as needed during the growing season. All other sites were dryland. Composite soil samples were collected from a 15 cm depth from each small plot before planting and fertilizer application. Plant population was measured in a 7.6-m section of two central rows of each plot, for both crops. Site means ranged from 60,601 to 80,783 plants ha^{-1} for corn and 170,377 to 363,999 plants ha^{-1} for soybean. The aboveground parts of 10 corn plants were collected from each site at the V6 growth stage to evaluate early growth, nutrient content and uptake. Corn ear leaves were collected at silking (R1) and analyzed for N, P and K concentration. Soybean leaf samples consisting of the most recently developed, fully expanded trifoliolate leaf (petiole excluded) were collected between early bloom (R1) and full bloom (R2) stages and analyzed for N, P and K concentration. Nutrient uptake was calculated from concentrations and oven-dried weights. After corn and soybean reached physiological maturity, grain yield was determined by harvesting the center two rows of each plot. Grain yield was adjusted to a moisture content of 150g kg^{1} H_2O for corn and 130g kg^{-1} H_2O for soybean.

Statistical analysis was completed using the generalized linear mixed model (GLIMMIX) procedure of SAS (SAS, 2006) assuming fixed treatment effects and random block and site effects in the model. For all ANOVA procedures least significant difference (LSD) was used to compare treatment means by site, across years within each county and across site-years only

Table 1. Site description, soil data, hybrids, varieties and planting date for 2011 and 2012 trials.

Year	Site	County	Soil classification		Soil-test values				Variety§/ Hybrid¶	Planting date
			Series†	Subgroup‡	STP	STK	pH	OM		
					ppm			%		
				Corn						
2011	1	Riley	Eudora SL	F. Hapludolls	24	449	6.2	2.5	DK-6342	29/04
2011	2	Shawnee	Eudora SL	F. Hapludolls	17	228	6.8	1.6	DK-6449 VT3	28/04
2012	3	Riley	Eudora SL	F. Hapludolls	26	370	5.8	2.4	DK C63-49	18/04
2012	4	Shawnee	Eudora L	F. Hapludolls	16	249	6.5	1.7	DK-6323	19/04
				Soybean						
2011	5	Riley	Rossville SL	C. Hapludolls	12	306	6.7	2.2	KS 3406RR	11/05
2011	6	Shawnee	Eudora SL	F. Hapludolls	16	161	6.2	1.6	LG C3616RR	16/05
2012	7	Riley	Eudora SL	F. Hapludolls	24	458	6.3	2.8	KS 3406RR	10/05
2012	8	Shawnee	Eudora SL	F. Hapludolls	18	135	6.8	1.3	Asgrow 3282	14/05

† SL, Silt Loam; S, Loam

‡ F, Fluventic; C, Cumulic;

§ LG, LG SEEDS; KS, Kansas AES.

¶ Corn Hybrid: DK, DeKalb.

when the interaction between treatments or the treatment means were statistically significant at $P \leq 0.10$. County sites studies were always located in different fields. When significant, plant population was used as covariate in the analysis.

Results and Discussion

Corn

Individual sites or analysis across site-years showed no significant effect of starter and broadcast treatments or interaction between the two placements methods (Table 3). Nevertheless, when yield data was analyzed across years within location there was a significant response due to starter in Riley County (figure 1).

Corn early growth was increased at three sites: 1, 2 and 4 (table 2). Although broadcast P-K rate was almost ten times greater than starter rate, biomass results shows statistically similar response between starter and broadcast applied alone at all sites or across (site) years analysis. This indicates similar response to placement when it comes to corn early growth response. Across years in Riley County (sites 1 and 3), the combination of starter and broadcast was higher than other treatments although it was not statistically significant. A significant response in biomass was observed across years in Shawnee County under conventional tillage conditions (site 2 and 4). In this case, there was an interaction between the two placements methods. Starter after broadcast application showed the highest biomass value being statistically different than the other treatments. Analysis across years, within location, demonstrated that placement methods under no till and conventional tillage systems can stimulate early growth differently. Under no till system, starter or broadcast showed an increased biomass over the control. Nevertheless there was an additional effect when they were applied in combination showing an increase on early growth over the starter or broadcast applied alone.

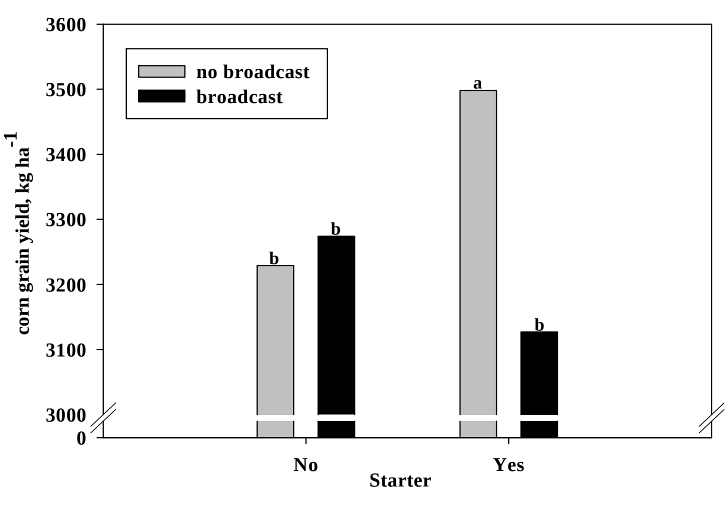

Figure 1. Fertilization effect on corn yield across years in Riley County. Different letters represent statistically significant differences at the 0.10 probability level.

Table 2. Corn yield and early growth as affected by starter and broadcast fertilizations by site, across years within locations and across site-years.

Treatment	Riley 2011	Riley 2012	Riley Across years	Shawnee 2011	Shawnee 2012	Shawnee Across years	Across site- years
			yield, kg ha^{-1}				
Control	3703	2699	3229b†	9164	15316	12213	7728
Starter (S)	3955	3139	3498a	8976	15128	12015	7775
Broadcast (B)	3829	2699	3274b	9541	14939	12195	7735
S + B	3578	2762	3127b*	8913	15755	12213	7663
			plant dry weight, g plant^{-1}				
Control	8.4b	8.2	8.3	6.5b†	3.3c	4.9c	6.6c
Starter (S)	8.1b	7.8	8.3	10.4a	6.1b	8.4b	8.3b
Broadcast (B)	8.3b	8.6	8.4	10.1a	5.3b	7.3b	8.1b
S + B	9.5a	8.7	9.3	11.3a**	8.8a	9.9a*	9.5a

† Numbers followed by different letters within each column represent statistically significant differences at the $P \leq 0.10$.
* Significant interaction at $P \leq 0.10$.
**Significant interaction at $P \leq 0.05$.

Fertilizer treatments affected P concentration of young corn plants at three sites (1, 2, and 4) of which all had a significant interaction between starter and broadcast (Table 3). Across years in Riley County, fertilization had no significant effect in early plant P concentration. At Shawnee County on the other hand, there was an interaction between starter and broadcast treatments. Starter alone decreased P concentration over the control; this can be explained by fertilization effects on early growth and the known nutrient dilution effects (Plenet and Lemaire, 1999). Only the combination of starter and broadcast increased P concentration over the control, which might be result of the interaction effect, with a compensated dilution effect through higher P uptake. Analysis across sites-years, the response was the same as across years in Shawnee County. Early P uptake was increased at three sites. Fertilization showed a significant effect in P uptake across years in Riley County. In this case, there was an interaction between placements where only the combination of starter and broadcast increased P uptake over the control. Across years in Shawnee County, starter and broadcast alone increased P uptake over the control. When P uptake was analyzed across site-years, same outcome occurred.

Table 3 . Placement effects on early plant P concentration and uptake in corn (V6 growth stage).

Site	Year	Treatments							
				Broadcast				Broadcast	
		Control	Starter	No starter	Starter	Control	Starter	No starter	Starter
		— plant P concentration, g kg^{-1} —				— plant P uptake, mg $plant^{-1}$ —			
	2011	4.0ab†	3.9b	3.9b	4.2a*	33.5b	33.6b	32.2b	39.5a*
Riley	2012	3.7	3.7	3.6	3.5	30.2	28.3	30.7	30.0
	Across years	3.8	3.8	3.7	3.9	31.7b	31.2b	31.5b	35.8a*
	2011	2.8c	2.7c	3.3b	3.7a*	18.9d	27.9c	33.4b	41.5a
Shawnee	2012	3.0a	2.5b	2.8a	3.0a*	10.0c	15.0b	15.0b	26.0a*
	Across years	2.9b	2.5c	3.0b	3.4a*	14.4c	21.4b	24.2b	33.9a
	Across site-years	3.4b	3.2c	3.4b	3.6a*	23.1c	26.2b	27.8b	34.7a

† Numbers followed by different letters in the same row represent statistically significant differences at the P ≤ 0.10;
* Significant interaction at P ≤ 0.10;

Fertilizer treatments did not decrease early plant K concentration. There was no interaction between starter and broadcast when analyzing early plant K concentration and K uptake (data not shown). Thus only the main effects of starter and broadcast are presented (table 4). Broadcast increased K concentration at all sites and across (site) years and starter only at sites 1 and 4 and across years in Riley County. Starter had no effect on K concentration across site-years. There was a significant difference between starter and broadcast at site 2, across years in Shawnee County and across site-years, where broadcast increased K concentration more than starter. Starter and broadcast alone enhanced K uptake at sites 1, 2 and 4, across years at both Counties and across site-years (table 4).

Table 4. Potassium concentration and uptake at V6 to V7 corn growth stage as effected by starter and broadcast application

Site	Year	Treatment							
		Starter		Broadcast		Starter		Broadcast	
		No	Yes	No	Yes	No	Yes	No	Yes
		— plant K conc., g kg^{-1} —				— plant K uptake, mg $plant^{-1}$ —			
Riley	2011	52.0b†	54.2a	51.9b	54.3a	433b	492a	440b	484a
	2012	52.0	53.2	51.2b	53.9a	436	440	468	408
	Across years	52.0b	53.8a	51.5b	54.3a	434b	475a	428b	481a
Shawnee	2011	47.8	46.1	44.2b	49.7a	406b	504a	376b	533a
	2012	48.8b	51.8a	48.7b	52.0a	215b	390a	233b	371a
	Across years	48.3	48.5	46.1b	50.7a	310b	444a	306b	449a
	Across site-years	50.1	51.1	48.8b	52.5a	372b	456a	366b	463a

†Different letters following number represent significant differences (LSD, P≤0.10) when there was a significant treatment main effect within each treatment.

Soybean

Soybean grain yield was not significantly affected by fertilizer treatments at any site or across (site) years (table 5). At sites 5, 6 and 8 soil test P was classified as low or below the critical level of 20 ppm according to Kansas State University guidelines (Leikam et al., 2003). On this basis yield response was expected as soil test P was at the crop responsive range for yield.

However, because no yield response was found, soybean yield seems not to be limited by soils with P in the low range or between 12 and 18ppm like we found at these three sites. At site 7, there was an increase trend on seed yield, where the combination of starter and broadcast or broadcast alone increased yield by 350 kg ha^{-1} over the control, although this difference was not statistically significant.

Table 5. Soybean yield as affected by starter and broadcast fertilizations by site, across years within locations and across site-years.

Treatment	Riley 2011	Riley 2012	Riley Across years	Shawnee 2011	Shawnee 2012	Shawnee Across years	Across site- years
	yield, kg ha^{-1}						
Control	2090†	2010	1790	3300	4900	4100	2980
Starter (S)	2150	2310	2220	3430	4880	4190	3230
Broadcast (B)	2220	2350	2260	3360	4980	4140	3240
S + B	2020	2360	2190	3360	4890	4140	3200

† Treatment means were not statistically significant different at the $P \leq 0.10$.

Interaction effects for leaf P concentration were not significant at any site or across (site) year analysis (data not shown). Therefore only the main effects were evaluated. Broadcast always increased leaf P concentration over the control (Table 6) and starter only enhanced P concentration at Shawnee County across years.

Table 6. Phosphorus and potassium concentration at R2-R3 growth stage on soybean trifoliolate as effected by broadcast application

Location	Year	Treatment: Broadcast No	Yes	No	Yes
		P conc., g kg^{-1}		K conc., g kg^{-1}	
	2011	3.6b†	3.9a	24.7b	23.6a
Riley	2012	4.0b	4.3a	20.9	20.5
	Across years	3.8b	4.1a	22.0b	22.8a
	2011	3.9b	4.2b	23.0	23.2
Shawnee	2012	4.1b	4.4a	16.3b	17.3a
	Across years	4.0b	4.3a	19.7	19.7
	Across site-years	3.9b	4.2a	21.2	21.1

†Statistical significance of the treatment main effect at 0.10 probability level.

Leaf K concentration showed no significant response to starter fertilizer at any site (data not shown). Broadcast showed some decrease in leaf K concentration across years in Riley County (table 7). In Shawnee County, starter showed an average lower K leaf concentration over the control. There was a significant interaction in this case, where broadcast alone or in combination did not change K concentration compare to the control treatment. Across site-years, both starter and broadcast showed lower leaf K concentration. Again, there was an interaction between placements, where starter after broadcast application was not statistically different than any treatment. Some of these tendencies may be attributed to some dilution effect with increased plant biomass with the fertilizer treatments.

Table 7. Fertilization effects K concentration in trifoliolate soybean at R2 stage.

Site	Year	C†	S	B	S + B
		K concentration, g kg^{-1}			
	2011	25.3	24.0	23.6	23.6
Riley	2012	20.9	21.0	19.9	21.1
	Across years	23.1a	22.5ab	21.8b	22.2b
	2011	23.7a‡	22.3b	22.9ab	23.5a*
Shawnee	2012	16.4	16.2	16.9	17.7
	Across years	20.0a	19.3b	19.2ab	20.6a*
Across site-years		21.6a	20.9b	20.8b	21.4ab*

† C, Control; S, Starter; B, broadcast;
‡ Numbers followed by different letters between each column represent statistically significant differences at the $P \leq 0.10$.
*Significant interaction at $P \leq 0.05$

Summary

Results of this study suggest that corn yield response to starter may occur under no till and some stress conditions such as drought likely affecting soil properties soil nutrient availability. There was no yield increase across years in Shawnee County or across site-years (conventional tillage). Therefore early growth and nutrient uptake response to starter and/or broadcast were not reliable indicators of grain yield response. Soybean seed yield was not affected by any fertilization treatment even at sites with soils tests below the critical level for soil test P. This could be explained by the high concentration of P and K found on the soybean trifoliates, and likely these nutrients were not limiting soybean yield.

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