EFFECT OF TIMING OF BROADCAST POTASSIUM (K) ON SOYBEAN YIELD AND SEED K CONTENT

Fabian Fernandez and Sylvie M. Brouder
Purdue University, West Lafayette, Indiana

Abstract

In Indiana, the common practice is for K fertilizer to be applied in advance of the corn crop for both crops in the rotation, relegating soybean to feed on the application residual. Producers are concerned that current University guidelines and common practices for K management in corn-soybean rotations do not fully recognize the particular K needs of the soybean crop as differentiated from the corn crop. A four-location, six-year field study was conducted to investigate the effects of rate and timing of K application on soybean yield and seed K composition. Among all location-years, soybean yields were largely unresponsive to either rates or timings of K applications when soil test K levels were near or above current University guidelines for soil critical levels (evaluation of the accuracy of the critical levels is on-going). Likewise, analysis of K concentration and removal in soybean seed found few significant treatment effects. A lack of strong response of seed K concentrations to K rate without an accompanying yield response suggests that, unlike other plant tissues, seeds do not luxury-accumulate K. If seed K concentration is a trait that is largely conserved once soil K levels are sufficient to optimize yields, it calls into question whether or not there is a K management objective for oil that is independent of the management objective for yield.

Introduction

In recent years, the soybean crop in the corn-soybean rotation has increased in relative economic importance. In Indiana, the common practice is for K to be applied in advance of the corn crop for both crops in the rotation, relegating soybean to feed on the residual of the fertilizer application. When compared to a corn crop, soybean requires more K per unit product (Vitosh et al., 1996), has a less dense root system (Barber, 1995) especially in surface soils where soil test K levels are greatest, and accumulates K later in the growing season when soils tend to be dry, and rainfall scarce and intermittent. Producers are concerned that current University guidelines and common practices for K management in corn-soybean rotations do not fully recognize the particular K needs of the soybean crop as differentiated from the corn crop. Interest in K fertility management explicitly tailored to soybean has also increased in response to reports suggesting that soybean value-added traits such as grain composition may be linked to plant K status. Our primary objective was to determine whether soybean yields would be boosted on low and medium testing soils by applying K directly to the soybean crop. A related objective was to determine whether soybean seed K concentration could be increased with a primary- versus residual-feeder fertilization strategy.

Approach

A six-year experiment was conducted at four locations in Indiana. The locations were the Davis, Northeast, Southeast and Throckmorton Purdue Agricultural Centers (DPAC, NePAC, SePAC, and TPAC, respectively). The sites were selected to be representative of major agronomic soils of Indiana. The individual fields at each PAC were selected by the farm manager based on previous soil testing records that had identified these fields as being low in K fertility. The locations, tillage methods and soils are described in Table 1. At each location, adjacent fields were planted to corn or soybean in 1997 with the crops rotated annually between the two fields in every subsequent year.

The experimental design was a split block with timing of application as the block level treatment within a crop field. Timing of K application was either annual (preplant every year) or biennial (preplant in odd years only). Application rate treatments were randomized within the timing treatments. The annual application rates were 0, 30, 60, 120, and 180 lbs. K_2O per acre while biennial application rates were 0, 60, 120, 180, and 360 lbs. K_2O per acre. The cumulative amounts of K added are shown in Table 2. Each timing and rate treatment was replicated three or four (SePAC only) times. Individual plots measured 30 x 100 feet.

Soils were sampled (0-8 inches) in each treatment plot prior to starting the experiment in March of 1997. Samples were then collected in-season every year just prior to the period of rapid crop K uptake (V6 in corn and R1 in soybean). Soils were also sampled after harvest in the fall of even years. All soil samples were analyzed for ammonium acetate extractable K content. Yields were harvested from the 5 x 30 foot (soybean) or 15 x 85 foot (corn) centers of each plot. A subsample of grain was ground and analyzed for nutrient content.

In order to directly evaluate the effects of both rate and timing of application on soybean yield and seed K composition, analysis of variance was applied to data from the even years (1998, 2000, and 2002) of the experiment. With respect to the cumulative amount of fertilizer applied, annual treatments of 30, 60, and 180 lbs. K_2O are equivalent to the biennial treatments of 60, 180, and 360 lbs. K_2O per acre, respectively, in the even years. Two types of statistical tests were used on results from each year and location. The Least Significant Difference (LSD) test was used to determine differences between one specific treatment and all other treatments, while a Contrasts test was used to specifically test whether or not an individual treatment or group of treatments was different from another individual treatment or group of treatments.

Finally, in order to evaluate the relationships between yield, K uptake in grain and K uptake during crop growth and development, a supplemental experiment was conducted in 2003 and 2004 at TPAC. During these years no additional K was added but nine areas of the field were identified for season long observations. Of these nine areas, three had low in-season soil test K (55 to 73 ppm K at 0-8 in), three had medium soil test K (80 to 120 ppm K at 0-8 in), and three had high soil test K (165 to 200 ppm K at 0-8 in). Whole plant samples were collected in each observation area at VE, V6/R1, R2/R3, R4/R5, and R6 growth stages. Plants were partitioned into leaves, stems, pods and seed, and each component was analyzed for weight and K content. At maturity, yields were harvested as described above and a grain subsample was analyzed for K content.

Results

According to the common Indiana-Ohio-Michigan K recommendations, a soil is expected to be responsive to fertilizer K when soils are below a critical level (CL) that is linked to the soil cation exchange capacity (Vitosh et al., 1996). The CLs for DPAC, NePAC, SePAC, and TPAC are 106, 96, 88, and 105 ppm, respectively, measured in the top 8 inches of the soil profile (Table 3). Analysis of the in-season soil samples collected in 1998 from the control plots showed that field-average K levels were at or below the CL at DPAC, NePAC and SePAC but well above the CL at TPAC. However, soil test K levels varied substantially among the individual replicates of the control. At DPAC and NePAC, minimum soil test K levels ranged from 20 ppm K below the CL to 20 ppm (NePAC) or 100 ppm (DPAC) above the CL. At TPAC, soil test K levels observed in the controls ranged from the CL to 100 ppm above the CL. Only at SePAC were K levels observed in all control treatments well below the CL. By 2002, mean soil test K levels were at or below the CL at all locations, but, at all locations except SePAC, individual control plots that tested well above the CL could still be found.

Analysis of soybean yields found very few significant treatment effects (Table 4). The LSD test found significant effects of treatments only at SEPAC and only in the last year of the study. This is particularly remarkable as the low soil test levels indicate that this location should have been highly responsive to K addition in the first year of the study. However, it should be noted that the Avonberg soil at SePAC has long been identified by Indiana farmers as a soil for which the current guidelines for responsiveness to fertilizer K seem incorrect.

The contrast analysis tests were specifically designed to evaluate timing of application by comparing all annual rates to all biennial rates (annual 30, 60, 180 to biennial 60, 120, 360), the two highest annual results to the two highest biennial results (annual 60, 180 to biennial 120, 360), and the highest annual rate to the highest biennial rates (annual 180 to biennial 360) (Table 4). This analysis found occasional but small and inconsistent effects of timing of K application on yield. For example, at DPAC in 2002, annual applications resulted in higher yields when compared to biennial applications, but, at TPAC in 1998, biennial applications outperformed annual applications. It should also be noted that, in both of these cases, comparison of all rates to the controls indicated that the sites were not responsive to K. Overall, there appeared to be no practical difference in yield for annual versus biennial K applications.

Likewise, analysis of K concentration and removal in soybean seed found few significant treatment effects. Contrast analysis found seed K concentrations were responsive to K rate at DPAC in 2000 and at SePAC in 2002 (Table 5). Seed K concentrations were only responsive to timing of K applications at DPAC in 2000 (annual > biennial). Contrast analysis found seed K removal responsive to K rate at SePAC (2000 and 2002) and to timing at DPAC (2002) (Table 6). As with the yield results, the significant effect of K application timing at DPAC in 2002 occurred without a significant effect of rate, and, thus, the result appears to have little practical meaning.

The lack of strong response of seed K concentrations to K fertilizer treatments without an accompanying yield response suggests that, unlike other plant tissues, seeds do not luxury-accumulate K. Analysis of K uptake throughout crop growth further supports this concept. At

TPAC in 2003 and 2004, soybean yields were not significantly different on medium when compared to high testing soils and seed K concentrations were virtually identical (data not shown); consequently, seed K removal was statistically the same for medium and high testing soils (Fig. 1). However, analysis of K accumulation in aboveground dry matter throughout the growing season found greater total K uptake in high when compared to medium testing soils (Fig. 2).

Summary

In rain-fed production systems with conservation tillage and broadcast K management, soybean yields were largely unresponsive to either rates or timings of K applications when soil test K levels were near current University guidelines for soil CLs. In most location-years, soil test K levels in control plots were highly variable and regions of fields that were substantially below expected CLs could be identified; a statistical approach other than the analysis of variance presented here will be required to use this data to evaluate whether or not current CL guidelines are accurate. This analysis is currently in process.

In this study, seed K concentrations were also not strongly impacted by treatments. Several recent studies have focused on the linkages between K management, K seed content and seed quality attributes (Gaydou and Arrivets, 1983; Sale and Campbell, 1986; Vyn et al., 2002; Yin and Vyn, 2003). These studies have observed a positive relationship between seed K concentration and oil concentration. However, if seed K concentration is a trait that is largely conserved once soil K levels are sufficient to optimize yields, it calls into question whether or not there is a K management objective for oil that is independent of the management objective for yield.

References

Barber, S.A. 1995. Soil Nutrient Bioavailability: A Mechanistic Approach. 2nd Ed. John Wiley and Sons, Inc., New York.

Gaydou, E.M., and J. Arrivets. 1983. Effects of phosphorus, potassium, dolomite, and nitrogen fertilization on the quality of soybean. Yields, protein and lipids. J. Agric. Food Chem. 31:765-769.

Sale, P.W., and L.C. Campbell. 1986. Yield and composition of soybean seed as a function of potassium supply. Plant Soil 96:317-325.

Vitosh, M.L., J.W. Johnson, and D.B. Mengel (eds.). 1996. Tri-state fertilizer recommendations for corn, soybeans, wheat, and alfalfa. Ext. Bull. E-2567, Michigan State University Ext., East Lansing.

Vyn, T.J., X.H. Yin, T.W. Bruulsema, C.J.C Jackson, I. Rajcan, and S.M. Brouder. 2002. Potassium fertilization effects on isoflavone concentrations in soybean. J. Agric. Food Chem. 50:3501-3506.

Yin, X., 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. Site information for the K timing and rate experiment.

Site	IN Location	Tillage	Soil Type	CEC
DPAC	East Central	Chisel	Blount-Pewamo	12.4
NePAC	North East	No-Till	Glynwood	8.4
SePAC	South Central	No-Till	Avonberg	5.2
TPAC	West Central	No-Till	Toronto-Millbrook	12.0

Table 2. Annual, biennial and cumulative amounts of K fertilizer added to specific timing and rate treatments. Equivalent rates for the timing treatments are shown in bold face.

			Cumulative K Added					
Trt. Code	Timing	Rate	1997	1998	1999	2000	2001	2002
			Lbs. K_2O per acre					
Annual 0	Annual	0	0	0	0	0	0	0
Annual 30		30	30	***60***	90	***120***	150	***180***
Annual 60		60	60	***120***	180	***240***	300	***360***
Annual 120		120	120	240	360	480	500	620
Annual 180		180	180	***360***	540	***720***	900	***1080***
Biennial 0	Biennial	0	0	0	0	0	0	0
Biennial 60		60	60	***60***	120	***120***	180	***180***
Biennial 120		120	120	***120***	240	***240***	360	***360***
Biennial 180		180	180	180	360	360	540	540
Biennial 360		360	360	***360***	720	***720***	1080	***1080***

Table 3. Expected soil critical levels and measured ammonium acetate-extractable K levels (mean, standard deviation, minimum, and maximum values) in control plots at each location in 1998 and 2002.

		Soil Test K in 1998				Soil Test K in 2002			
Site	Critical Level	Mean	Std. Dev.	Min.	Max.	Mean	Std. Dev.	Min.	Max.
					ppm K				
DPAC	106	113	60	73	228	103	62	64	226
NePAC	96	90	18	70	119	96	41	55	168
SePAC	88	60	8	49	68	36	5	29	43
TPAC	105	153	42	109	210	113	30	88	151

Table 4. Mean yield (bu/Ac) by treatment for each year and location. Treatment codes and cumulative amount of K added are given in Table 2.

Application time and rate	DPAC			NePAC			SePAC			TPAC		
	1998	2000	2002	1998	2000	2002	1998	2000	2002	1998	2000	2002
	bushels acre^{-1}											
Annual 0 (A1)	43.1a	56.8a	42.6a	32.9a	41.4a	39.2a	62.6a	41.8a	37.3c	53.2a	54.6a	63.5a
Annual 30 (A2)	43.1a	55.2a	40.3a	31.1a	30.9a	42.4a	70.9a	50.7a	49.2ab	56.7a	58.6a	63.2a
Annual 60 (A3)	43.1a	58.6a	40.7a	33.8a	43.9a	39.4a	70.4a	55.9a	52.6ab	54.2a	53.5a	59.4a
Annual 120 (A4)	43.1a	62.1a	41.2a	34.0a	44.7a	45.1a	68.0a	52.2a	51.9ab	55.0a	53.5a	58.1a
Annual 180 (A5)	42.8a	56.6a	43.8a	34.8a	40.6a	41.7a	71.9a	54.3a	48.1abc	46.6a	52.6a	55.2a
Biennial 0 (B1)	43.5a	56.7a	37.6a	33.9a	36.8a	38.2a	68.6a	50.0a	42.8bc	60.3a	55.5a	57.4a
Biennial 60 (B3)	43.4a	58.5a	34.7a	33.0a	40.1a	39.3a	66.2a	54.4a	49.2ab	59.5a	56.8a	62.2a
Biennial 120 (B4)	43.5a	52.3a	34.1a	30.9a	38.6a	39.2a	71.3a	54.0a	55.0a	55.3a	58.5a	59.9a
Biennial 180 (B5)	43.0a	59.2a	44.1a	34.3a	44.5a	42.5a	70.6a	56.3a	54.5a	55.2a	57.4a	59.8a
Biennial 360 (B6)	43.0a	57.3a	40.7a	33.8a	43.5a	40.0a	70.8a	51.4a	51.0ab	60.2a	55.5a	54.2a
	Contrasts‡											
A 2,3,5 vs. B 3,4,6	0.133	0.820	**0.012**	0.769	0.462	0.570	0.342	0.880	0.368	**0.050**	0.290	0.751
A 3,5 vs. B 4,6	0.216	0.522	**0.042**	0.467	0.766	0.790	0.949	0.442	0.270	**0.044**	**0.105**	0.891
A 5 vs. B 6	0.533	0.919	0.334	0.789	0.581	0.736	0.702	0.509	0.392	**0.011**	0.390	0.724
A 1 vs. A all	0.574	0.781	0.666	0.870	0.648	0.457	**0.003**	**0.003**	**<0.001**	0.983	0.987	**0.053**
B 1 vs. B all	0.277	0.982	0.739	0.756	0.265	0.802	0.713	0.258	**0.001**	0.472	0.570	0.462

†Within columns, means followed by the same letter are not significantly different according to LSD (0.05).

‡ Probability > F.

Table 5. Mean seed K concentration (percent) by treatment for each year and location. Treatment codes and cumulative amount of K added are given in Table 2.

Application time and rate	DPAC			NePAC			SePAC			TPAC		
	1998	2000	2002	1998	2000	2002	1998	2000	2002	1998	2000	2002
							% K					
Annual 0 (A1)	1.72a	1.91abc	1.80a	1.66a	1.80a	1.51a	1.72a	1.82a	1.67cd	1.65a	1.88a	2.04a
Annual 30 (A2)	1.72a	1.99ab	1.80a	1.74a	1.93a	1.60a	1.77a	1.82a	1.78bcd	1.59a	1.94a	1.95a
Annual 60 (A3)	1.78a	2.03a	1.74a	1.71a	1.85a	1.54a	1.74a	1.86a	1.90abcd	1.67a	1.94a	2.01a
Annual 120 (A4)	1.72a	1.96abc	1.94a	1.63a	1.96a	1.65a	1.77a	1.90a	1.93abc	1.70a	1.90a	2.07a
Annual 180 (A5)	1.75a	1.98ab	1.98a	1.63a	1.89a	1.69a	1.77a	1.96a	1.95ab	1.72a	1.94a	2.10a
Biennial 0 (B1)	1.73a	1.81c	1.77a	1.62a	1.91a	1.70a	1.68a	1.80a	1.63d	1.61a	1.86a	1.91a
Biennial 60 (B3)	1.65a	1.87bc	1.78a	1.67a	1.99a	1.62a	1.77a	1.88a	1.88abcd	1.59a	1.93a	1.93a
Biennial 120 (B4)	1.74a	1.93abc	1.73a	1.72a	1.95a	1.65a	1.74a	1.86a	1.84abcd	1.64a	1.90a	1.94a
Biennial 180 (B5)	1.72a	1.94abc	1.83a	1.71a	1.84a	1.67a	1.78a	1.85a	1.88abcd	1.60a	1.94a	1.96a
Biennial 360 (B6)	1.71a	1.94abc	1.87a	1.63a	1.94a	1.58a	1.79a	1.92a	2.08a	1.66a	1.95a	1.98a
							Contrasts‡					
A 2,3,5 vs. B 3,4,6	0.193	**0.003**	0.334	0.561	0.205	0.926	0.890	0.862	0.230	0.269	0.597	0.305
A 3,5 vs. B 4,6	0.418	**0.031**	0.323	0.874	0.263	0.975	0.888	0.606	0.520	0.179	0.618	0.244
A 5 vs. B 6	0.531	0.316	0.229	1.000	0.625	0.198	0.781	0.520	0.113	0.188	0.888	0.247
A 1 vs. A all	0.643	**0.040**	0.345	0.671	0.164	0.113	0.375	0.139	**0.002**	0.540	0.212	0.925
B 1 vs. B all	0.655	**0.009**	0.671	0.167	0.782	0.289	**0.071**	**0.087**	**<0.001**	0.670	**0.073**	0.591

†Within columns, means followed by the same letter are not significantly different according to LSD (0.05).

‡ Probability > F.

Table 6. Mean K removal (pounds elemental K per acre) by treatment for each year and location. Treatment codes and cumulative amount of K added are given in Table 2.

Application time and rate	DPAC			NePAC			SePAC			TPAC		
	1998	2000	2002	1998	2000	2002	1998	2000	2002	1998	2000	2002
	lbs. K acre^{-1}											
Annual 0 (A1)	38a	57a	40ab	29a	39a	31a	56a	39b	32c	46a	54a	68a
Annual 30 (A2)	38a	57a	38ab	29a	31a	36a	66a	48ab	46ab	47a	59a	64a
Annual 60 (A3)	40a	63a	37ab	30a	42a	32a	64a	54a	52a	47a	54a	63a
Annual 120 (A4)	38a	63a	42ab	29a	45a	38a	63a	52ab	53a	49a	54a	63a
Annual 180 (A5)	39a	59a	45a	29a	40a	37a	66a	55a	49ab	42a	54a	61a
Biennial 0 (B1)	39a	54a	36ab	29a	37a	34a	60a	46ab	37bc	51a	54a	57a
Biennial 60 (B3)	38a	57a	32b	29a	41a	33a	61a	53ab	48ab	49a	57a	63a
Biennial 120 (B4)	39a	53a	31b	28a	39a	34a	64a	53ab	53a	47a	58a	62a
Biennial 180 (B5)	38a	60a	42ab	30a	43a	33a	65a	54a	54a	46a	58a	61a
Biennial 360 (B6)	38a	58a	40ab	29a	44a	33a	66a	52ab	55a	52a	56a	56a
	Contrasts‡											
A 2,3,5 vs. B 3,4,6	0.295	0.384	**0.011**	0.603	0.263	0.658	0.484	0.893	0.177	0.115	0.457	0.509
A 3,5 vs. B 4,6	0.554	0.304	**0.033**	0.502	0.901	0.793	0.912	0.306	0.209	0.110	0.195	0.512
A 5 vs. B 6	0.593	0.949	0.155	0.831	0.494	0.483	0.936	0.337	0.116	**0.033**	0.416	0.462
A 1 vs. A all	0.709	0.504	0.981	0.776	0.995	0.286	**0.002**	**<0.001**	**<0.001**	0.907	0.657	0.232
B 1 vs. B all	0.506	0.551	0.686	0.951	0.265	0.856	0.114	**0.074**	**<0.001**	0.589	0.248	0.459

††Within columns, means followed by the same letter are not significantly different according to LSD (0.05).

‡ Probability > F.

Fig. 1. Potassium Removal By Seed TPAC 2003 (kg/ha = 1.12xlbs/Ac).

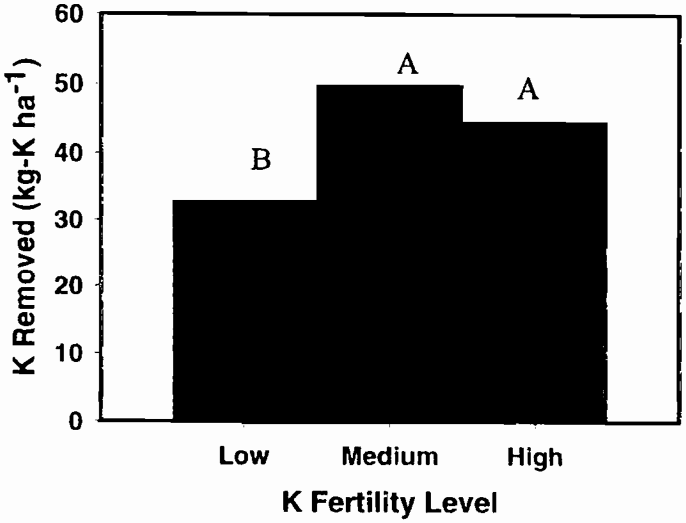
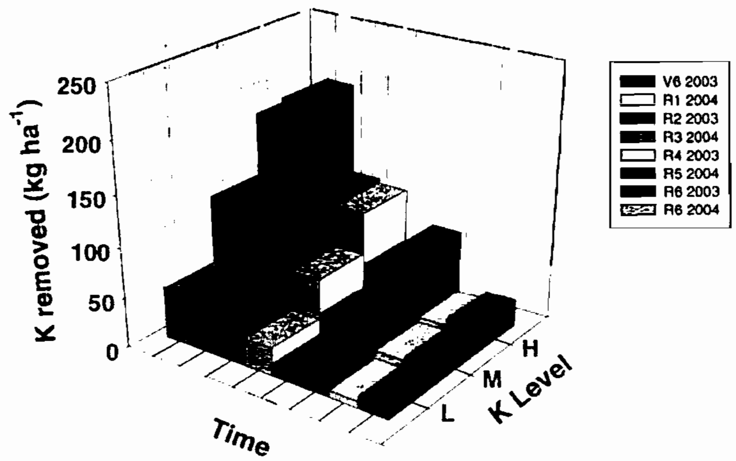


Fig. 2. K removal by vegetative tissue (TPAC 2003-2004; kg/ha =1.12 x lbs/Ac).



PROCEEDINGS OF THE

THIRTY-FIFTH NORTH CENTRAL EXTENSION-INDUSTRY SOIL FERTILITY CONFERENCE

Volume 21

November 16-17, 2005
Holiday Inn Airport
Des Moines, IA

Program Chair:
Brad Joern
Purdue University
West Lafayette, IN
(765) 494-9767

Published by:
Potash & Phosphate Institute
772 – 22nd Avenue South
Brookings, SD 57006
(605) 692-6280
Web page: www.ppi-ppic.org

Our cover: To world food security and agricultural production, the Haber-Bosch process has been the most economical means for fixation of nitrogen for fertilizer. Fritz Haber won the Nobel Prize for Chemistry in 1918 and Carl Bosch shared the prize in 1931.