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Rice and Soybean Response to Annual Potassium Fertilization Rate

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ABSTRACT

The balance between nutrient inputs as fertilizer and removals by the harvested portion of the crop plus soil properties and management are needed to evaluate the sustainability of fertilizer rates recommended using various fertilization philosophies. A long-term study K fertilization was initiated at the Pine Tree Branch Station in 2000 and cropped to rice and soybean. After seven crops, data shows that when <60 lbs K_2O/acre/year is applied soil-test K declines and K nutrition becomes a yield-limiting factor for rice and soybean yields with soybean yields being more sensitive to K deficiency than rice yields. Over the last 4-years rice and soybean yields have tended to be the greatest when >60 lbs K_2O/acre/yr is applied.

INTRODUCTION

Fertilizer rate recommendations are correlated and calibrated using data from trials that are conducted for a single year across numerous sites and years. Data from such trials are quite useful in determining how accurate soil tests are at predicting the need for P and K fertilizers and calibrating the fertilizer rates that are needed to maximize crop yields for specific soil properties. However, fertilization trials that are conducted for a single year across numerous sites reveals little about how the annual fertilization rate influences the yields of subsequent crops and how soil-test K responds to fertilization across time. The balance between nutrient inputs as fertilizer and removals by the harvested portion of the crop plus soil properties and management are needed to evaluate the sustainability of fertilizer rates recommended using various fertilization philosophies.

Growers often question the sustainability of recommendations made using the '*fertilize the crop*' philosophy which recommends fertilization only when a positive crop yield response is expected. Consistently high crop yields combined with potential nutrient-loss pathways may remove more P and K than is recommended for application. A negative nutrient balance (annual loss/removal > input) can slowly reduce a soils fertility level and make subsequent crops more susceptible to nutrient deficiencies and ultimately reduce the soils productivity, especially for poorly buffered soils and when soil samples are submitted for analysis once every three or four years. The primary objectives of this project were to evaluate the effect of different annual K fertilization rates on rice and soybean yields and soil-test K across time.

PROCEDURES

A K-fertilization trial was established in 2000 at the Pine Tree Branch Station (PTBS) on a Calhoun silt loam. In May 2000, plot boundaries were established and a composite soil sample consisting of 6 to 8, 1-inch diameter soil cores (0-to 4-inch depth) was collected from each plot to evaluate initial soil properties and uniformity of soil-test K among plots. Soil samples were oven-dried at 55°C, crushed, and passed through a 2-mm sieve. Soil water pH was determined in a 1:2 soil weight:water volume mixture, plant-available nutrients were extracted using the Mehlich-3 method, and elemental concentrations in Mehlich-3 extracts were determined using inductively coupled plasma spectroscopy (ICPS). Each year a composite soil sample was taken from each plot and processed as described previously. Annual soil samples were always taken in February or March following harvest of the previously grown crop. Selected soil chemical property means for each year are listed in Table 1.

Each individual plot measured 16-ft long by 25-ft wide which allowed for planting four strips per treatment with a 6-ft wide small plot drill. Phosphorus fertilizer was applied annually at a rate of 50 lbs P_2O_5/acre. Zinc fertilizer (10 lb Zn/acre) was applied in 2000, 2004, and 2006 before rice was grown and B fertilizer (1 lb B/acre) was applied before soybean was seeded in 2003 and 2005. In 2000, 2002, 2004, and 2006 'Wells' rice was drill seeded (7.5-inch drill spacing) at 100 lb seed/acre. In 2001, 2003, and 2005, soybean was seeded in 7.5- or 15-inch wide rows (Table 2). Rice was seeded into a conventionally tilled seedbed in 2000. To minimize soil and K movement among plots, all crops planted from 2001 to 2004 and 2006 were established in untilled seedbeds (i.e., no-till). Tillage was performed in 2005 to remove combine tire tracks from the 2004 rice harvest. Management with respect to seeding rate, irrigation, and weed control was performed following University of Arkansas Cooperative Extension Service recommendations for rice and soybean.

Muriate of potash (KCl, 60% K_2O) was broadcast to the soil surface shortly before or after planting at rates of 0, 30, 60, 90, and 120 lb K_2O/acre each year from 2000-2005. Rates were increased to 0, 40, 80, 120, and 160 lbs K_2O/acre in 2006. Rates will be identified by the initial K rates (applied in 2000) throughout the paper. Potassium fertilizer rates were arranged as a randomized complete block with eight replications. At maturity, rice and soybean yields were determined by harvesting the middle 3- to 5-ft of each drill pass in four 12- to 14-ft long strips from each K rate. Grain moisture contents were adjusted to 12% moisture for rice and 13% for soybean for statistical analysis of yield data.

Plant samples were collected in all years, except 2004, to monitor plant-K uptake. For rice, whole, aboveground plants in a 3-ft section of the first inside row were harvested near panicle differentiation, dried, weighed for dry matter, ground to pass a 2-mm sieve, digested, and analyzed for nutrient concentrations. For soybean, whole plants were sampled in 2001 and 2003 (2-linear ft of row) and trifoliate leaves (20) in 2005 and processed as described for rice samples.

Analysis of variance procedures were conducted by year with the PROC GLM procedure in SAS (SAS Institute, Inc., Cary, NC). When appropriate, mean separations were performed using Fisher's Protected Least Significant Difference method at a significance level of 0.10. Linear regression was performed on data means to delineate trends.

RESULTS

Soil-test K

Initial soil samples taken in 2000 showed that soil-test K was uniform among treatments before K fertilizer treatments were applied (Table 3). Based on the annual soil-test K of the unfertilized control, the recommended (revised recommendations, 2006) K-fertilizer rates were 90 lb K_2O/acre for rice in 2000, 120 K_2O/acre for soybean in 2001, 60 lbs K_2O/acre for rice in 2002, 60 lbs K_2O/acre for soybean in 2003, 90 lbs K_2O/acre for rice in 2004, 120 K_2O/acre for soybean in 2005, and 90 lbs K_2O/acre for rice in 2006. The recommended rates of K fertilizer for all other treatments were identical to the unfertilized control in all years except 2001, 2004, and 2006 when lower K-fertilizer rates would have been recommended for the 90 and/or 120 lbs K_2O/acre/year rates.

Soil-test K in the unfertilized control fluctuated somewhat among years ranging from a low of 65 ppm in 2006 to a high of 103 ppm in 2003 (Table 3). Following application of K treatments, the range of soil-test K among annual K rates generally increased each year and varied from 12 ppm in 2001 to 32 ppm in 2006. Soil receiving the two lowest rates (0 and 30 lb

K_2O/acre) of K fertilizer always contained the lowest soil-test K values and the highest soil-test K was always from one of the two highest K application rates (90 or 120 lbs K_2O/acre). Each year, soil-test K increased linearly as annual K rate increased with 4 to 12 lb K_2O/acre required to increase Mehlich-3 soil-test K by 1 ppm. Soil samples collected in spring 2006, showed that application of 60 lbs K_2O/acre had maintained the initial soil-test K and rates >60 lb K_2O/acre increased soil-test K by about 1 ppm per every 4 lbs K_2O/acre/year. Data shows that building soil-test K by application of K rates greater than the crop removal rate is possible, albeit slow.

Yield Response

During the first two complete rice-soybean rotations, only soybean yields in 2001 were significantly increased by K fertilization (Table 4). Although not statistically significant, consistent, numerical yield increases were observed during 2002 and 2003. However, rice and soybean yields were significantly increased by K fertilization during the third crop rotation cycle (2004-2005) and in 2006. In both 2004 and 2005, application of 120 lb K_2O/acre produced the greatest rice and soybean yields. Across time rice yields declined 2.5%/year when 0 lbs K_2O/acre/yr was applied and remained constant ($\geq$95% of maximum yields) at rates $\geq$30 lbs K_2O/acre/yr. Similarly, soybean yields declined by 4.5 and 3.4%/yr when 0 and 30 lbs K_2O/acre/yr was applied annually.

The average yields across the 4-years for rice were 152, 160, 164, 164, and 168 bu/acre (LSD0.10 = 9 bu/acre) for 0, 30, 60, 90, and 120 lbs K_2O/acre, respectively. The average yields across the 3-years for soybean were 39, 42, 45, 46, and 47 bu/acre (LSD0.10 = 4 bu/acre) for 0, 30, 60, 90, and 120 lbs K_2O/acre, respectively. Averaged across years, yield data suggests that $\geq$30 lbs K_2O/acre/yr and $\geq$60 lbs K_2O/acre/yr allowed production of near maximal rice and soybean yields, respectively. The minimum K rate needed to produce near maximal yields, 30 lbs K_2O/acre for rice and 60 lbs K_2O/acre for soybean, closely matched the K removal rate by the mean yields for rice (0.18 lbs K_2O/bu) and soybean (1.4 K_2O/bushel)during this 7-year period. Potassium removal in harvested grain largely explain the decline, maintenance, and increase in soil-test K among K rates.

Tissue K Concentrations

Each year K concentrations in rice (panicle differentiation) and soybean tissues (R2) increased as K application rate increased (Table 5). Also, rice tissue K concentrations in the unfertilized control tended to decrease across time indicating less soil-available K. The tissue K data when considered with yield data provides insight concerning the tissue K concentrations that can be considered deficient and sufficient for crop growth. Ideally, whole plant K concentrations for rice at panicle differentiation should be above 2.0%.

PRACTICAL APPLICATION

The data provide strong evidence that soybean yield is more sensitive to K deficiency than rice suggesting that K-fertilizer recommendations should be targeted to maintain soybean yields. Data collected from this study were used as an aid to revise fertilizer recommendations for silt-loam soils used for rice and soybean production. The data indicate that annual applications $\geq$60 lb K_2O/acre were needed to produce high annual rice and soybean yields as well as maintain soil-test K. Annual K fertilizer rates >60 lb K_2O/acre tended to produce the greatest crop yields during the third rotation cycle and were needed to gradually build soil-test K. The study will be continued to monitor rice and soybean yields, crop K nutrition, soil-test K, and other crop growth and management considerations (e.g., stand, vigor, disease, lodging, etc...) in future years.

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Table 1. Selected soil chemical property means of the annual K fertilizer rate test site conducted at the Pine Tree Branch Station from 2000 to 2005.

Year	Soil pH	Mehlich-3 extractable soil nutrients							
		P	Ca	Mg	Na	S	Mn	Zn	Cu
		mg kg^{-1}							
2000	6.9	15	1424	272	58	11	109	2.6	0.9
2001	7.2	6	1439	292	58	24	58	4.9	0.6
2002	7.7	15	1763	314	51	7	125	4.8	1.0
2003	7.5	15	1672	310	47	12	119	6.2	1.2
2004	7.8	19	1695	311	39	8	95	3.5	1.1
2005	7.3	17	1718	280	51	13	109	3.3	0.9
2006	7.7	23	1799	323	28	11	363	3.3	0.7

Table 2. Selected agronomic information for crops planted in long-term K fertilization study.

Year	Crop Planted	Cultivar	Drill Spacing	Plant Date
			inches	month/year
2000	Rice	Wells	7.5	May 17
2001	Soybean	Caviness	7.5	June 22
2002	Rice	Wells	7.5	April 16
2003	Soybean	Caviness	15	May 29
2004	Rice	Wells	7.5	May 11
2005	Soybean	Armor 53K3	15	May 12
2006	Rice	Wells	7.5	April 13

Table 3. Soil-test K (measured in February or March each year) as affected by annual K application rate in a multi-year study conducted at the Pine Tree Branch Station from 2001-2006.

Annual K Rate	2000 Rice	2001 Soybn	2002 Rice	2003 Soybn	2004 Rice	2005 Soybn	2006 Rice
lbs K_2O/acre	- - - - - - - - - - - mg Mehlich-3 extractable K/kg soil - - - - - - - - - - -						
0	78	80	99	103	80	68	65
30	80	83	109	104	82	69	71
60	83	85	114	107	87	72	76
90	83	85	122	121	106	88	90
120	80	92	110	114	110	86	97
LSD0.10	NS	6	11	NS	7	7	8
P-value	0.7336	0.0328	0.0289	0.2446	0.0001	0.0001	0.0001
C.V., %	9.3	8.7	11.9	15.2	9.0	10.8	11.5
Linear regression (means)†							
Slope	--	0.087*	0.117	0.13*	0.280*	0.183*	0.277*
r^2	--	0.8667	0.4394	0.6590	0.9000	0.8149	0.9692

* denotes coefficient was significant at the 0.10 probability levels.

Table 4. Rice and soybean yields as affected by annual K application rate in a multi-year study conducted at the Pine Tree Branch Station from 2000-2006.

Annual K Rate	2000 Rice	2001 Soybn	2002 Rice	2003 Soybn	2004 Rice	2005 Soybn	2006 Rice
lbs K_2O/acre	- bushels/acre -						
0	136	42	176	32	139	41	157
30	137	46	180	34	148	47	177
60	140	46	180	35	153	52	180
90	139	46	185	39	152	53	181
120	138	48	187	35	160	56	187
LSD0.10	NS	3	NS	NS	7	2	8
P-value	0.9680	0.0490	0.3297	0.4733	0.0011	0.0001	0.0001
C.V., %	5.3	6.5	5.7	20.6	5.9	6.5	5.2

† Annual K fertilizer rates were changed to 0, 40, 80, 120, and 160 lbs K_2O/acre/yr in Spring of 2006.

Table 5. Rice (whole plants at panicle differentiation stage) and soybean (whole plant or trifoliate leaves at R2 stage) tissue K concentrations as affected by annual K application rate in a multi-year study conducted at the Pine Tree Branch Station from 2000-2006.

Annual K Rate	2000 Rice	2001† Soybn	2002 Rice	2003† Soybn	2004 Rice	2005† Soybn	2006‡ Rice
lbs K_2O/acre	- -			% K			- -
0	2.36	1.50	1.79	1.07	--	1.48	1.63
30	2.65	1.47	1.98	1.25	--	1.72	2.14
60	2.90	1.53	2.10	1.33	--	1.96	2.45
90	3.00	1.69	2.46	1.62	--	1.96	2.94
120	3.14	1.62	2.54	1.69	--	2.13	3.09
LSD0.10	0.19	NS	0.21	0.16	--	0.13	0.25
P-value	0.0001	0.3828	0.0001	0.0001	--	0.0001	0.0001
C.V., %	5.2	15.6	11.3	13.9	--	8.0	12.1

† Whole aboveground soybean plants sampled in 2001 and 2003. Recently matured trifolaite leaves sampled in 2005.

‡ Annual K fertilizer rates were changed to 0, 40, 80, 120, and 160 lbs K_2O/acre/yr in spring of 2006.