EFFECT OF TILLAGE AND POTASSIUM FERTILIZATION ON SOYBEAN YIELD[1/]

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There continues to be considerable interest in P and K fertilizer placement among cash grain producers for numerous reasons. Growers have faced low commodity prices for several years and are interested in placement methods that improve the efficiency of nutrient use and potentially reduce input costs. This issue seems be more important in high residue management systems where broadcast, incorporated applications are not possible because of the need to maintain surface crop residue for conservation purposes. Wisconsin research has shown response to banded P and K for corn in conservation tillage systems, but little research has been conducted regarding fertilizer placement for soybean. It is not known what effect tillage will have on the uptake of K by soybean, and if this crop will respond like corn to localized K placement in no-till and other low-disturbance tillage systems.

Soybean has become an important crop to Wisconsin grain producers. The Wisconsin Agricultural Statistics (WDATCP, 2003) shows that over 1.5 million acres of soybean were grown in the state in the past three seasons, representing a 0.5-million acre increase over the acreage in 1998. Recent observations by many agronomists have shown situations where K deficiency has developed, especially in no-till systems. This may be an issue for soybean because the majority of the crop as is planted as “Roundup Ready” seed with minimal disturbance or no-till. Furthermore, many grain crops are grown on rented land that is typically not manured and commonly has relatively low soil test K levels.

Research is currently being conducted at the Arlington Agricultural Research Station that addresses some of the issues mentioned above. A long-term rotation x tillage x fertilizer placement study was established in 1997. This work is expected to identify sustainable K fertilization practices for Wisconsin cash grain producers. The objectives of this research are to examine the response of corn and soybean to the application of a fertilizer containing both P and K. This report summarizes the accomplishments related to the tillage/fertilizer placement study for soybean for 2002–2004.

Methods and Materials

A tillage/rotation study was established in 1997 on a Plano silt loam soil at the Arlington Agricultural Research Station. The initial soil test values were pH 6.8, and P and K of 41 and 105 ppm, respectively. The main plot treatment is rotation (continuous corn, soybean/corn, and corn/soybean). These treatments are subdivided into tillage subplot treatments (fall chisel/spring field cultivator, strip-till, and no-till). These treatments were maintained from 1997–2000 and the plots did not receive additional P and K fertilizer until the fall of 2000 when the current fertilizer treatments were installed.

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The sub-subplot treatment is fertilizer placement. A rate of 200 lb/acre of a 9-23-30 material was applied as a fall broadcast prior to primary tillage, in the row on a 2x2 placement at planting, and 6 to 8 inches deep in the strip-till treatment only. Similar fertilizer treatments were made in both corn and soybean. An untreated control was included. All treatments were replicated four times in a split-split plot treatment arrangement.

The chisel system employed a fall twisted shank coulter chisel plow, followed by a single pass with a combination field cultivator in the spring. Strip-tillage was conducted in the fall with a tool that features finger coulters, a ripple coulter, a mole knife that runs 7 to 8 inches deep, followed by closing disks that form a ridge about 4 inches high. This tool is manufactured by Remlinger Mfg. of Kalida, OH, who has loaned the tool to the University to use in tillage research and Extension programs. Strips were alternated between rows each year. The succeeding crop was planted on the ridge the next spring. A Gandy air-delivery fertilizer system was mounted on the tool to permit deep fertilizer placement. The no-till treatments receive no tillage other than the pass with a four-row Kinze corn planter equipped with a dry row fertilizer attachment and a double-disk opener for the seed unit. The same planter was used in all tillage treatments and was adjusted for changes in soil condition between treatments.

Soybean (Asgrow AG2107, zone 2.1) were planted in 21, 21, and 7 May 2002–2004, respectively in 30-inch rows to establish a population of approximately 150,000 to 175,000 plants per acre. The soybean variety has the "Round-up Ready" trait so that weed control could be performed on the plots that would be adjacent to Round-up Ready corn.

Measurements made included: (1) population; (2) surface crop residue; (3) bi-weekly dry matter accumulation; (4) soybean whole-plant K concentration for each dry matter sampling; (5) soil samples collected incrementally by depth in 2002 and from the 0- to 6-inch depth in 2004; and, (6) yield and seed K concentration. Population counts were made by counting the number of plants along a measured length of row at about 45 days after planting. Three crop residue measurements were taken shortly after planting using the line-transect method in each tillage subplot. Early-season plant samples were taken beginning at about 45 days after planting (third trifoliate) by collecting 10 plants per plot. Plants were dried, weighed, and ground for analysis. Yield was measured by harvesting the middle two rows of the four row plots with a small plot combine.

Data were analyzed with an analysis of variance for a split-split plot treatment arrangement using SAS (Statistical Analysis System, Cary, NC). Where significance was found at the p=0.05 level, a Fisher's LSD was calculated. Means for the data collected for the deep-placement treatment within the strip-till plots are shown for comparison purposes, but these were not included in the statistical analysis shown in this paper.

Results and Discussion

Table 1 shows the surface crop residue in the soybean following corn for each year of the study. Measurements were made shortly after planting. As expected the chisel treatment had significantly lower residue although at an average of 34% significant conservation benefits could be expected. The strip-till and no-till treatments were similar at about 70% surface cover. It should be indicated that the strip-till tool is not designed to work in corn residue and therefore did not move enough residue that would result in a relatively residue-free zone.

Table 1. Surface crop residue in soybean following corn as affected by tillage, Arlington, WI, 2003.

Tillage	2002	2003	2004	Average
	------------------------------- % -------------------------------			
Chisel	29	40	33	34
Strip-till	62	69	69	67
No-till	74	68	72	71
LSD	8	16	19	
Pr>F	<0.01	<0.01	<0.01	

Although the residue levels were similar between no-till and strip-till plant stand tended to be affected by tillage and fertilization (Table 2). Stands were somewhat variable between seasons. In general the highest stands were in the chisel treatment, but there was a much greater difference between strip-till and no-till compared to strip-till and chisel. Tillage only significantly affected stand in 2004. Fertilizer placement also tended to affect stand. The lowest stand each year was found where row placement was made. Even the broadcast treatment, which was made the previous fall, resulted in lower stands compared to the untreated plots. It would be hard to imagine that this was due to high salt concentrations. Fertilizer placement only significantly affected stand in 2003.

Table 2. Main effect of tillage and fertilizer treatment on the population of soybean, Arlington, WI, 2003–2004.

	Tillage*				Fertilizer			
Year	CH	ST	NT	Pr>F	None	Bdct.	2x2	Pr>F
	------ plt./acre (x 1000) -----				------- plt./acre (x 1000) ------			
2002	115	123	112	0.47	119	116	115	0.57
2003	144	139	123	0.12	144	132	125	0.01
2004	166	161	145	0.05	164	160	150	0.16

* CH=Chisel, ST=Strip-till, NT=No-till

Soil samples were collected in 2002 from the unfertilized and broadcast treatments in all tillage systems in 2-inch increment to a depth of 8 inches. The broadcast treatment was selected to avoid sampling banded situations. Samples were collected from the same fertilizer placement treatments in 2004 and were taken to a 6-inch depth as a single core across all tillage plots. Soil samples were not collected in 2003. Table 3 shows the incremental soil test results for K in 2002 and the routine analysis (pH, organic matter, P and K) in 2004. A mathematical average of the 0- to 6-inch depth (average of 0- to 2-, 2- to 4-, 4- to 6-inch increments) for the soil test K from the 2002 sampling is shown for comparison purposes. Soil test P is in the excessively high range for this soil and pH is well above the level considered optimum for soybean production in Wisconsin (6.3). These data show that overall the soil test K for the 2004 sampling is higher than that for the 2002 sampling. The reason for this observation is not readily apparent, since samples were collected in the early summer in both years. The addition of 200 lb 9-23-30/acre appears to exceed crop removal and has resulted in an increase in both soil test P and K. While tillage did not significantly affect soil test K in the 2004 sampling, there appears to be a trend for lower values in the high residue systems.

Table 3. Effect of tillage and fertilization on the soil test at, Arlington, WI, 2002 and 2004.*

	No fertilizer				Bdct. fertilizer		
	CH	ST	NT		CH	ST	NT
2002 Incremental sampling							
Depth (inch)	Soil test K (ppm)						
0 - 2	114	101	104		161	160	142
2 - 4	80	68	70		106	93	68
4 - 6	65	59	64		77	72	62
6 - 8	59	54	60		75	68	59
Avg. (0-6 in.)	86	76	79		115	108	91
Pr>F	0 – 2	2 – 4	4 – 6	6 – 8			
Tillage	0.20	<0.01	0.07	0.27			
Fertilizer	<0.01	<0.01	0.03	0.03			
T x F	0.64	0.07	0.14	0.20			
2004 Sampling (0–6 inch)							
P (ppm)	54	50	39		68	73	50
K (ppm)	113	92	93		134	133	116
pH	6.7	6.7	6.6		6.8	6.6	6.6
OM (%)	3.8	3.9	3.8		3.5	4.0	3.8
Pr>F	P	K	pH	Organic matter			
Tillage	0.17	0.27	0.69	0.17			
Fertilizer	<0.01	<0.01	0.74	0.21			
T x F	0.49	0.31	0.16	0.20			

* Fertilizer rate = 18+46+60 lb N+P_2O_5+K_2O/acre. CH=Chisel, ST=Strip-till, NT=No-till.

Table 4 shows the main effects of tillage and fertilization on the dry matter accumulation of soybean on 23 June, 7 July, 24 July, 21 August, and 10 September 2003. These sampling dates represent sampling on 33, 47, 64, 92, and 112 days after planting. A sampling was conducted on 6 August; however the samples were mistakenly ground for analyses prior weighing. The last sampling was conducted just as the crop was senescing, and therefore some dry matter may have been lost by leaf drop. Soybean growth in 2003 got off to a good start, but was substantially reduced by droughty conditions in August. Soybean yields throughout most of Wisconsin were lower because the drought caused many pods to abort or fill with fewer small seeds. These data show consistently significant differences related to tillage throughout the season until senescence. The dry matter produced in the chisel treatment remained higher than both the strip-till and no-till treatments until this time when the soybean growth in these treatments caught up to that of the chisel. There was also a response to fertilization such that the row fertilizer treated plots tended to have the higher dry matter content early in the growing season. As the season continued the broad cast treatment had greater dry matter accumulation. This difference was only significant at the p=0.05 level at the final sampling.

Table 4. Main effect of tillage and fertilizer placement on the dry matter content of soybean, Arlington, WI, 2003.*

Treatment	6/23/03	7/7/03	7/24/03	8/21/03	9/10/03
	------------------------------ lb/acre ------------------------------				
Tillage					
Chisel	495	1112	3271	6249	7412
Strip-till	301	678	2544	5433	7530
No-till	307	711	2628	5154	7396
LSD	55	72	563	856	NS%
Fertilizer					
None	346	820	2711	5148	6709
Bdct.	368	798	2818	5982	8201
Row	389	883	2914	5706	7428
Deep **	390	890	2395	4990	6602
LSD	30	NS	NS	NS	1081
Pr>F					
Tillage	<0.01	<0.01	0.04	0.05	0.96
Fertilizer	0.02	0.26	0.46	0.06	0.03
T*F	0.11	0.22	0.71	0.43	0.56

* Fertilizer rate=18+46+60 lb N+P_2O_5+K_2O/acre.
** Deep-placement data not included in the ANOVA.
% NS, not significant.

Table 5. Main effect of tillage and fertilizer placement on the K concentration of soybean, Arlington, WI, 2003. *

Treatment	6/23/03	7/7/03	7/24/03	8/21/03	9/10/03	Seed
	------------------------------------- % ---					
Tillage						
Chisel	2.07	1.95	1.78	1.49	1.22	1.72
Strip-till	1.87	1.78	1.62	1.39	1.11	1.65
No-till	1.81	1.95	1.61	1.45	1.23	1.66
LSD	NS%	NS	NS	NS	NS	NS
Fertilizer						
None	1.52	1.42	1.28	1.12	0.85	1.61
Bdct.	2.12	2.11	1.92	1.60	1.37	1.72
Row	2.11	2.15	1.84	1.61	1.34	1.70
Deep **	2.36	2.09	1.81	1.48	1.23	1.68
LSD	0.20	0.23	0.37	0.23	0.20	0.05
Pr>F						
Tillage	0.12	0.39	0.56	0.86	0.47	0.12
Fertilizer	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
T*F	0.44	0.09	0.42	0.61	0.46	0.91

* Fertilizer rate=18+46+60 lb $N+P_2O_5+K_2O$/acre.
** Deep-placement data not included in the ANOVA.
% NS, not significant.

Table 5 shows the grain and whole-plant K concentration for the sampling dates in 2003. Tillage did not significantly affect either the grain or whole-plant K concentration at any sampling time. Where the Pr>F level was relatively small (first whole-plant sampling and grain), the K concentration tended to be higher in the chisel. Fertilization significantly affected the K concentration in the grain and at all sampling times. In all cases there was no difference between broadcast and the 2x2 placement. The unfertilized treatment was lower than either placement. The whole-plant samples for the unfertilized treatments had K concentrations that were about 30% lower than the fertilized treatments, yet the difference in the grain was less than 10%. In general, the interaction between tillage and fertilization was not significant for either dry matter or tissue K concentration.

Figure 1 shows the K uptake for the whole-plant samples separated by tillage treatment. The K uptake value is the product of the dry matter yield and tissue K concentration. The K uptake was greater in 2004 compared to 2003 due to greater dry matter production. In general, the uptake curves were similar for the broadcast and 2x2 treatments. Where there were differences, usually the 2x2 was lower than the broad cast treatment.

Table 6 shows the effect of tillage and fertilization on soybean yield. Overall yield was substantially reduced in 2003 because of the dry conditions that occurred late in the growing season. Historically yield levels in this experiment have been in the 50–60 bu/acre range. Tillage significantly affected yield in 2004 such that the chisel system produced a higher yield than the no-till treatment. A 2-bu/acre difference in favor of the chisel system was noted when averaged for the 3 years of the study. Possible explanations for this difference include the somewhat lower population, lower soil test K, and slower growth found in no-till. Fertilization did not significantly affect yield in any year, however there was a trend for higher yield with the broadcast treatment in 2003, and either the broadcast or 2x2 placements in 2004. A 2-bu/acre response to fertilization was measured when averaged over the 3 years of the study. Either method of application appeared to be appropriate. A significant interaction between tillage and fertiliza-tion was observed in 2004 that showed a greater responsiveness to the 2x2 placement in both the strip-till and no-till relative to the chisel treatment.

Table 6. Main effect of tillage and fertilizer placement on the yield of soybean, Arlington, WI, 2002–2004.*

Placement	2002	2003	2004	Average
	------------------------------- bu/acre -------------------------------			
Tillage				
Chisel	51	32	57	47
Strip-till	50	31	54	45
No-till	49	32	53	45
LSD	NS%	NS	3	
Fertilizer placement				
None	49	31	53	44
Bdct.				
Row	51	31	56	46
Deep**	53	31	50	45
LSD	NS	NS	NS	
Pr>F				
Tillage	0.88	0.90	0.04	
Fertilizer	0.49	0.07	0.06	
T x F	0.46	0.12	0.02	

* Fertilizer rate = 18+46+60 lb $N+P_2O_5+K_2O$/acre.

** Deep-placement data not included in the ANOVA.

% NS, not significant.

Summary

A 3-year study evaluating the response of soybean following corn to tillage and fertilization was conducted at the Arlington Agricultural Research Station from 2002–2004. Crop residue levels were adequate for conservation purposes in all tillage systems. Population and early season dry matter accumulation were greater in the chisel system. Dry matter production appeared to "catch-up" in the strip-till and no-till treatments. Fertilization tended to reduce stand and showed a trend of increasing dry matter early in the growing season. Fertilization substantially increased whole-plant K concentration during the season; however, the difference between the unfertilized and fertilized treatments was relatively small in the grain. Grain yield was significantly affected by tillage and fertilizer treatment in one year. When averaged over three seasons, grain yields were two bu/a higher in the chisel system compared to strip-till and no-till, and were 2 bu/acre higher compared to the unfertilized treatment, where fertilization was made either as broadcast or 2x2.

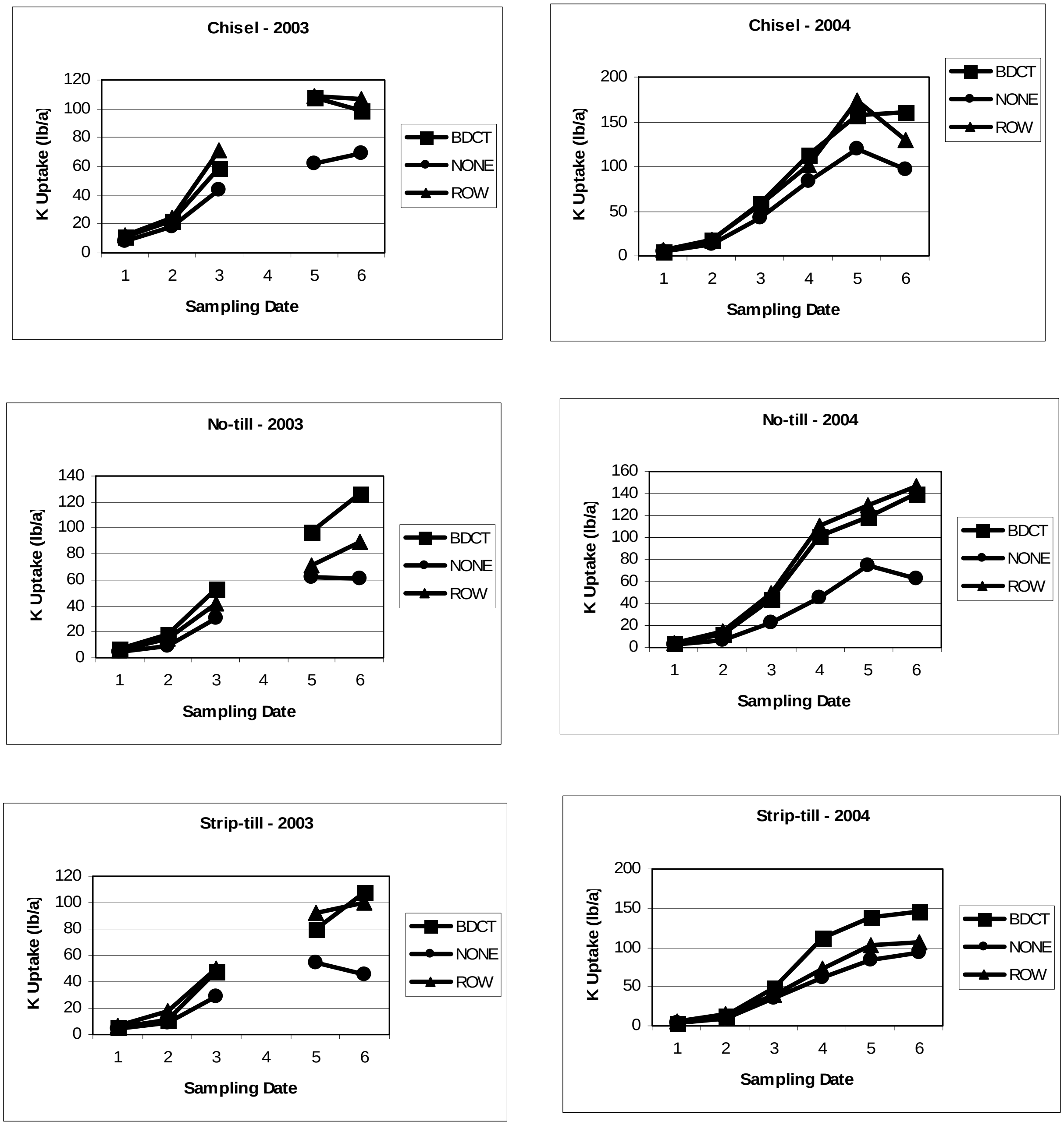

Figure 1. Whole-plant K uptake by soybean for three tillage systems, Arlington, WI, 2003 and 2004.