WISCONSIN CORN AND SOYBEAN RESPONSES TO FERTILIZER PLACEMENT IN CONSERVATION TILLAGE SYSTEMS [1/]

Richard P. Wolkowski [2/]

There continues to be considerable interest in P and K fertilizer placement among cash grain producers for several reasons. Growers have faced low commodity prices for several years and are interested in certain placement methods that may enhance the efficiency of nutrient use and therefore reduce their input costs. This issue seems be more important in high residue management systems where broadcast, incorporated applications are not possible because there is the need to maintain surface crop residue for conservation purposes. Wisconsin research has shown response to banded P and K in conservation tillage systems. Moncrief (1981) demonstrated a beneficial response to row-placed fertilizer in no-till and ridge-till systems. Bundy and Widen, 1992 demonstrated the importance of using a complete row fertilizer. Recent research conducted by this author demonstrated a response to both fall- and spring-applied banded fertilizer in high residue systems, but not in a chisel system (Wolkowski, 2000). It seems likely that the soil and environmental condition of the seedbed under no-till increase the potential for response to localized P and K placement.

While it has been understood that P availability is lower under cool, wet spring conditions, the need for K has also been identified. Bundy and Andraski, 1999 found that the probability of response to row-placed fertilizer increased when the soil test K was below 140 ppm. This may be due to several reasons, including compaction, omission of broadcast treatments, and failure to replace all the K removed by previous crops. Furthermore, some producers that have stopped the use of row fertilizer altogether because of time and logistical issues at planting. Also a number of growers use liquid starter fertilizers that have a relatively low K analysis.

Strip-tillage is gaining popularity in some regions of the state. Several dealerships now offer custom strip-tillage service that can be accompanied by the deep placement of fertilizer in the future row area. It has been suggested that fall application may eliminate the need for row fertilizer in the spring and avoid the delays that are associated with spring fertilizer application with the planter. Strip-tillage also loosens the seedbed and should overcome some of the common problems associated with no-till planting such as imperfect planter slot closure, hair-pinning of residue, and compaction by the planter unit that limits early plant growth. The suggestion has been made that deep placement may offset concerns with nutrient stratification in no-till. Strip-tillage usually buries slightly more residue than no-till and offers a reasonable compromise to full-width tillage.

Research is currently being conducted at the Arlington Agricultural Research Station that addresses some of the issues mentioned above. This work is expected to identify sustainable P and 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. Treatments are made in both a continuous corn and corn/soybean rotation using three tillage systems. This paper will summarize the research results obtained in 2001 and 2002.

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[2/] Extension Soil Scientist, Dept. of Soil Science, Univ. of Wisconsin-Madison.

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.

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. The rate of P and K approximates the UWEX recommendation for 175 bu/acre of corn. Similar fertilizer treatments were made in both corn and soybean. An untreated control was included. All treatments are 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 of 2000 and 2001 with a tool that features finger coulters, a ripple coulter, a mole knife that runs 7-8 in. deep, followed by closing disks that form a ridge about four in. high. 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. A planter equipped with finger coulters was used in the fall from 1997-2000 for this tillage treatment. 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.

A full season corn hybrid (RM 105 days) or soybean (zone 2.1) were planted in early May in 30” rows. The corn hybrid and soybean variety had the “Round-up Ready” trait so that weed control could be performed on the side-by-side plots. UWEX recommendations were followed for all non-treatment crop inputs including pest management and supplemental N application (160 and 190 lb N/a in chisel; and strip-till and not-till treatments).

Measurements made include (1) emergence; (2) surface crop residue; (3) early growth; (4) incremental plowlayer soil test; and, (5) yield. Emergence counts were made by counting the number of plants visible along a measured row length for several days. A final plant count was taken 45 days after planting. Three crop residue measurements were taken using the line-transect method in the tillage subplot and were averaged. Early season plant samples were taken 45 days after planting (approximately the V6 growth stage in corn and the third trifoliate in soybean) by collecting ten plants per plot. Plants were dried, weighed, and ground for analysis. Incremental soil samples were taken at this time also by collecting six cores to eight in. from the unfertilized and broadcast fertilizer sub-subplot. Cores were then dissected into four-two in. segments. Yield was measured by harvesting the middle two rows of the four row plots with a small plot combine.

Data were analyzed with a 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.

Results and Discussion

The study location used for this research had been maintained in the previously described rotation and tillage treatment since 1997. The surface crop residue levels for 2001 are shown in Table 1. These data show the cumulative effects of management for the previous four seasons. These data show that rotation did not affect residue cover when corn was the previous crop, but as expected residue was lower if soybean was the previous crop. The reduction in surface cover following soybean was less in the strip- and no-till treatments compared to chisel.

Table 1. Surface crop residue as affected by crop rotation and tillage, Arlington, Wis., 2001.

Tillage	CC†	SbC	Csb
	------------------------ % ----------------------		
Chisel	36	17	34
Strip-till	66	57	65
No-till	86	76	82
Pr>F			
Rotation (R)	<0.01		
Tillage (T)	<0.01		
R*T	0.08		

†CC=Continuous corn; SbC=Corn after soybean; CSb=Soybean after corn.

The variation in residue caused by the rotation and tillage treatments had a minimal effect on the final plant stand for both crops as shown in Table 2. These data show that the only significant effect resulting from either factor was an increase in corn population with either strip- or no-till compared to chisel in 2001. Row fertilizer reduced stand in that year compared to the unfertilized treatment. Corn populations were not affected in 2002 by any treatment. Soybean stands were more variable and tended to be higher in the strip-till treatments, although the differences were not statistically significant. The higher stand associated with the deep placement in soybean in 2001 appears anomalous. The 2x2 placement was not used in soybean in 2001.

Emergence (data not shown) and early growth and nutrient uptake were affected by most of the treatment variables. Table 3 shows the dry matter accumulation and P and K uptake 45 days after planting when the tallest corn was at the V6 growth stage. The corn was significantly taller and had accumulated more P in the corn following soybean compared to the continuous corn. Rotation did not affect K uptake, although the value was approximately 5% greater in the corn following soybean. Potassium uptake was significantly lower in the no-till compared to either the strip-till or chisel treatments. This response confirms the relationship between K uptake and no-till and may help explain the importance of K containing row fertilizer for conservation tillage systems. The 2x2 placement was most effective for increasing early dry matter production and P uptake. This placement also resulted in the highest amount of K in the plant, with the broadcast and deep placements intermediate to the unfertilized treatment.

Table 2. Main effects of rotation, tillage, and fertilizer placement on the population of corn and soybean 45 days after planting, Arlington, Wis. 2001-2002.

Effect	Corn 2001	Corn 2002	Soybean 2001	Soybean 2002
	------------------ plants/acre (x1000) -------------------			
Rotation †				
CC	29.3	31.2	--	--
SbC	30.2	31.9	--	--
Significance	NS	NS		
Tillage				
Chisel	28.7	31.7	116.0	114.8
Strip-till	30.2	31.5	120.5	120.9
No-till	30.3	31.4	110.2	112.2
LSD	1.1	NS	NS	NS
Fertilizer ‡				
None	30.5	31.8	114.6	118.8
Broadcast	30.1	31.3	112.5	116.4
Row	29.0	31.5	--	114.7
Deep	29.0	31.1	132.5	115.1
LSD	1.4	NS	12.1	NS
Pr > F				
Rotation (R)	0.08	0.12	--	--
Tillage (T)	0.03	0.87	0.38	0.54
R*T	0.91	0.84	--	--
Fertilizer (F)	0.03	0.65	0.02	0.72
R*F	0.08	0.81	--	--
T*F	0.20	0.49	0.99	0.05
R*T*F	0.66	0.71	--	--

† CC=Continuous corn; SbC=Corn after soybean.

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

Emergence (data not shown) and early growth and nutrient uptake were affected by most of the treatment variables. Table 3 shows the dry matter accumulation and P and K uptake 45 days after planting when the tallest corn was at the V6 growth stage. The corn was significantly taller and had accumulated more P in the corn following soybean compared to the continuous corn. Rotation did not affect K uptake, although the value was approximately 5% greater in the corn following soybean. Potassium uptake was significantly lower in the no-till compared to either the strip-till or chisel treatments. This response confirms the relationship between K uptake and no-till and may help explain the importance of K containing row fertilizer for conservation tillage systems. The 2x2 placement was most effective for increasing early dry matter production and P uptake. This placement also resulted in the highest amount of K in the plant, with the broadcast and deep placements intermediate to the unfertilized treatment.

Table 3. Main effects of rotation, tillage, and fertilizer placement on the dry matter accumulation and P and K uptake of corn 45 days after planting, Arlington, Wis. 2001.

Effect	Dry matter	P uptake	K uptake
	g/plant	mg/plant	mg/plant
Rotation			
CC	7.6	35	189
SbC	9.7	45	202
Significance	**	**	NS†
Tillage			
Chisel	9.1	39	214
Strip-till	8.8	43	208
No-till	7.9	36	159
LSD	NS	NS	26
Fertilizer ‡			
None	8.0	37	146
Broadcast	8.2	37	181
Row	10.1	46	261
Deep	7.9	38	189
LSD	0.8	4	38
Pr > F			
Rotation (R)	0.02	0.03	0.56
Tillage (T)	0.26	0.13	0.04
R*T	0.10	0.40	0.41
Fertilizer (F)	<0.01	<0.01	<0.01
F*R	0.83	0.85	0.21
T*F	0.19	0.06	0.26
R*T*F	0.14	0.36	0.21

** Significant at 0.01 probability level.

† NS, not significant.

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

One concern associated with reduced tillage systems is the stratification of nutrients. Soil samples were collected in 2-inch increments to 8 inches in 2002 from the unfertilized and broadcast treatments in all rotation and tillage combinations. The broadcast treatments had been made for the previous two seasons and it was the sixth season for the rotation and tillage treatments. Table 4 shows the results for soil test P and K for the 2002 incremental sampling. Rotation and tillage did not consistently affect soil test P or K except for the 0- to 2-inch layer where P tended to be lower and K higher under continuous corn. Fertilization significantly affected both soil test levels in the upper 4 inches. The more interesting responses were the consistent interactions between rotation and tillage (especially P) and between fertilizer and rotation for both nutrients.

Table 4. Effect of rotation, tillage, and fertilizer placement on the incre-mental soil test P and K, Arlington, Wis. 2002. †

Rotation/ tillage ‡	Fert.	Phosphorus 0-2”	2-4”	4-6”	6-8”	Potassium 0-2”	2-4”	4-6”	6-8”
		ppm							
CC									
Chisel	–	49	46	34	26	133	94	75	67
	+	52	37	26	19	153	96	68	63
Strip-till	–	50	42	43	30	155	104	84	87
	+	72	47	38	28	166	97	77	74
No-till	–	53	60	49	30	136	101	83	75
	+	67	45	37	26	149	93	74	72
CSb									
Chisel	–	50	45	42	26	114	80	65	59
	+	75	64	56	40	161	106	76	75
Strip-till	–	54	51	48	38	101	68	59	54
	+	84	64	66	52	160	93	72	68
No-till	–	43	40	39	29	104	70	64	60
	+	69	39	34	24	142	68	62	59
SbC									
Chisel	–	46	44	43	27	113	87	68	59
	+	65	47	42	25	146	105	81	70
Strip-till	–	41	38	38	24	101	75	69	70
	+	82	53	46	30	166	88	74	68
No-till	–	42	49	47	28	120	80	71	65
	+	79	60	56	40	178	101	81	75
Pr > F									
Rotation (R)		0.02	0.74	0.24	0.28	0.06	0.13	0.21	0.41
Tillage (T)		0.60	0.79	0.17	0.10	0.79	0.07	0.99	0.32
R*T		0.19	<0.01	<0.01	0.05	0.24	0.09	0.25	0.06
Fertilizer (F)		<0.01	0.11	0.36	0.18	<0.01	<0.01	0.22	0.23
F*R		<0.01	0.02	0.02	0.15	0.03	0.02	0.03	0.04
T*F		0.04	0.16	0.30	0.34	0.71	0.33	0.64	0.38
R*T*F		0.72	0.47	0.33	0.33	0.76	0.43	0.79	0.43

† Initial incremental soil test (1997): 47, 42, 40, 32; and, 151, 103, 88, 78 for the 0-2, 2-4, 4-6,

and 6-8 inch depths for P and K, respectively. Fertilizer rate = 18 + 46 + 60 lb N+P_2O_5+K_2O/ acre broadcast the fall of 2000 and 2001.

‡ CC = Continuous corn; SbC = Corn after soybean; Csb = Soybean after corn.

The response of corn to rotation, tillage, and fertilizer placement is shown in Table 5. Corn yield was greater in corn following soybean, although the response in 2002 was significant at the 10% level. The interaction between rotation and tillage was highly significant in 2001 where similar yields were obtained in the chisel, but much higher yields were observed in the strip-till and no-till. The main effect response to fertilizer was relatively equal between the broadcast and 2x2. A significant interaction was noted between tillage and fertilizer placement in 2002.

Table 5. Effect of rotation, tillage, and fertilizer placement on corn yield, Arlington, Wis., 2001-2002. †

Fertilizer placement	CC‡ Chisel	CC‡ Strip-till	CC‡ No-till	SbC Chisel	SbC Strip-till	SbC No-till
	bu/acre					
			2001			
None	184	181	147	188	199	185
Broadcast	195	182	148	195	210	196
2 x 2	187	182	157	193	204	201
Deep	—	179	—	—	207	—
Pr > F						
Rotation (R)	0.04					
Fertilizer (F)	0.04					
Tillage (T)	0.13					
R*F	0.79					
T*F	1.00					
R*T	<0.01					
R*T*F	0.88					
			2002			
None	172	172	157	213	192	178
Broadcast	175	173	181	203	218	219
2 x 2	197	179	183	212	206	201
Deep	—	169	—	—	217	—
Pr > F						
Rotation (R)	0.08					
Fertilizer (F)	<0.01					
Tillage (T)	0.40					
R*F	0.07					
T*F	0.02					
R*T	0.43					
R*T*F	0.60					

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

‡ CC = Continuous corn; SbC = Corn after soybean.

The effect of tillage and fertilization on soybean yield for the 2 years of the study is shown in Table 6. Soybean yield was significantly affected by both tillage and fertilization in 2001. Yields were lower in no-till compared to strip-till and chisel and a modest response to broadcast fertilizer was observed in that year. The row fertilizer treatment was not employed in the soybean in 2001. Soybean yield was not affected by treatment in 2002. It is interesting to note that in both years the lowest yield was found in the unfertilized no-till treatment.

Table 6. Effect of tillage and fertilizer placement on soybean yield, Arlington, Wis., 2001-2002. †

Fertilizer	2001			2002		
placement	Chisel	Strip	No-till	Chisel	Strip	No-till
	---------------------------- bu/acre---------------------------------					
None	55	57	50	52	50	45
Broadcast	58	60	56	51	50	50
Row	—	—	—	50	52	52
Deep	—	61	—	—	53	—
Pr > F						
Tillage (T)	0.05			0.87		
Fertilizer (F)	<0.01			0.49		
T*F	1.00			0.45		

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

References

Bundy, L.G., and T. A. Andraski. 1999. Site-specific factors affecting corn response to starter fertilizer. J. Prod. Agric. 12:664-670.

Bundy, L.G., and P. Widen. 1992. Crop response to starter fertilizer: Planting date and tillage effects. Better Crops with Plant Food. Potash and Phosphate Inst. Atlanta, GA.

Moncrief, J.F. 1981. The effect of tillage on soil physical properties and the availability of nitrogen, phosphorus, and potassium to corn (*Zea mays* L.). Ph.D. thesis, Univ. of Wisconsin-Madison.

Wolkowski, R.P. 2000. Row-placed fertilizer for maize grown with an in-row crop residue management system in southern Wisconsin. Soil Tillage Res. 54:55-62.