ROTATING CONSERVATION TILLAGE SYSTEMS: EFFECTS ON CORN AND SOYBEAN PRODUCTIVITY

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INTRODUCTION

Many Kentucky corn and soybean producers have become concerned with improving crop productivity on marginal and sometimes steeply sloping landforms to increase their income. Net income is increased by conservation tillage systems which reduce time and energy requirements, both in terms of labor and fuel consumption (Frye, 1985). Conservation tillage systems leave adequate crop residues to intercept rainfall and also minimize evaporation. This increases soil moisture and reduces soil and agricultural chemical losses to erosion (Seta et al., 1993).

Conservation tillage systems are defined according to the amount of remaining surface residues and the extent of soil mixing. They include no-tillage, chisel, disk, stubble mulch, and rotary tillage (Hayes, 1982a). No tillage has very little or no mechanical mixing of residues or added amendments on the soil surface compared to the other conservation tillage systems. This lack of mixing may cause vertical stratification of immobile nutrients such as P and K. Concerns regard nutrient stratification being coincident with stratification of soil acidity and the possibility for limited nutrient availability in dry years. The latter problem seems most likely when surface residue levels are reduced (Grove, 1986).

Blevins et al. (1986) showed that the upper three inches of no-tillage soil contained twice as much extractable K as that found in the 6-12 inch depth and positively contributed to corn K uptake. Research from the Northern U.S.. however, has shown lower corn uptake of P and K under no-tillage (Randall, 1980; Moncrief et al., 1979). Reasons for reduced uptake were attributed to the colder soil temperatures, reduced diffusion, and lower soil aeration imposed by increased soil density and poor drainage. Tollner et al. (1984) showed that increased soil density also inhibited subsurface root proliferation, hence reducing nutrient uptake. Soil strength and bulk density under no-tillage and conventional tillage systems were not high enough to have an inhibitory effect on plant root growth (Hill et al., 1985).

A summary of yield research data from conservation tillage systems by Hayes (1982) concluded that on soils with little or no slope, there was very little difference between corn yields following moldboard plowing or conservation tillage. One exception was that no-tillage yields were significantly lower on poorly drained soils. No-tillage outyielded conventional tillage where there was considerable slope. For soybean, conventional and other conservation tillage systems yielded higher then no-tillage. Reduced no-tillage soybean yields were associated with lower plant populations and increased weed competition.

Winter cover crops have been used to contribute to nutrient recovery by summer annual crops, especially the legumes for nitrogen (Frye and Blevins. 1989). Potassium is also likely cycled by these winter annual species as it can be taken up by plants in large amounts and does not require mineralization from organic compounds when covers are killed. Eckert (1991) reported that addition of rye cover increased exchangeable potassium on the soil surface. The greater surface residue associated with conservation tillage systems increases organic matter, which has a reduced preference for monovalent cations like K (Grove, 19831.

With the increased surface soil strength and greater nutrient stratification in no-tillage soils, there is interest in determining whether no-till should be rotated with other forms of tillage to provide some mixing and aeration. A study was initiated to evaluate the effect of rotating two conservation tillage systems on corn and soybean yields at different K fertility levels with different winter cover management options.

MATERIALS AND METHODS

Two adjacent areas were subjected to the same treatment protocol on a well drained Loradale silt loam soil (fine silty, mixed, mesic

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Typic Argiudoll) at the Kentucky Agriculture Experiment Station Farm near Lexington, KY. One area was cropped to corn following rye as the winter annual cover and the other area to soybean following wheat. The two crop species and cover crops were reversed over the two areas to give a corn/soybean rotation following rye and wheat, respectively.

The experiment for each area was a split plot laidout in randomized blocks. There was a main plot factorial (2 x 2 x 3) consisting of two types of tillage for current year (no-till vs. chisel plow plus light disk), two types of tillage for the past year (no-till vs chisel plus light disk), and three types of winter annual cover crop management (previous crop fallow vs. cover removed at planting vs. cover killed and left at planting). The combination of past and present tillage results in four tillage rotation treatments: continuous no-tillage, chisel following no-tillage, no-tillage following chisel, and continuous chisel. Sub-plot treatments were fertilizer K rates of 0, 45, 90, and 135 lbs K_2O A^{-1}. Two replications of the randomized block design made a total of 96 plots per area and 192 plots for the two cropping areas in the rotation. Sub-plot size was 12 ft wide by 30 ft long.

Aroostock rye and Verne wheat were planted in mid-October of each year at a 7 inch row spacing at 115 lbs seed A^{-1} using a Lilliston 9680 No-Till drill. Covers were killed in certain plots at the end of March the following year, prior to significant growth, with Gramoxone herbicide to create the fallow no-cover treatment. Cover crops were harvested on the cover removed treatment in mid-April and tillage treatments were performed shortly thereafter. The chisel plow was followed by disking two times. Gramoxone herbicide was again sprayed over the entire area to kill all remaining cover just prior to planting.

Pioneer 3295 corn was planted at the end of April at 23,100 seed A^{-1} using a no-till corn planter set at a 36 inch row spacing. Herbicides for weed control were sprayed at planting. All K treatments and 50 lbs N A^{-1} as NH_4NO_3 were broadcast applied during the first week of May. Shield spraying was for escaped weeds. Another 150 lbs N/A as NH_4NO_3 was applied at the end of May. Sevin insecticide was sprayed for Japanese beetle control in early July. Earleaf samples were taken from each plot at complete silking for analysis. Corn ears were hand harvested the last week of September or in early October from 20 ft sections of the center two rows. Plant counts were taken and the harvested ear weight measured. Five harvested ears were randomly selected, dried, weighed, shelled, and reweighed to determine dry weight, moisture content, shelling fraction and these parameters used in the calculation of grain yield. Yields of corn were expressed at 15.5% moisture. Grain samples were taken for analysis.

Pioneer 9442 (1992) and 9461 (1993) soybean seed were treated with inoculum and planted in late May or early June at 7 seed ft^{-1} in 21 inch rows using the Lilliston 9680 No-Till drill. Weed and insect control measures were implemented according to University of Kentucky recommendations. Leaf tissue samples were taken at growth stage R5 for analysis. The two center rows of each 6 row plot were harvested in early October using a Hege 1258 combine. Soybean grain was dried, weighed, and sampled for analysis. Grain yields are reported at 13.5% moisture.

All grain and tissue samples were analyzed for N, P, and K using wet digestion and atomic absorption spectrocopy for K and micro-Kjeldahl digestion and automated colorimetry for N and P. Results were used to determine plant composition and grain nutrient removal.

Ammonium acetate extractable K was determined on 10 composite soil samples per plot at depths of 0-3, 3-6, 6-9. and 9-12 inches. Samples were taken to include both in- and between- row areas. Soil resistance was measured with a penetrometer at the same depths from which soil was sampled, but also including the surface layer which was also measured from the tip to the top of the penetrometer's cone. Measurements were made at 4 different positions going away from the row in wheel tracked and un-wheel tracked areas within a tillage plot. All data were analyzed using ANOVA in SAS.

RESULTS AND DISCUSSION

Cover crop dry matter production and grain yields were higher in 1992 than 1993 (Table 1). This could be attributed to the higher precipitation during the 1992 growing season (Figure 1). In 1992, K fertility rates did not have

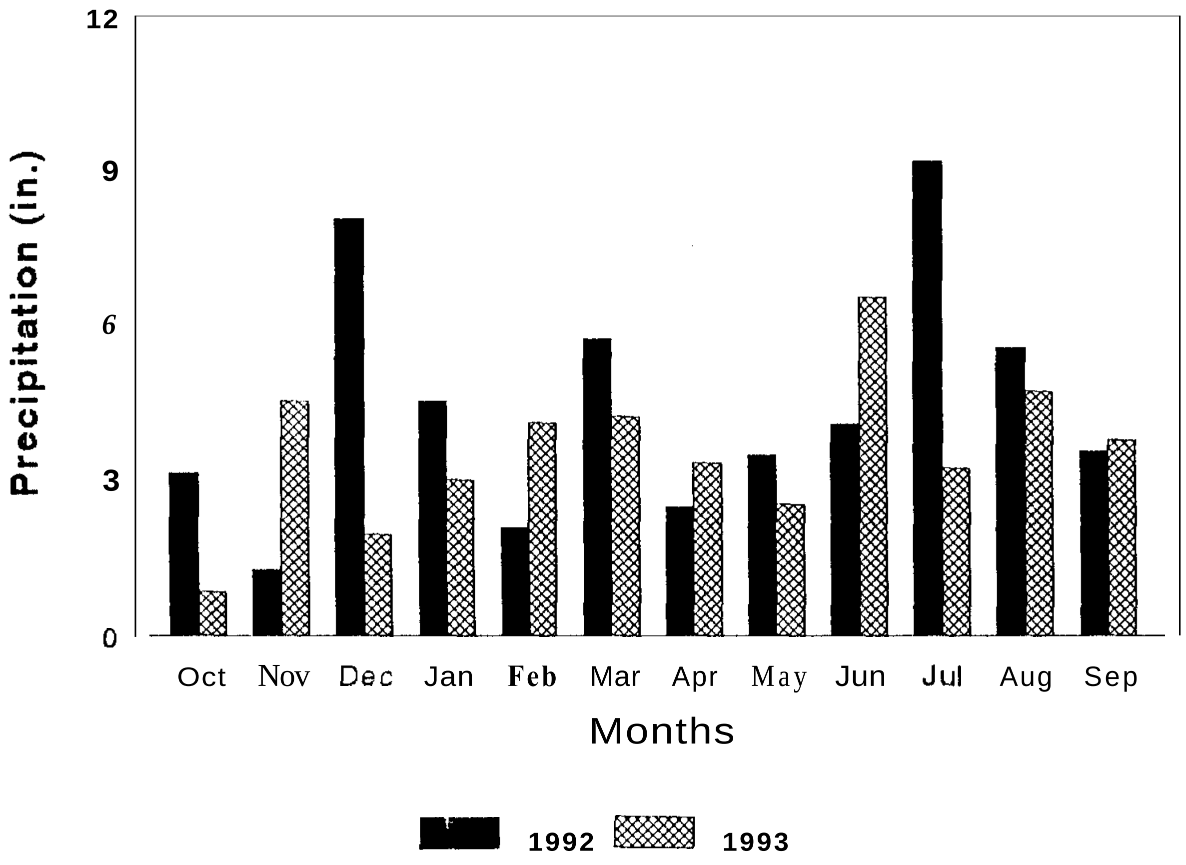

Figure 1. Average monthly precipitation.

a significant effect on rye or wheat dry matter production or on soybean grain yield. However, corn grain yield did increase significantly with increasing K fertility rates (Table 2). In 1993, both corn and soybean yields responded positively to K fertility (Table 3). Cover crop dry matter production did not respond to K fertility in 1993 (Table 3).

Table 1. Average cover crop dry matter production and corn and soybean grain yields.

	CROP			
Year	Rye	Wheat	Corn	Soybean
	(lbs/A)		(bu/A)	
1992	2931	4658	185	70.7
1993	1189	3106	156	50.0

Treatments where winter cover was grown (whether cover was left or removed) produced significantly less corn grain than where the area was winter fallowed (Table 2). Lower corn yields could be attributed in part to removal of nutrients in the cover removed treatment and in part to a reduced plant density from a difficult planting operation where the rye cover was left behind. Cover treatments did not have a significant impact on soybean yield in 1992 (Table In). In 1993, both the fallow and cover left treatments contributed to significantly higher corn and soybean yields than the cover removed treatment (Table 3).

Present and past tillage did not have a significant effect on rye or wheat dry matter production or on corn soybean grain yield in 1992 (Table 2). This may be due to the exceptional growing season, where precipitation was higher than normal and largely off set any tillage effects of water availability. Past chisel

Table 2. Management effects on cover crop dry matter production and corn and soybean grain yields, 1992.

Management	CROP			
	Rye	Wheat	Corn	Soybean
	(lbs/A)		(bu/A)	
Fertilizer (lbs K/A)				
0	3007a	5336a	174a	68.5a
45	2815a	5174a	183a	69.9a
90	2800a	3638a	198ab	71.8a
135	3102a	4489a	193b	72.7a
Cover				
Fallow	--	--	197a	71.1a
Removed	--	--	177b	70.1a
Left	--	--	180b	71.0a
Past Tillaae				
No Till	2882a	4687a	187a	70.5a
Chisel	2981a	4550a	183a	71.Oa
Present Tillaae				
No Till	3017a	5083a	184a	71.Oa
Chisel	2845a	4234a	183a	70.4a

Means in a column followed by the same letter are not significantly different at the 95% level of confidence.

Table 3. Management effect on cover crop dry matter production and corn and soybean grain yields, 1993.

Management	CROP			
	Rye	Wheat	Corn	Soybean
	(lbs/A)		(bu/A)	
Fertilizer (lbs K/A)				
0	1067a	3098a	146a	45.9a
45	1267a	3293a	157b	49.7b
90	1167a	2921a	157b	52.0b
135	1253a	311l a	161b	52.2b
Cover				
Fallow	--	--	158a	52.6a
Removed	--	--	148b	46.0b
Left	--	--	161a	51.2a
Past Tillage				
No Till	1131a	2882a	153a	50.4a
Chisel	1247a	3329b	158a	49.3a
Present Tillaae				
No Till	1434a	3503a	159a	50.6a
Chisel	944b	2709b	152a	49.3a

Means in a column followed by the same letter are not significantly different at the 95% level of confidence.

and disk produced significantly higher wheat dry matter than no-tillage in 1993. Corn and soybean yields, and rye dry matter production, were not significantly affected by past tillage (Table 3). Present tillage had no effect on corn or soybean yields on this soil in 1993 (Table 3). even though this was a drier season than that observed in 1992. Cover treatments had no significant effect on soil resistance (Table 4). Present year tillage treatments showed significantly different soil strengths as indicated by the penetrometer resistance measurements. No-till soil strength was consistently higher than that under the chisel system. This effect was demonstrated from the surface to a six inch depth in the wheel-track and to 9 inches where not wheel-tracked. Below these depths, there was no difference between the two tillage systems. Continuous no-tillage tended to have the highest soil strength of the tillage rotation systems, while continuous chisel tended to have the lowest. Despite lower compaction where previously no-till plots were

Table 4. Soil resistance as measured bv the cone oenetrometer, 1992.

	Soil Depth (inches)							
Manasement	0-3		3-6		6-9		9-12	
	(lbs/in^2)							
	NWT	WT	NWT	WT	NWT	WT	NWT	WT
				Corn Plots				
Cover								
Fallow	85a	115a	83a	117a	98a	131a	128a	133a
Removed	74a	108a	83a	108a	123a	125a	137a	129a
Left	57a	108a	99a	117a	187b	127a	138a	130a
Present Tillage								
NT	107a	128a	109a	124a	123a	131a	135a	132a
CH	49b	92b	69b	103b	104b	125a	133a	129a
Past/Present Tillase								
NT/NT	119a	136a	123a	128a	135a	134a	136a	132a
NT/CH	95a	128a	96a	120a	111a	128a	134a	127a
CH/NT	45b	83b	63b	99b	103a	125a	133a	124a
CH/CH	51b	102b	75b	107ab	104a	126a	133a	140a
Cover								
Fallow	144a	166a	145a	155a	155a	178a	204a	217a
Removed	158a	154a	151a	142a	146a	172a	199a	235a
Left	148a	160a	155a	168a	162a	89a	201a	204a
Present Tillage								
NT	203a	187a	197a	188a	183a	96a	216a	234a
CH	97b	132b	104b	122b	126b	63b	186b	186b
Past/Present Tillase								
NT/NT	199a	182a	196a	196a	182a	192a	210a	233a
NT/CH	103b	136b	116b	122b	133b	160a	196a	208a
CH/NT	205a	193a	197a	179a	182a	199a	222a	233a
CH/CH	90b	127a	91b	122b	119b	164a	179a	198a

Means in a column followed by the same letter are not significantly different at the 95% level of confidence.

NWT - No Wheel Traffic
WT - Wheel Traffic passage
NT - No Tillage
CH- Chisel + disk

Table 5. Tilllage rotation effect on corn and soybean grain yields.

Tillage Rotation	CROP Corn	Soybean
	----(lbs/A)----	------(bu/A)------
Past/Present	1992	
NT/NT	191a	70.3a
NT/CH	182a	70.6a
CH/NT	178a	71.8a
CH/CH	188a	70.1a
	1993	
NT/NT	154a	52.0a
NT/CH	151a	48.8a
CH/NT	164a	49.2a
CH/CH	152a	49:9a

Means in a column followed by the same letter are not significantly different at the 95% level of confidence.
NT- No Tillage CH- Chisel plus light disk

chiseled, rotating conservation tillage systems did not significantly affect cover dry matter production nor grain yields in either years (Table 5).

CONCLUSION

Cover crop dry matter production and grain yields were higher in 1992 than in 1993 due to higher precipitation during the growing season. Increasing K fertility increased grain yields, especially during the dry year. Cover left on the surface contributed to the nutrition in both years (data not shown), but reduced stands due to difficult planting operations that affected grain yields by reducing plant densities. The fallow cover treatment produced high corn and soybean yields in both years. Tillage rotation was not beneficial to cover crop dry matter production or to corn or soybean grain yields despite lower compaction where no-till soils were chiseled. Continuous no-tillage with fallow or winter cover residues left at planting would be the most economical system as it produces high corn and soybean yields, saves labor and fuel consumption, and reduces soil losses.

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