No-Tillage Performance on a Piedmont Soil

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ABSTRACT

Many Piedmont soils in southeast USA are crust-prone and develop low infiltration rates. Maintaining residue cover may reduce surface sealing and decrease surface water runoff, soil loss and the loss of agricultural chemicals. The effectiveness of no-tillage (NT) to reduce runoff, erosion, and the loss of chemicals from row crops relative to the conventional plow/disk practice (CT) was investigated. Over a 5-year period, reductions in runoff in NT relative to CT were 22% during cropping periods and 35% during non-cropping periods. The reduction in runoff also fostered a decrease in the loss of soil, nutrients, and herbicides. Soil loss reductions were predominant during cropping periods, especially during erosive rainstorms following tillage and seedbed preparation. On average, CT had 59 times more soil loss than NT during cropping periods (23.4 *vs*. 0.4 ton acre^{-1}) and 4 times more soil loss during non-cropping periods (1.7 *vs*. 0.4 ton acre^{-1}). Crop growth and grain yield were generally greater in NT; this was attributed to greater soil water content. The formation of a seal soon following planting in CT explained the greater runoff and lower soil water content in this system. Tillage practices leaving crop residues on the soil surface, such as NT, can reduce surface runoff, soil loss, and loss of nutrients and herbicides while increasing crop growth and yield.

KEYWORDS

Runoff, soil erosion, nutrient loss, herbicide loss, corn, soybean

INTRODUCTION

Enhanced crop yields with conservation tillage systems are commonly obtained in southeastern USA, particularly on the sloping lands of the Piedmont and Appalachian Plateau. In most cases, yield increases due to conservation tillage are attributed to greater infiltration of soil water (Hargrove, 1985; Wager and Denton, 1989; 1992; Cassel *et al.*, 1995). Increased infiltration rates in conservation tillage systems have been attributed to the presence of surface residue. Residues protect the soil surface from raindrop impact, prevent seal formation, and reduce the transport capacity of surface flow (Laflen *et al.*, 1978; Foster *et al.*, 1985).

In the Piedmont and Appalachian Plateau, plowing plus disking is the conventional method of land preparation. This management system leaves the soil bare for several months, promotes surface sealing and, on drying, promotes crust formation (Radcliffe *et al.*, 1988). Surface seals substantially reduce infiltration because of their low hydraulic conductivity. Chiang *et al.* (1993) found the hydraulic conductivity for a Cecil soil crust to be one to two orders less than that of the underlying unsealed soil. Steady state infiltration rate on this sealed soil was 0.07 in hour^{-1} or less.

Other factors that promote soil erosion with conventional tillage are the lack of appreciable canopy cover in early crop vegetative stages, the likelihood of intense, erosive storms during seedbed preparation, and the sloping topography of fields. Thus, the need to evaluate the effects that conservation tillage systems have on soil erosion in the Piedmont and Appalachian Plateau is well warranted.

The main objective of this study was to investigate the effectiveness of no tillage to reduce runoff and erosion from row crops relative to the conventional plow/disk practice. Additional evaluations included crop response and losses of herbicide and nutrients.

MATERIALS AND METHODS

The study was conducted at the North Carolina A&T Farm, Greensboro, North Carolina. The site had soil types Enon clay loam and Mecklenburg sandy clay loam (fine, mixed, thermic Ultic Hapludalfs). Treatments were first

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implemented on May of 1994, but the collection of runoff and soil loss did not begin until May of 1995. The experiment was designed as a randomized complete block, replicated four times. Treatments were conventional tillage (CT) and no-tillage (NT). Conventional tillage consisted of chisel plowing to the 8-inch depth in mid spring followed by disking prior to planting. No tillage consisted of opening a small slit by means of a coulter running ahead of a planter unit with openers. Tractor traffic was confined to alternate interrow areas. Plot dimensions were 40 feet long by 24 feet wide designed for eight rows of corn or soybeans spaced 3 feet apart. Corn and soybeans were planted in the following order: soybeans in 1994, corn in 1995 and 1996, soybeans in 1997 and 1998, and corn in 1999.

Permanent soil erosion subplots were installed within each experimental plot and were similar in design to the unit plots used for runoff and soil loss data collection for development of the universal soil loss equation (USLE). Subplots isolated an area 33 feet long by 12 feet wide encompassing four crop rows. To achieve this, 48-inch long by 8-inch wide galvanized metal borders were forced into the ground to a depth of 4 inches. A trough made of PVC material was installed in the lower side for runoff and sediment interception. Troughs were designed to deliver runoff and sediment to a multislot divisor that delivered 0.9 of the flow to adjacent collection tanks. The system was designed to handle 8 inches of runoff. Runoff volume and sediment concentration was measured from each tank immediately after each rainfall event.

Herbicides measured in runoff and sediment included metalochlor in 1996 and atrazine in 1999. Nutrients measured in the runoff were nitrogen and phosphorous. Both herbicides were applied a day prior to planting, metalochlor at a rate of 3.1 lbs $acre^{-1}$ and atrazine at a rate of 2.7 lbs $acre^{-1}$. A total of 107 lbs N $acre^{-1}$ as NH_4NO_3, 53 lbs P $acre^{-1}$ as P_2O_5, and 53 lbs K $acre^{-1}$ as K_2O were applied. One third of each fertilizer source was surface banded along the planted row and the remainder was row-banded six weeks after planting.

Inorganic–N, PO_4 and total P (perchloric acid digestion) were measured with a Technicon Auto Analyzer. Total-N was measured using a CHNS analyzer. Atrazine and metolachlor were extracted using C-18 columns (solid phase extraction method). Concentrations were measured using a Hewlett Packard (HP) 5890-II gas chromatography and using a J&WD13-1 column for atrazine and a DB-17 capillary column for metalochlor. An HP 5973 auto-sampler was used.

Residue cover was measured at planting with the method of Sloneker and Moldenhauer (1977) using a 35 ft transect with 35 points. Transect end points were in diagonally opposed corners. Crop canopy height and cover were measured at the tasseling stage for corn and at the flowering stage for soybeans. Canopy cover measurements were based on three sets of ten readings per plot and using a PAR SF-80 Sunflex Ceptometer. Canopy height was based on five measurements per plot and performed by measuring the height from the soil surface to the upper most part of the canopy.

Statistical analyses were conducted using analysis of variance procedures (SAS Institute Inc., 1985). The statistical model was based upon a randomized block design. Comparisons between treatments means were done using Fishers Protected LSD test (Steel and Torrie, 1980).

RESULTS AND DISCUSSION

Crop residue cover was measured at planting on both trafficked and non-trafficked interrows. The ANOVA showed no treatment x position interaction and no position effect. On average, conventional tillage had the least cover (18%) and no-tillage had the most cover (85%) (Table 1).

Averaged over the five-year period, total runoff was 22% less in NT than in CT in cropping periods. A similar response was observed in non-cropping periods (35% reduction), despite the full surface cover remaining after harvest in both treatments. In general, the sealed condition of the CT surface during this period eliminated any beneficial residue effects on infiltration. For example, surface residue is known to retard surface runoff and increase infiltration.

Soil losses were highly reduced in no-tillage. The reduc-

Table 1. Percent surface residue cover, runoff, and soil loss in each treatment. Cropping periods were from planting in May or April through harvest in late October.

	Tillage	
Parameter	CT	NT
Residue Cover, %	18a†	85 b
Runoff, inches		
Cropping Periods	6.2 a	3.5 b
Non-Cropping Periods	8.0 a	5.4 b
Soil Loss, ton $acre^{-1}$		
Cropping Periods	23.6 a	0.4 b
Non-Cropping Periods	1.7 a	0.4 b
Rainfall, inches		
Cropping Periods	21.3	
Non-Cropping Periods	21.4	

† For each parameter, means followed by the same letter are not significantly different at P = 0.05 based on Fisher's protected LSD test.

tion was more pronounced during the cropping period and was related to rainstorm characteristics during this period. In the North Carolina Piedmont, frequent rainstorms occur during the months of April, May, and June. These storms are of short duration, but their high intensity favors particle detachment and leads to the formation of surface seals. On average, there was 59 times more soil loss in CT during cropping periods (23.4 *vs*. 0.4 ton acre^{-1}) and 4 times more soil loss during non-cropping periods (1.7 *vs*. 0.4 ton acre^{-1}).

The nutrient and herbicide data shows a significant reduction in loss of inorganic-N, sediment-N, and metolachlor in NT (Table 2). Most of the inorganic-N loss was in the form of NO_3-N. However, concentrations were much less than the 10 ppm EPA standard. Significant losses of N occurred in CT because of the high loss of soil. A total of 20.3 lbs N acre^{-1} was found to be tied-up with sediment in CT, whereas only 7.8 lbs N acre^{-1} were found in NT. Overall, losses of herbicide were low except for metolachlor in CT (0.7 lbs acre^{-1}). Approximately 60% of this loss occurred in the month of May following the application of herbicide. No metolachlor was found in runoff or sediment after harvest in October.

As indicated by the canopy cover and canopy height data, crop growth was generally greater in NT compared with CT (Table 3). Generally, plants in NT were taller and heavier (dry weight data not shown) than CT plants. Over the five-year period, NT grain yield was equal to or better than that in CT. The greater plant growth and grain yield in NT is attributed to greater soil water content (not shown). Each year, we visually observed the formation of a seal soon following planting in CT, which explains the greater runoff and lower soil water content in this system.

The higher soil water content and lack of surface sealing found in NT are attributed to the presence of surface residue, which reduces the effect of raindrop impact on particle detachment and therefore maintains better conditions for infiltration.

Table 2. Losses of nutrients and herbicides in runoff and sediment. Nutrient losses are the losses averaged over 1995 and 1996 crop periods. Metolachlor loss was measured in the 1996 crop period and atrazine loss in the 1997 crop period.

Parameter	Tillage CT	NT
Nutrients		
Inorganic N, lbs acre^{-1}	7.6a	10.2b
PO_4, lbs acre^{-1}	2.2 a	3.7 a
Sediment N, lbs acre^{-1}	20.3 a	7.8 b
Sediment P, lbs acre^{-1}	0.3 a	0.1 a
Herbicides		
Metolachlor, lbs acre^{-1}	0.7 a	0.1 b
Atrazine, lbs acre^{-1}	0.05 a	0.01 a

† For each parameter, means followed by the same letter are not significantly different at $P = 0.05$ based on Fisher's protected LSD test.

Table 3. Measurements of crop growth (canopy cover and height) and grain yield for corn and soybeans. Data for corn is the average of results in 1995, 1996, and 1999. Data for soybeans beans is the average of results in 1997 and 1998.

Parameter	Tillage CT	NT
Canopy cover, %		
Corn	79.6 a	88.6 b
Beans	92.0 a	97.0 a
Canopy height, inches		
Corn	71.3 a	83.5 b
Beans	37.0 a	45.8 b
Grain yield, bu acre-1		
Corn	88.7 a	98.9 b
Beans	40.9 a	43.2 a

† Means within each **row** followed by the same letter are not significantly different at $P = 0.05$ based on Fisher's protected LSD test.

CONCLUSION

Many Piedmont soils are crust-prone because of kaolinite predominance in the clay fraction and low soil organic matter content. Surface crop residue provides protection against raindrop impact and seal formation increasing rainfall capture and infiltration. Tillage practices that leave crop residues on the soil surface, such as NT, can reduce surface runoff, soil loss, and loss of nutrients and herbicides while increasing crop growth and yield.

LITERATURE CITED

Cassel, D.K., C.W. Raczkowski, and H.P. Denton. 1995. Tillage effects on corn production and soil physical conditions. Soil Sci. Soc. Am. J. 59:1436-1443.

Chiang, S.C., D.E. Radcliffe, and W.P. Miller. 1993. Hydraulic properties of surface seals in Georgia soils. Soil Sci. Soc. Am. J. 57:1418-1426.

Foster, G.R., R.A. Young, M.J.M. Romkens, and C.A. Onstad. 1985. Processes of soil erosion by water. pp. 137-162. *IN* R.F. Follett and B.A. Stewart (ed.) Soil erosion and crop productivity. ASA, CSSA, and SSSA, Madison, WI.

Hargrove, W.L. 1985. Influence of tillage on nutrient uptake and yield of corn. Agron. J. 77:763-768.

Laflen, J.M., J.L. Baker, R.O. Hartwig, W.F. Buchele, and H.P. Johnson. 1978. Soil and water losses from conservation tillage systems. Trans. ASAE 18:1-10.

Radcliffe, D.E., E.W. Tollner, W.L. Hargrove, R.L. Clark, and M.H. Golabi. 1988. Effect of tillage practices on infiltration and soil strength of a Tipic Hapludult after ten years. Soil Sci. Soc. Am. J. 52:798-804.

SAS Institute, Inc. 1985. SAS user’s guide: Statistics, version 5 edition. SAS Institute, Inc., Cary, NC.

Sloneker, L.L., and W.C. Moldenhauer. 1977. Measuring the amounts of crop residue remaining after tillage. J. Soil Water Conserv. 32:231-236.

Steel, R.G., and J.H. Torrie. 1980. Principles and procedures of statistics. McGraw-Hill Publ., New York.

Wagger, M.G., and H.P. Denton. 1989. Tillage effects on grain yields in a wheat, double-crop soybean, and corn rotation. Agron. J. 81:493-498.

Wagger, M.G., and H.P. Denton. 1992. Crop and tillage rotation: Grain yield, residue cover, and soil water. Soil Sci. Soc. Am. J. 56:1233-1237.