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Subsoiling, Contouring, And Tillage Effects On Erosion And Runoff

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SUBSOILING, CONTOURING, AND TILLAGE EFFECTS ON EROSION AND RUNOFF

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ABSTRACT

A study to evaluate the effectiveness of subsoiling on reducing soil erosion and water runoff from continuous corn production was conducted. A rotating boom rainfall simulator was used on replicated treatments having either preplant in-row subsoiling or postplant between-row subsoiling used in both tilled and untilled surface conditions. Tilled and untilled treatments without subsoiling were used as checks. These six treatments were used up-and-downhill and on the contour.

Subsoiling reduced the rate of water runoff but did not significantly reduce the soil erosion rate after equilibrium had been reached between water application and runoff rates. Surface condition and farming direction did not significantly affect runoff. However, the untilled surface treatments had about 55% less soil loss than the tilled surfaces. The contour farming direction treatments also had about 65% less soil loss than up-and-downhill farming.
KEYWORDS. Subsoiling, No-till, Contour, Erosion, Runoff

INTRODUCTION

Conservation of soil and water resources is essential to sustain agricultural productivity in the Great Plains. Annual Nebraska soil losses due to water erosion are estimated at more than 127 million metric tons (140 million tons) with about 75% of these losses coming from row crop production (NNRC, 1979). Residue management is one of the most effective methods of controlling erosion. This erosion control is the result of two factors: 1) crop residue protects the soil surface from raindrop impact, thus reducing soil particle detachment; and 2) residue slows the runoff velocity, which minimizes transport of the detached soil. Erosion also can be reduced by cultural practices that reduce water runoff.

While runoff and erosion from rainfall are major problems associated with crop production, runoff from irrigated row crops also can be of concern. This runoff can cause soil erosion and result in inefficient use of the applied water. Research on a center pivot irrigated silty clay loam soil in southeast Nebraska showed that runoff was 7.9, 13.1, and 17.6% of the total irrigation and precipitation applied on land slopes of 2, 4, and 8%, respectively (Hanna et al., 1983). Addink (1975) found runoff to be as high as 65% under a low pressure spray center pivot system on a very fine sandy loam soil compared to 22% under a high pressure system.

Runoff from crop land can be reduced by several methods including: 1) leaving additional crop residue on the soil surface; 2) subsoiling to loosen the soil and increase infiltration; and 3) creating additional surface storage to decrease runoff and to allow more time for infiltration. Storing additional moisture in the soil can result in reduced irrigation or increased production under non-irrigated conditions.

Several investigators have studied inter-row tillage practices that might increase the infiltration of precipitation and irrigation water. One inter-row technique for reducing runoff is to subsoil or deep chisel. This operation, generally called layby subsoiling, is the last tillage operation of the season and is performed when the corn is in the 6 to 10 leaf stage. DeBoer and Beck (1982) reported that runoff from 30 mm (1.2 in.) irrigation water applications with a center pivot averaged 2 mm (0.08 in.) using layby subsoiling and 7 mm (0.27 in.) with conventional tillage practices. Bockstadter et al. (1989) found that layby subsoiling on center pivot irrigated fields resulted in 28 to 40 mm (1.1 to 1.6 in.) of additional stored water in the soil profile at the end of the irrigation season. However, there was no yield response to the additional soil moisture.

Although layby subsoiling appears to be an effective cultural practice for minimizing runoff, the technique may cause substantial soil loss. Kranz (1989) reported no statistical differences in runoff among three inter-row tillage treatments used up-and-downhill on a silty clay loam soil having a 10% slope. But the layby subsoiling treatment had significantly greater soil losses than the non-subsoiled treatment. Runoff water was concentrated in the opening left by the subsoiling shank, which caused greater rill erosion than would have otherwise occurred.

Some equipment manufacturers are promoting layby subsoiling for increasing infiltration on sloping soils. In addition, preplant in-row subsoiling is being promoted as a method of enhancing root growth on soils having a restricting soil layer. Concerns have been raised about subsoiling, whether layby or preplant, and the impact on soil erosion, especially on moderate to steeply sloping soils. It may be possible that no-till planting or other conservation practices, such as contour farming, could reduce both runoff and erosion. Furthermore, these treatments may be less expensive than subsoiling because of lower power requirements for tillage and planting.

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The objective of this project was to evaluate the effectiveness of preplant in-row subsoiling or postplant between-row subsoiling in reducing runoff and soil erosion from tilled and untilled soil surfaces having up-and-downhill and contour farming directions.

PROCEDURES

The study was conducted at the University of Nebraska Rogers Memorial Farm in Lancaster County, near Lincoln, NE. The silty clay loam soil at the dryland site was within the Wymore Series (Aquic Argiudoll, fine, montmorillonitic, mesic) on a 5% slope (SCS, 1980). Anhydrous ammonia fertilizer was knifed into the entire plot area in the spring of 1985. The entire area was disked twice following fertilizer application and randomized plots were established. Corn was planted in 1985 to establish row direction. The average yield was about 7.5 t/ha (120 bu/ac). In 1986, the entire area was no-till planted to corn directly into the established rows to preserve the residue. Dry broadcast fertilizer was used and the corn yielded 9.1 t/ha (145 bu/ac) in 1986. The tillage treatments evaluated in this study were imposed in 1987 onto the corn residue covered plots having an established row direction.

The experiment was a randomized 2×2×3 factorial design. Replicated plots having preplant in-row subsoiling and postplant between-row subsoiling were evaluated in both tilled and untilled surface conditions. Tilled and untilled plots without subsoiling were used as checks. These six treatments were evaluated for both up-and-downhill and contour farming directions. Because of field layout, the up-and-downhill treatments were replicated three times and the contour treatments were replicated four times. Up-and-downhill plots were 9.1 m wide × 23 m long (30 × 75 ft) and contour plots were 18.2 m wide × 23 m long (60 × 75 ft).

Moldboard plowing in April 1987, followed by two diskings, was used to create the tilled surface condition. The plow was operated 20 cm (8 in.) deep and the disk was operated 15 cm and 10 cm (6 in. and 4 in.) deep for the initial and final diskings, respectively. The entire experimental area was preplant sprayed for weed control after the first disking on the tilled plots. No stalk shredding or fertilizer was used.

A Bush Hog* Ro-Till implement was used on 11 May to perform the preplant in-row subsoiling on the appropriate treatments. Each row of the 6-row Bush Hog implement consisted of a parabolic subsoiler shank followed by two fluted coulters, one on each side of the shank, operating at an angle to close the slot opened by the subsoiler shank. A roller packer attached behind the coulters firmed the soil into the slot. The subsoiler shank operated approximately 36 cm (14 in.) deep. In the untilled surface condition, the shank was operated directly in the old row.

All the treatments were planted on 11 May after the preplant in-row subsoiling operation. For the in-row subsoiling treatments, rows were placed directly over the area tilled with the subsoiler shank. A six-row John Deere Max-Emerge 7000 planter with heavy duty rippled coulters was used. Row spacing was 76 cm (30 in.) and planting depth was 3.8 cm (1.5 in.).

Immediately following planting, a Blu-Jet* Sub-Tiller subsoiler with "summer till" points was used to subsoil between the rows in the postplant between-row subsoiling treatments. The Blu-Jet implement had a straight shank subsoiler operated approximately 36 cm (14 in.) deep with a coulter in front of each shank to minimize soil disturbance. The "summer till" point has a narrow profile and is designed to open a slot with less total soil disturbance than a conventional point designed for fracturing compacted soils. There were no subsequent attachments or field operations to close the slot or smooth the soil surface. The timing of the layby subsoiling was moved forward in the experiment in order to have equivalent soil moisture conditions for the erosion study. Normally, a subsoiling operation such as this would follow crop cultivation at layby time and be called "layby subsoiling" .

A rotating boom rainfall simulator (Swanson, 1965) was used to apply water at a rate of 63.5 mm/h (2.5 in./h) to 3 m wide × 9.1 m long (10 × 30 ft) subplots within the main tillage plots. Sheet metal borders were used to define subplot size and contain the runoff. On the downhill end of the plots, sheet metal collection flumes were placed to concentrate the surface runoff for sampling purposes. Outside the subplots of both the preplant in-row subsoiling, and the postplant between-row subsoiling treatments, but within the wetted area of the rainfall simulator, a trench was dug deeper than the depth of subsoiling, perpendicular to the subsoiling direction, and a vertical sheet of plastic film was installed to prevent subsurface flow into or out of the subsoiled plots.

The rainfall was applied to a dry soil surface and measurements were taken until the runoff rate had been at equilibrium with the water application rate for approximately 15 min. Every 5 min, the runoff rate was determined from gravimetric measurements and a 0.5 L (1 pt) sample of runoff water was collected to determine sediment concentration. Soil loss rate, total soil loss, and total runoff were determined from this information. The percentage of the soil surface covered with residue immediately prior to rainfall simulation was measured using the photographic grid method (Laflen et al., 1978). Rainfall simulation took place 12 through 20 May 1987 immediately following the last tillage operation. On the night of 18 May, 17.8 mm (0.7 in.) of rainfall occurred. At that point, runoff and erosion measurements had been completed on 29 of the 42 plots which included at least two replications from each treatment. Data from all 42 plots were included in the analysis. Prior to this rainfall, the soil surface was relatively dry as no appreciable rainfall had occurred since before moldboard plowing.

To evaluate the differences in the data, SAS general linear model analysis of variance treatment mean comparison was used (SAS Institute Inc., 1982). All treatment differences were tested at the 0.05 level of significance. The Duncan's multiple-range test was also used to determine differences in multiple levels of the same factor.

*Mention of brand names is for descriptive purposes only; endorsement is not implied.

TABLE 1. Residue cover remaining on the soil surface after all tillage and planting operations

Factor*	Level	Residue Cover (%)	P-Value
Subsoiling	Preplant in-row	19.4	0.0489
	Postplant between-row	21.3	
	None	26.8	
Surface	Tilled	4.2	0.0001
	Untilled	40.8	
Direction	Up-and-downhill	23.7	0.3636
	Contour	21.6	(ns)†

* An interaction existed between the subsoiling and surface factors (P = 0.0131).

† ns = no significant difference between levels within a factor.

Results and Discussion

Residue Cover

As anticipated, farming direction did not influence residue cover (Table 1). The tilled surface averaged only 4% cover after all tillage and planting operations, whereas the surface that was untilled prior to imposing the three subsoiling treatments averaged 41% cover after all tillage and planting operations. The non-subsoiled treatments averaged 27% cover which was significantly greater than the preplant in-row subsoiling treatments and the postplant between-row subsoiling treatments. In general, the subsoiling operation resulted in a 25% reduction in residue cover.

Time to Initiate Runoff

Both the preplant in-row subsoiling and postplant between-row subsoiling treatments required more rainfall to initiate runoff than did the non-subsoiled treatments. The non-subsoiled treatments averaged 20 min or 20 mm (0.8 in.) of rainfall to initiate runoff (Table 2). The between-row subsoiling treatments averaged 48 min or 51 mm (2.0 in.) of rainfall to initiate runoff. These treatments had a relatively open slot that increased surface storage and thus required more time to initiate runoff. The in-row subsoiling implement had slot closure devices and was followed by a planting operation, which helped close the slot at the soil surface. Because of this closure, less time was needed to initiate runoff for the in-row treatment than was required for the between-row subsoiling treatment, 33 min compared to 48 min.

Since this experiment involved the first runoff event following all tillage and planting operations, no surface drainage network had been established. However, there was no significant difference between levels in time to initiate runoff in either the surface or direction factor (Table 2).

TABLE 2. Time between the start of rainfall and the initiation of water runoff

Factor*	Level	Time, min	P-Value
Subsoiling	Preplant in-row	32.9	0.0001
	Postplant between-row	47.6	
	None	19.8	
Surface	Tilled	36.1	0.1324
	Untilled	30.8	(ns)
Direction	Up-and-down hill	29.1	0.0735
	Contour	36.8	(ns)†

* No significant interactions among factors.

† ns = no significant difference between levels within a factor.

Total Runoff Depth and Equilibrium Runoff Rate

Both the in-row subsoiling and between-row subsoiling treatments had significantly less total runoff after 1.5 h of rainfall than did the non-subsoiled treatments (Table 3). However, the Duncan's multiple-range test for differences among treatments within the subsoiling factor showed no significant difference between the in-row or the between-row treatments. Thus, on average, the subsoiled treatments had 20 mm (0.8 in.) or about 70% less runoff than the non-subsoiled treatments after 95 mm (3.75 in.) of rainfall. The difference in runoff between subsoiled and non-subsoiled treatments was partially the result of the difference in time to initiate runoff between these treatments.

There was also a significant difference in the runoff rate after equilibrium had been established between water runoff and water application for the levels within the subsoiling factor. The Duncan's multiple-range test showed a significant difference in average runoff rate between the 34.5 mm/h (1.4 in./h) for the non-subsoiled treatments and the 22.2 mm/h (0.9 in./h) postplant between-row subsoiled treatments.

The depth of runoff from the untilled surface treatments averaged 7.6 mm (0.3 in.) more runoff after 95 mm (3.75 in.) of rainfall than did the tilled surface treatments. However, there was no significant difference between the tilled and untilled surfaces in the runoff rate after equilibrium had been established. There were no significant differences in either runoff or equilibrium runoff rate for farming direction.

In general, for the soil condition evaluated and for the first runoff event after tillage and planting, both in-row subsoiling and between-row subsoiling averaged less runoff and had a lower runoff rate than the non-subsoiled treatments after equilibrium conditions had been achieved. Surface condition and farming direction were of lesser importance and did not have significant impacts on the equilibrium runoff rate.

Soil Loss and Erosion Rate

Cumulative soil losses from the 12 treatments are shown in figure 1. When evaluating individual treatments, the greatest amount of erosion occurred from the non-subsoiled, up-and-downhill tilled surface. Subsoiling on the up-and-downhill tilled treatments reduced erosion, but the non-subsoiled, untilled surface (no-till) was even more

TABLE 3. Total runoff depth after 1.5 hours or 95 mm (3.75 in.) of water application and runoff rate at equilibrium

Factor*	Level	Total runoff depth, mm(in.)	P-Value	Equilibrium runoff rate, mm/h (in./h)	P-Value
Subsoiling	Preplant in-row	11.7 (0.46)	0.0001	26.9 (1.06)	0.0195
	Postplant between-row	7.0 (0.28)		22.2 (0.88)	
	None	29.4 (1.16)		34.5 (1.36)	
Surface	Tilled	12.2 (0.48)	0.0317	27.8 (1.09)	0.9883
	Untilled	19.8 (0.78)		28.0 (1.10)	(ns)
Direction	Up-and-downhill	19.6 (0.77)	0.0725	31.6 (1.25)	0.0580
	Contour	13.3 (0.52)	(ns)†	25.1 (0.99)	(ns)

* No significant interaction among factors for either runoff depth or runoff rate.

† ns = No significant difference between levels within a factor.

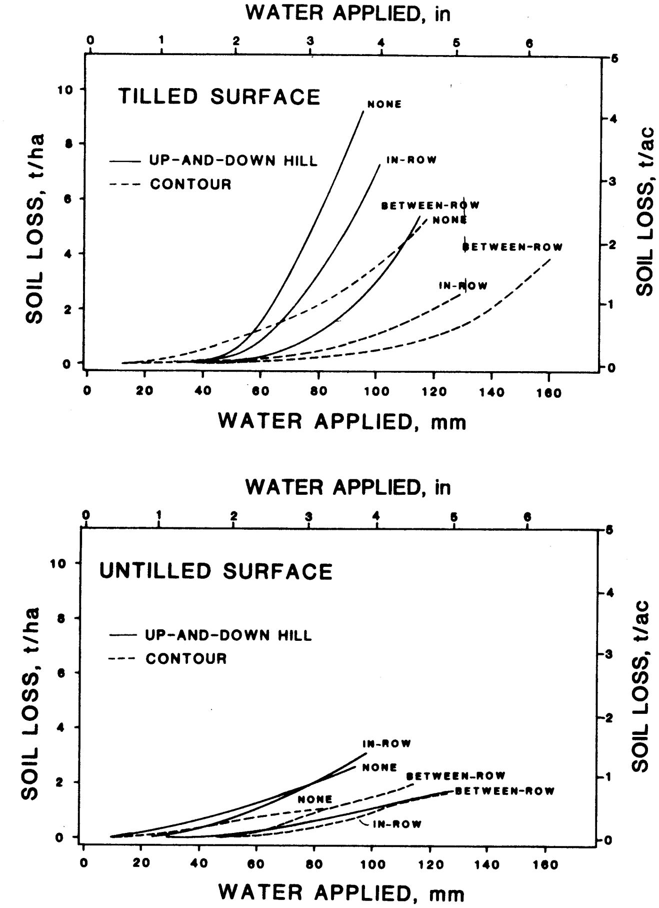

Figure 1–Cumulative soil loss vs. water application for treatments used on a 5% slope in corn residue.

effective in reducing the erosion.

Soil loss after 1.5 hours or 95 mm (3.75 in.) of rainfall application, on the average, was greatest for the non-subsoiled treatments and least for the postplant between-row subsoil treatments, 3.8 t/ha (1.7 t/ac) as compared to 1.2 t/ha (0.5 t/ac) (Table 4). These differences reflect the greater time required to initiate runoff for the subsoiled treatments as well as a lower runoff rate. Using Duncan's multiple-range test, there was no significant difference between the soil loss from the in-row and between-row subsoil treatments. Further, the erosion rates at runoff equilibrium were not statistically different among the subsoiling treatment levels.

Observations during rainfall simulation showed that flow was somewhat channelized in the slots created during the subsoiling operation. Since the slot area tended to be residue free, soil was more easily detached in the slot and the channelized flow provided additional transport ability compared to the non-subsoiled treatments. There was some additional rill erosion that occurred in the slot that did not occur on the non-subsoiled treatments.

Surface condition significantly influenced both the erosion rate at runoff equilibrium and soil loss after 95 mm (3.75 in.) of water application. The untilled surface had 55% less soil loss than the tilled surface, probably the result of the difference in residue cover. The untilled and tilled surface treatments averaged 41% and 4% covers, respectively. The erosion rate at runoff equilibrium was 75% less for the untilled surface. Even though there was more runoff on the untilled surface, the residue cover reduced the soil loss.

Farming on the contour resulted in 65% less soil loss after 95 mm (3.75 in.) of water application than up-and-downhill farming. Similarly, the erosion rate at equilibrium was 56% less. Although the runoff rates were similar for both farming directions, the contouring effect resulted in reduced soil loss. Observations showed that the furrows and ridges resulting from tillage provided temporary surface storage on the contour plots which allowed time for deposition of sediment. The ponded water also reduced the opportunity for soil detachment by rainfall. As a comparison, Jasa et al. (1986) measured a 74% reduction in soil loss and a 65% reduction in soil erosion rate for contour treatments used in soybean residues on 5 and 10% slopes.

SUMMARY AND CONCLUSIONS

A rotating boom rainfall simulator was used to evaluate the effectiveness of three subsoiling treatments in reducing runoff and soil erosion. The treatments were evaluated in tilled and untilled soil surface conditions, both up-and-downhill and on the contour. The research was conducted on a silty clay loam soil with a 5% slope and having continuous corn production.

For the first rainfall event after tillage, both preplant in-row subsoiling and postplant between-row subsoiling reduced the total runoff depth and the soil loss when compared to non-subsoiled treatments after 95 mm (3.75 in.) of water had been applied. More time was required to initiate runoff for the subsoiling treatments than for the non-subsoiled treatments. Also, the between row subsoiling treatments had less runoff than the in-row subsoiling treatments. However, after runoff equilibrium had been reached, there was no significant difference in the erosion rates for subsoiled and non-subsoiled treatments.

On the average, contour farming reduced soil loss after 95 mm (3.75 in.) of water application and erosion rate after runoff equilibrium had been reached by 65% and 56%, respectively, as compared to up-and-downhill farming.

The average total soil loss for the tilled surface was more than double the untilled surface. The erosion rate after runoff equilibrium averaged four times more for the tilled than the untilled treatments. The difference in soil loss was due, in part, to soil residue cover. The untilled soil

TABLE 4. Soil loss after 1.5 hours or 95 mm (3.75 in.) of water application and erosion rate at equilibrium

Factor*	Level	Soil loss, t/ha (t/ac)	P-Value	Equilibrium erosion rate, t/ha/h (t/ac/h)	P-Value
Subsoiling	Preplant in-row	2.39 (1.07)	0.0004	4.93 (2.20)	0.6704
	Postplant between-row	1.21 (0.54)		4.76 (2.12)	(ns)†
	None	3.82 (1.70)		5.43 (2.43)	
Surface	Tilled	3.38 (1.51)	0.0003	8.06 (3.60)	0.0001
	Untilled	1.56 (0.68)		2.02 (0.90)	
Direction	Up-and-downhill	3.95 (1.76)	0.0001	7.42 (3.31)	0.0001
	Contour	1.37 (0.61)		3.26 (1.46)	

* Interactions between subsoiling and surface factors (P = 0.0064) and between direction and surface factors (P = 0.0014) for soil loss and an interaction between direction and surface factors (P = 0.0004) for erosion rate.

† ns = No significant difference between levels within a factor.

surface treatments averaged about 41% residue cover as compared to the tilled surface cover of 4%.

Maintaining residue cover through the use of no-till planting or adopting contour farming practices appeared to be more effective in reducing erosion than the use of either preplant in-row subsoiling or postplant between-row subsoiling. However, the subsoiled treatments did reduce the amount of runoff for the first runoff event after tillage. Additional research is needed to determine if subsoiling will reduce the amount of runoff for subsequent events, especially after a drainage network has been established.

REFERENCES

Addink, J.W. 1975. Runoff potential of spray-nozzle and sprinkler center pivots. ASAE Paper No. 75-2056. St. Joseph, MI: ASAE.

Bockstadter, T.L., D.E. Eisenhauer, W. Kranz and T. Retka. 1989. Final report of the irrigation management component, Agricultural Energy Conservation Project. Cooperative Extension, University of Nebraska. SCREC 89-3. 22 pp.

DeBoer, D.W. and D.L. Beck. 1982. Tillage practice to enhance infiltration under sprinkler irrigation. ASAE Paper No. 82-2002. St. Joseph, MI: ASAE.

Hanna, A.Y., P.W. Harlan and D.T. Lewis. 1983. Effects of slope on water balance under center-pivot irrigation. *Soil Sci. Soc. Am. J.* 47: 760-764.

Jasa, Paul J., E.C. Dickey and D.P. Shelton. 1986. Soil erosion from tillage and planting systems used in soybean residue: Part II. Influences of row direction. *Transactions of the ASAE* 29(3): 761-766.

Kranz, W.L. 1989. Control of runoff from sprinkler irrigation systems. Conservation Tillage. Cooperative Extension, University of Nebraska. *Conservation Tillage Proceedings* 8: 127-132.

Laflen, J.M., J.L. Baker, R.O. Hartwig, W.F. Buchele and H.P. Johnson. 1978. Soil and water loss from conservation tillage systems. *Transactions of the ASAE* 21(5): 881-885.

Nebraska Natural Resources Commission. 1979. Section 208 Water Quality Management Plan for the State of Nebraska.

SAS Institute Inc. 1982. SAS User's Guide: Statistics. SAS Institute Inc., Cary, NC.

Soil Conservation Service. 1980. Soil survey of Lancaster County, Nebraska. USDA-SCS.

Swanson, N.P. 1965. Rotating-boom rainfall simulator. *Transactions of the ASAE* 8(1): 71-72.