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ABSTRACT

A rainfall simulator was used to compare soil losses from various tillage and planting systems used in residue from soybeans which had been grown in both wide and narrow spaced rows the previous season. Up-and-down hill tillage and planting treatments ranging from a double disk system to no-till planting were evaluated using replicated plots on a silt loam soil in the Nora Series having a 10% slope.

Tillage and planting systems used in soybean residue from narrow spaced rows had soil erosion and soil erosion rates that were reduced by approximately 50% compared to the same systems used in residue from wide spaced soybeans. However, the reductions were significant only for the double disk tillage system. There was a trend for the start of runoff to be delayed and for residue cover, accumulated runoff, runoff rate, and sediment concentration to be reduced for tillage systems used in narrow row soybean residue compared to the same systems used in residue from wide spaced rows.

INTRODUCTION

Most soybeans produced in the midwestern United States are grown in a corn-soybean rotation. In Nebraska, soybean production grew to a record of nearly one million hectares in 1982 (NCLRS, 1984), nearly double the area of 1975. Several studies (Dickey et al., 1985; Laflen and Colvin, 1982; Laflen and Moldenhauer, 1979; Siemens and Oschwald, 1978) have shown that soil erosion following soybeans can be more than double the erosion following corn.

Tillage and planting systems which leave a protective cover of crop residue on the soil surface have been shown to reduce soil losses, and are among the least costly erosion control practices (Nicol et al., 1974; Seay, 1970). Leaving as little as 20% of the soil surface covered with corn or soybean residue reduced erosion by 50% of that which occurred from a cleanly tilled, residue free surface (Dickey et al., 1984, 1985). Similarly, a no-till system which left a 95% cover of wheat residue, reduced erosion by 99.8% of that which occurred from a moldboard plow system (Dickey et al., 1983).

After soybean harvest, about 80% of the soil surface is often covered with residue. However, soybean residue tends to be fragile and easily destroyed by tillage operations (Erbach, 1982; Colvin et al., 1980). The fragile residue combined with the loose, mellow soil that generally occurs following soybeans substantially contributes to soil erosion from soybean production areas.

Two general perceptions often given in relation to the planting of soybeans in narrow rows are that; (a) there is a grain yield increase, and (b) soil erosion is reduced. According to Moomaw (1985), increased yields have typically not occurred with narrow row soybeans in Northeast Nebraska, which was also the case in this study. Colvin and Erbach (1982) did, however, report increased yields in Iowa for solid seeded soybeans compared to soybeans planted in 76 cm rows.

Colvin and Laflen (1981) concluded that if surface conditions are the same, soil losses should be only slightly influenced by narrow row cropping systems compared to wide row cropping. There appears to be little basis to the idea that narrow row planting of soybeans would reduce soil erosion while the plants are growing. Further, for a study involving three tillage and planting systems (moldboard plow, chisel plow, and no-till), Laflen and Colvin (1982) concluded that the effects of soybean row width on erosion and runoff were negligible both during the year soybeans were grown and the year following soybeans. However, the Laflen and Colvin study did not evaluate disking, which is the most common tillage system in Nebraska (Dickey and Rider, 1980).

OBJECTIVES

The overall objective of this research was to evaluate soil erosion during the period between spring planting and crop canopy establishment for selected tillage systems used in soybean residue. Specific objectives were to measure and compare soil surface residue cover, soil erosion, water runoff, and sediment concentration for tillage systems used up-and-down hill in residue from soybeans which had been grown in wide and narrow spaced rows (Part I). A concurrent study (Part II) compared tillage and planting systems used up-and-down hill and on the contour in soybean residue from wide spaced rows (Jasa et al., 1986).

METHODOLOGY

This study was conducted at the University of

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TABLE 1. SUMMARY OF TILLAGE AND PLANTING OPERATIONS WITHIN THE SYSTEMS EVALUATED.

Tillage and planting system — operations
Double disk — disk (15 cm deep), disk (10 cm deep), plant
Till-plant — till-plant into old row
Strip rotary-till — rotary-till (13 cm deep; 25 cm wide tilled strips) centered on old row, plant
No-till — slot-plant into old row

Nebraska Northeast Research and Extension Center in Dixon County near Concord, NE. The silt loam soil at this location was in the Nora Series (Udic Haplustoll, fine-silty, mixed, mesic) on a 10% slope (SCS, 1978). The Soil Conservation Service describes this soil as friable with soil erosion from water constituting the main hazard.

To obtain similar initial conditions prior to planting soybeans in 1982 for the production of residue, all areas for plots were rotary tilled. The soybean variety Century was planted at approximately 371,000 seeds/ha with row spacings of 76 cm for wide row planting and 25 cm for narrow row planting.

At harvest in the fall of 1982, residue was distributed behind the combine with a straw spreader attachment. Soybean grain yields were 2,390 and 2,000 kg/ha for the wide and narrow row plot areas, respectively.

A completely randomized design was used to compare two treatments in a series of tillage and planting systems. The primary treatment comparison was between residue from soybeans which had been grown in wide spaced (76 cm) rows and residue from soybeans which had been grown in narrow spaced (25 cm) rows.

Individual tillage plots, which were 9.1 m wide and 22.9 m long, were positioned to obtain nearly equivalent slopes. All tillage and planting operations were performed in the spring of 1983 using standard production implements. Four tillage and planting systems, replicated three times, were evaluated in the soybean residue. Specific field operations, in order, within each system are listed in Table 1.

The till-plant plots were planted with a model 4500 six-row Buffalo* All-Flex Till-Planter (76 cm spacing, 25 cm sweep). All other plots were planted with a four-row John Deere model 7100 planter (76 cm spacing) with rippled coulters. All planting occurred on the same date, and planting depth was 5 cm.

Soil erosion was measured, soon after planting and prior to the establishment of virtually any canopy cover, from a sub-plot, 3.0 m wide and 10.7 m long, located within each of the larger individual tillage plots. A rotating boom rainfall simulator (Swanson, 1965) was used to apply water at a rate of 63.5 mm/h until runoff had been at equilibrium for approximately 20 min. Equilibrium conditions were usually reached within 30 to 45 min after rainfall initiation. The rainfall simulator, applying 63.5 mm of rainfall in an hour, has a rainfall erosion index (EI) similar to a single storm event expected to occur once every two yr in eastern Nebraska (Wischmeier and Smith, 1978). Every 3 min, the runoff rate was determined from gravimetric mesurements and a 0.5 L sample of runoff water was collected to determine sediment concentration. The percentage of the soil surface covered with residue immediately prior to rainfall simulation was measured using the photographic grid method described by Laflen et al. (1978). Rainfall simulations took place May 24 through 31, 1983.

Duncan's Multiple Range Test was employed for the statistical analyses. The ten percent level (P=0.10) was used to determine significant differences.

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

TABLE 2. MEASURED SURFACE RESIDUE COVER, SOIL LOSS, AND SOIL EROSION RATE FOR TILLAGE AND PLANTING SYSTEMS USED IN RESIDUE FROM SOYBEANS THAT HAD BEEN GROWN UP-AND-DOWN HILL WITH BOTH WIDE (76 cm) AND NARROW (25 cm) ROW SPACINGS ON A SILT LOAM SOIL HAVING A 10% SLOPE.

	Residue cover,† %		Soil loss,‡ t/ha		Soil erosion rate,§ t/(ha·h)	
Tillage and planting system	Wide rows	Narrow rows	Wide rows	Narrow rows	Wide rows	Narrow rows
Double disk	10.6[a]	8.4[a]	10.1[ab] *	4.9[ab]	27.8[ab] *	16.2[ab]
Till-plant	23.9[a]	19.5[b]	14.2[a]	6.0[a]	41.6[a]	24.7[a]
Strip rotary-till	11.6[a]	14.5[b]	7.8[b]	5.1[ab]	22.3[b]	16.8[a]
No-till	48.4[b]	46.3[c]	5.1[b]	2.1[b]	13.1[b]	7.8[b]

*A significant difference exists between wide and narrow row residue for these tillage treatments only (Duncan's Multiple Range Test, 10% level of significance).
†Residue cover measurements taken after tillage and planting, but prior to rainfall simulation.
‡Total accumulated soil loss after 50 mm of water application.
§Soil erosion rate after reaching equilibrium conditions between water application and water runoff.
a,b,c Values within each column having the same superscript are not significantly different (Duncan's Multiple Range Test, 10% level of significance).

RESULTS AND DISCUSSION

Soil Surface Cover

Residue cover ranged from 8.4 to 48.4% for the tillage and planting systems evaluated (Table 2). There were no significant differences between the percent residue cover remaining after planting for the same systems used in residue from wide and narrow row soybeans. However, there tended to be less residue cover for the tillage treatments used in residue from narrow rows. The no-till treatment had significantly more cover than the other three systems for both residue spacings, while the double disk system had significantly less cover in the narrow row residue.

Definitions of conservation tillage indicate that at least 20 to 30% of the soil surface should remain covered with residue after planting (Dickey et al., 1984; CTIC, 1984). Only no-till planting consistently left more than a 20% surface cover in soybean residue (Table 2). Even though the average soybean residue cover for the till-plant treatment was about 20%, not all individual plots were consistently above the 20% criterion. The double disk and strip rotary-till systems did not leave enough residue cover to be considered as conservation tillage systems.

Soil Erosion

Cumulative soil losses from the tillage treatments evaluated are shown in Fig. 1. The till-plant system used in wide row residue had the greatest soil loss. The till-plant, double disk, and strip rotary-till systems used in narrow row residue all had similar soil losses up to approximately 45 mm of water application. Beyond this point, soil loss from the till-plant system increased more than the losses from the other systems. This illustrates that till-planting up-and-down hill may have appreciable soil erosion. Even though residue cover on the soil surface averaged about 20%, the residue was not

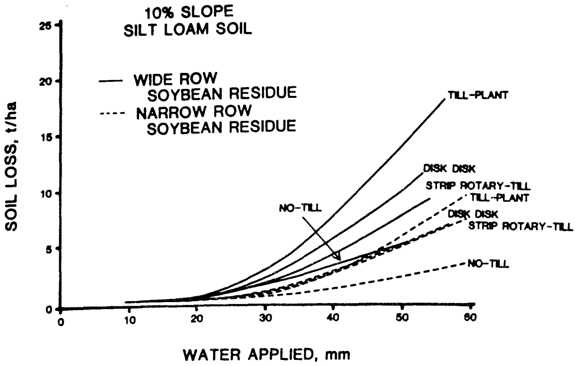

Fig. 1—Cumulative soil loss vs. water application for different tillage and planting treatments used in residue from soybeans that had been grown with wide (76 cm) and narrow (25 cm) row spacings.

uniformly distributed, which allowed channeling to occur in the cleanly tilled strips.

When averaged across tillage systems, soil losses were 52% less from treatments used in residue from narrow row soybeans compared to soil losses in residue from wide row soybeans, but the difference was significant only for the double disk system (Table 2). No-till planting had the least amount of soil loss for each soybean residue row spacing. When averaged across residue row spacing, no-till planting reduced erosion by approximately 54 and 65% compared to the double disk and till-plant systems, respectively.

For a more complete evaluation of soil losses from the various tillage systems and residue row spacings, soil erosion rates were determined for the period after equilibrium was reached between water application and water runoff (Table 2). Similar to the cumulative soil loss data, the equilibrium erosion rates averaged across tillage systems following narrow row soybeans were 37% less than from the wide row spacing. Only the double disk system showed a significant difference in soil erosion rate between residue from wide and narrow row soybeans. The no-till system achieved a 53 and 52% reduction in erosion rate compared to the double disk system, and an 81 and 62% reduction compared to the till-plant system used in residue from wide and narrow row soybeans, respectively. Even though these differences were substantial, they were significant only between the no-till and till-plant systems.

Soil Erosion and Surface Cover

The data on crop residue cover and soil erosion were analyzed using non-linear curve fitting techniques. The equation,

$$\text{Erosion} = Ae^{B \cdot RC} \quad \text{[1]}$$

where A and B are regression coefficients and RC is the percent surface cover, was fitted to the data to minimize the residual sum of squares of the untransformed data. The till-plant treatment was not included in these analyses because the residue was in strips between cleanly tilled rows and thus was not uniformly distributed. The data were separated by residue row spacing, and the correlation coefficients were 0.69 and 0.73 for the wide and narrow row soybean residues, respectively.

The B coefficients, which indicate the rate of change in soil erosion as a function of residue cover, were −0.012 for soybean residue in wide rows and −0.018 for residue in narrow rows, indicating that residue cover from either of the two row spacings would reduce erosion by about the same amount. These values were outside the range of −0.03 to −0.07 reported for row cropped land for other soil loss versus residue cover relationships (Laflen et al., 1980; Laflen and Colvin, 1981; Dickey et al., 1984 and 1985).

The intercept coefficient A, which predicts the soil erosion which would occur when no residue cover was present, was 9.8 t/ha following wide row soybeans and 5.9 t/ha following narrow rows. Thus, for a cleanly tilled, residue free soil condition, soil erosion would be 40% greater following wide row soybeans than following narrow row soybeans on this silt loam soil having a 10% slope.

The difference in the intercept coefficient (A) for the two residue spacings shows that there are other factors which influence erosion even though percent residue cover may be the fundamental factor. Evidence of this is also given by Dickey et al. (1985) in a comparison of corn and soybean residue where there were reported differences in total soil loss from the different types of residue, even though soil types and percent covers were the same.

Runoff

Accumulated runoff from all four tillage systems used in residue from wide row soybeans tended to be greater than for the same systems used in residue from narrow rows (Table 3). Although no statistical differences were measured in either water runoff or equilibrium runoff rates, the trends indicated that runoff was reduced by 30% and runoff rate was reduced by 11% for soybean residue in narrow rows compared to residue in wide rows. Residue in narrow rows therefore tended to be more effective in retaining moisture, similar to the trend for reduced soil loss. It may have been that in the narrow row residue treatments, soybean plant roots were distributed more uniformly over the plot area, thus providing a more uniform series of pathways for water infiltration.

The till-plant treatment used in residue from narrow row soybeans retained the most applied water of all treatments, as evidenced by the longest time for runoff to occur and the least amount of accumulated runoff (Table 3). This result is in contrast to the significantly high soil loss and soil erosion rate of the till-plant treatment, even in narrow row residue. A further contrast in tillage treatments is evident for the no-till system used in wide row residue, where the accumulated runoff was the greatest and the time to the start of runoff was short, but soil loss and soil erosion rate were relatively small. This illustrates that a no-till system may not necessarily be a superior system for reducing water runoff, but it tends to be the most effective for reducing soil loss. On the other hand, a till-plant system may be very effective in retaining moisture from low-volume rainfall events, but once runoff begins, soil losses may be large.

Sediment Concentration

Sediment concentrations in the runoff during rainfall simulation are illustrated in Fig. 2. The sediment

TABLE 3. MEASURED WATER RUNOFF START TIMES, ACCUMULATED WATER RUNOFF, RUNOFF RATE, AND AVERAGE SEDIMENT CONCENTRATION IN THE RUNOFF WATER FOR TILLAGE AND PLANTING SYSTEMS USED IN RESIDUE FROM SOYBEANS THAT HAD BEEN GROWN UP-AND-DOWN HILL WITH BOTH WIDE (76 cm) AND NARROW (25 cm) ROW SPACINGS ON A SILT LOAM SOIL HAVING A 10% SLOPE.

	Start of runoff,† min.		Accumulated runoff,‡ mm		Runoff rate,§ mm/h		Sediment concentration,‖ ppm	
Tillage and planting system	Wide rows	Narrow rows	Wide rows	Narrow rows	Wide rows	Narrow rows	Wide rows	Narrow rows
							(x1000)	
Double disk	11.0[a]	12.7[a]	11.9[a]	8.4[a]	34.3[a]	31.0[a]	90.0[b]	58.4[b]
Till-plant	14.7[b]	17.3[b]	10.7[a]	7.1[a]	30.7[a]	26.7[a]	129.3[a]	85.9[a]
Strip rotary-till	13.0[ab]	10.3[a]	10.9[a]	8.9[a]	30.0[a]	28.7[a]	71.4[bc]	56.9[b]
No-till	10.7[a]	11.7[a]	12.4[a]	7.9[a]	30.5[a]	25.4[a]	41.5[c] *	25.6[c]

*A significant difference exists between wide and narrow row residue for these tillage treatments only (Duncan's Multiple Range Test, 10% level of significance).

†Minutes of elapsed time from start of water application until runoff occurred.

‡Total accumulated water runoff after 50 mm of water application.

§Water runoff rate after reaching equilibrium conditions between water application and water runoff.

‖Sediment concentrations were determined by dividing the total accumulated soil loss by the total accumulated runoff after 50 mm of water application.

a,b,c Values within each column having the same superscript are not significantly different (Duncan's Multiple Range Test, 10% level of significance).

concentration tended to increase as the rate of runoff increased, until an equilibrium condition was obtained. Equilibrium conditions were generally established after a water application of 30 mm. Once equilibrum was established, the no-till system had the least sediment concentration in the runoff, regardless of residue row spacing. The till-plant system used in wide row residue had the greatest concentration of sediment in the runoff water, reflecting the high soil loss shown in Fig. 1.

The till-plant system used in wide row residue had the greatest total concentration of sediment in the runoff water, nearly 130,000 ppm (Table 3). This concentration was significantly greater than from the other three tillage and planting treatments. This further emphasizes the point made by Dickey et al. (1985), that till-planting can be a poor system choice for up-and-down hill planting.

The sediment concentration in the runoff water was reduced significantly when using a no-till system in narrow row residue (Table 3). This combination also gave the least sediment concentration of any row spacing and tillage combination despite the greater amount of

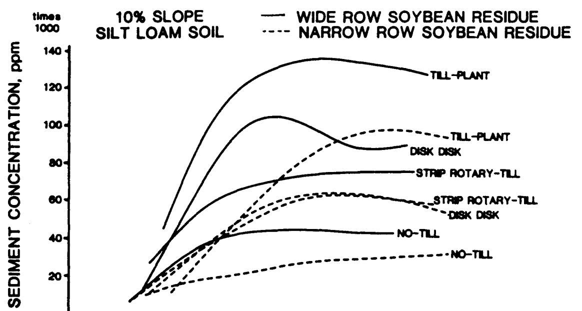

Fig. 2—Sediment concentration in the runoff water vs. water application for different tillage and planting treatments used in residue from soybeans that had been grown with wide (76 cm) and narrow (25 cm) row spacings.

runoff water. Overall, plots with residue from narrow rows had 32% lower sediment concentration than plots with residue from wide rows.

SUMMARY AND CONCLUSIONS

Soil erosion losses from selected tillage and planting systems were evaluated using a rotating boom rainfall simulator. The tillage systems were used on a silt loam soil in the Nora Series having a 10% slope. Replicated plots were established up-and-down hill in residue from soybeans that had been grown with both wide and narrow row spacings.

Soil erosion, averaged across tillage treatments, was reduced by more than 50% and soil erosion rate was reduced by 37% in residue from soybeans which had been grown in narrow rows compared to residue from wide rows. However, the differences between row spacings within the same tillage treatment were only significant at the ten percent level for the double disk tillage system.

While not significant, the time required for water runoff to occur was generally greater for the tillage systems used in the narrow row residue. Similarly, water runoff decreased by up to 36%, and water runoff rate was reduced by as much as 17% for tillage systems used in residue from narrow row soybeans as compared to systems used in wide row residue.

The till-plant system was effective in retaining moisture during the first portion of a rainfall event. However, once runoff began, soil losses were substantial. For effective erosion control, the till-plant system should not be used up-and-down hill.

No-till planting, without exception, left significantly more residue on the soil surface and had the least soil loss. However, no-till planting into residue from wide rows had the greatest accumulated water runoff.

No-till planting was the only system which consistently met the minimum conservation tillage criterion of 20% residue cover after planting in either the wide or narrow row soybean residue.

The amount of residue cover on the soil surface was the dominant factor in determining soil erosion. However, other influences among items such as tillage, soil properties, plant spacing, and residue type need to be investigated and further characterized.

References

1. Colvin, T. S. and D. C. Erbach. 1982. Soybean response to tillage and planting methods. TRANSACTIONS of the ASAE 25(6):1533-1535+.

2. Colvin, T. S. and J. M. Laflen. 1981. Effect of corn and soybean row spacing on plant canopy, erosion, and runoff. TRANSACTIONS of the ASAE 24(3):1227-1229.

3. Colvin, T. S., D. C. Erbach, and J. M. Laflen. 1980. Managing corn and soybean residue. ASAE Paper No. 80-1012, ASAE, St. Joseph, MI 49085-9659.

4. Conservation Tillage Information Center (CTIC). 1984. 1983 National Survey Conservation Tillage Practices. Fort Wayne, IN. 137 pp.

5. Dickey, E. C., C. R. Fenster, J. M. Laflen, and R. H. Mickelson. 1983. Effects of tillage on soil erosion in a wheat-fallow rotation. TRANSACTIONS of the ASAE 26(3):814-820.

6. Dickey, E. C. and A. R. Rider. 1980. Eastern Nebraska row-crop tillage systems. Proc. of Crop Production with Conservation in the 80's. ASAE Publ. 7-81. ASAE, St. Joseph, MI 49085-9659.

7. Dickey, E. C., D. P. Shelton, P. J. Jasa, and T. R. Peterson. 1984. Tillage, residue and erosion on moderately sloping soils. TRANSACTIONS of the ASAE 27(4):1093-1099.

8. Dickey, E. C., D. P. Shelton, P. J. Jasa, and T. R. Peterson. 1985. Soil erosion from tillage systems used in soybean and corn residues. TRANSACTIONS of the ASAE 28(4):1124-1129, 1140.

9. Erbach, D. C. 1982. Tillage for continuous corn and corn-soybean rotation. TRANSACTIONS of the ASAE 25(4):905-911, 918.

10. Jasa, P. 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 (this issue).

11. 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.

12. Laflen, J. M. and T. S. Colvin. 1981. Effect of crop residue on soil loss from continuous row cropping. TRANSACTIONS of the ASAE 24(3):605-609.

13. Laflen, J. M. and T. S. Colvin. 1982. Soil and water loss from no-till, narrow-row soybeans. ASAE Paper No. 82-2023, ASAE, St. Joseph, MI 49085-9659.

14. Laflen, J. M. and W. C. Moldenhauer. 1979. Soil and water losses from corn-soybean rotation. Soil Sci. Soc. Amer. J. 43:1213-1215.

15. Laflen, J. M., W. C. Moldenhauer, and T. S. Colvin. 1980. Conservation tillage and soil erosion on continuous row cropped land. Proc. of Crop Production with Conservation in the 80's. ASAE Publ. 7-81. ASAE, St. Joseph, MI 49085-9659.

16. Moomaw, R. S. 1985. Personal communication. Professor and Extension Agronomist. University of Nebraska Northeast Research and Extension Center, Concord, NE.

17. Nebraska Crop and Livestock Reporting Service (NCLRS). 1984. Nebraska Agricultural Statistics Annual Rpt. 1982-1983. Lincoln, NE.

18. Nicol, K. H., E. O. Heady, and H. L. Madsen. 1974. Models of soil loss, land and water use, spatial agricultural structure and the environment. Center for Agr. and Rural Develop., CARD Rpt. 49T. Iowa State Univ., Ames.

19. Seay, E. E. 1970. Minimizing abatement costs of water pollutants from agriculture. A parametric linear programming approach. Ph.D. thesis, Iowa State Univ., Ames.

20. Siemens, J. C. and W. R. Oschwald. 1978. Corn-soybean tillage systems: erosion control, effects on crop production, costs. TRANSACTIONS of the ASAE 21(2):293-302.

21. Soil Conservation Service (SCS). 1978. Soil survey of Dixon County, Nebraska. USDA-SCS.

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

23. Wischmeier, W. H. and D. D. Smith. 1978. Predicting rainfall erosion losses. USDA Agr. Handbook 537.