Runoff and Erosion as Affected by Corn Residue: Part I. Total Losses

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ABSTRACT

THE effects of varying rates of corn residue on runoff and erosion from a loess soil in southwestern Iowa were measured using a rainfall simulator. Consistent reductions in runoff, sediment concentration and soil loss resulted from increased residue application. Small amounts of surface cover produced substantial reductions in erosion. A regression equation relating surface cover to residue weight was obtained. Equations describing relative runoff, sediment concentration and soil loss as a function of surface cover were also developed using regression analysis.

INTRODUCTION

A thin surface seal with decreased infiltration capacity may develop near the soil surface as a result of raindrop impact (Epstein and Grant, 1967). Residue cover reduces soil compaction caused by impacting raindrops thus helping to maintain a greater infiltration rate (Mannering and Meyer, 1963). Maintenance of infiltration rate may result in reduced runoff (Kramer and Meyer, 1969).

Residue cover also protects a portion of the soil surface from raindrop impact, thus reducing soil detachment (Mannering and Meyer, 1963). A reduction in sediment transport capacity of flow could result from smaller runoff velocities caused by surface residue. Both of these factors may contribute to reduced sediment concentration.

Residue may also create small ponds in which sedimentation can occur (Laflen and Colvin, 1981; and Brenneman and Laflen, 1982). The volume of water stored in individual ponds may be small, but the cumulative effect caused by a large number of ponds can be substantial. Thus, residue cover serves to decrease soil loss because of induced ponding and reduction in runoff and sediment concentration.

Several rainfall simulation studies have been conducted using wheat straw residue (Mannering and Meyer, 1963; Meyer et al., 1970; Lattanzi et al., 1974; Harmon and Meyer, 1978; and Dickey et al., 1983). Rainfall simulation investigations on different tillage systems with varying rates of corn residue have been reported (Meyer and Mannering, 1961; Wittmuss and Swanson, 1964; Laflen et al., 1978; Hussein and Laflen, 1982; Dickey et al., 1984). The effects of soybean residue on runoff and erosion from different tillage systems have also been examined (Laflen and Colvin, 1981; Hussein and Laflen, 1982; and Dickey et al., 1985).

Many of the previous studies on the effects of crop residue on runoff and erosion were conducted using different tillage systems. The quantity of residue found on the soil surface for a given tillage system at a particular time is a function of many interrelated crop management factors. Differences in runoff and erosion rate between tillage systems may be influenced not only by residue cover but also by varying soil and crop management conditions.

The present study was designed to examine surface residue as an experimental variable without other compounding crop management factors. The two principal factors examined in the present investigation were antecedent soil water content and corn residue rate. The objective of this study was to determine the effects of varying rates of unanchored corn residue on runoff, sediment concentration and soil loss under uniform tillage conditions.

PROCEDURE

The study was conducted in southwestern Iowa near Treynor. The Monona soil at the site (fine-silty, mixed mesic typic Hapludolls) developed on a deep loessal mantle overlying glacial till. Average slope gradient at the location was 5.2%.

Crop residues on the soil surface were first removed and stored for future use. The area was then disked and roto-tilled to depths of approximately 15 and 8 cm, respectively. Following tillage, the plots were covered with plastic to maintain similarity in soil moisture conditions.

Prior to simulation testing, previously stored residue was returned to the plot surface in a random orientation at rates of 0.00, 1.12, 3.36, 6.73 and 13.45 t/ha. Each of the residue rates was replicated once. Residue cover was measured using the point quadrant method (Mannering and Meyer, 1963). Plots were 3.7 m across the slope by 22.1 m long.

A portable rainfall simulator designed by Schulz and Yevjevich (1970) was used to apply rainfall for a one hour duration at a design intensity of approximately 28 mm/h. The first rainfall application (initial run) occurred at existing soil-water conditions while the wet and very wet runs were conducted approximately 24 and 48 h later, respectively. Standard procedures were used to measure average rainfall intensity, runoff and soil loss (Meyer, 1960).

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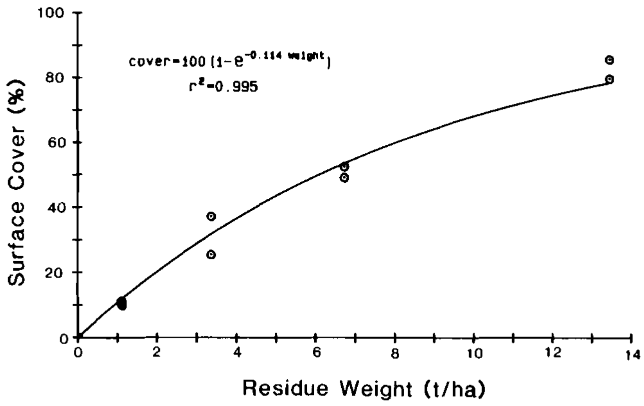

Fig. 1—The relationship between surface cover and residue weight.

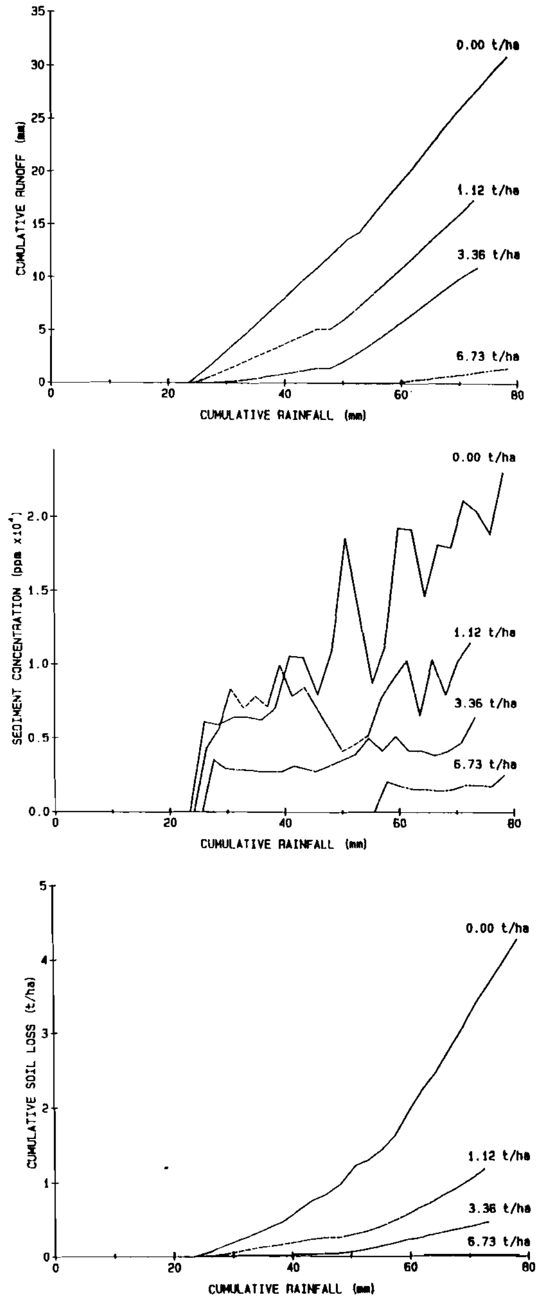

Fig. 2—The relationship between cumulative runoff, sediment concentration and cumulative soil loss and cumulative rainfall for four corn residue treatments.

RESULTS

Soil loss is the product of runoff times sediment concentration. Both runoff and sediment concentration may be significantly influenced by surface cover. Therefore, surface cover, runoff, sediment concentration and soil loss will be discussed separately to better describe the erosion process.

Surface Cover

Residue rates of 1.12, 3.36, 6.73 and 13.45 t/ha produced surface cover of 10, 31, 51 and 83%, respectively, as shown in Fig. 1. The data presented in Fig. 1 was used to develop the following regression equation:

$$\text{Surface cover} = 100\,(1-e^{-0.114\ \text{weight}})\ .\ .\ .\ .\ .\ .\ .\ .\ .\ [1]$$

where surface cover is given as a percentage and residue weight is measured in t/ha. The coefficient of determination, r^2, for the above equation is 0.995. The above equation allows estimation of surface cover from easily obtained residue weight measurements.

Runoff

Cumulative runoff for each of the corn residue treatments is shown in Fig. 2. Addition of increasing amounts of residue consistently reduced runoff. Total runoff and runoff rate during the final 5 min of each simulation event are reported in Table 1.

During the initial run, runoff did not occur on any of the treatments. Runoff was minimal on the 6.73 t/ha treatment, occurring only during the very wet simulation run. A residue rate of 13.45 t/ha prevented runoff for all three simulation events.

A runoff mulch factor - surface cover relation was obtained by dividing total runoff for each of the residue treatments (Table 1) by runoff for conditions without residue. The relationship between runoff mulch factor and surface cover is presented in Fig. 3. For surface

TABLE 1. RUNOFF, RUNOFF RATE, SEDIMENT CONCENTRATION, SOIL LOSS AND SOIL LOSS RATE FOR FIVE CORN RESIDUE TREATMENTS*

Residue rate, t/ha	Run	Runoff, mm	Runoff rate, mm/h†	Sediment concentration, ppm x 10^3	Soil loss, t/ha	Soil loss rate, t/ha h†
0.00	All runs	30.8a‡	15.6a	12.9a	4.26a	3.24a
1.12	All runs	17.4b	10.7ab	7.5ab	1.17b	0.94b
3.36	All runs	11.0c	6.0bc	3.7bc	0.46b	0.33b
6.73	All runs	1.4d	1.8c	2.1bc	0.03b	0.04b
13.45	All runs	0.0d	0.0c	0.0c	0.00b	0.00b
0.00	Wet	13.5a	15.6a	8.7a	1.21a	2.86a
1.12	Wet	5.1b	6.8b	7.1ab	0.25b	0.24b
3.36	Wet	1.4bc	2.5b	2.9ab	0.04b	0.07b
6.73	Wet	0.0c	0.0b	0.0b	0.00b	0.00b
13.45	Wet	0.0c	0.0b	0.0b	0.00b	0.00b
0.0	Very wet	17.3a	15.5a	17.0a	3.05a	3.61a
1.12	Very wet	12.3ab	14.5a	7.9ab	0.92ab	1.64ab
3.36	Very wet	9.6b	9.4b	4.4b	0.42b	0.59b
6.73	Very wet	1.4c	1.8c	2.1b	0.03b	0.04b
13.45	Very wet	0.0c	0.0d	0.0b	0.00b	0.00b

*Plots were 3.7 by 22.1 m with an average slope gradient of 5.2%. Values given are the average of two replications. Runs lasted for a 60-min duration. Rainfall intensity was approximately 28 mm/h.

†Average rate during the final 5 min of the run. Averages were calculated only for those runs in which runoff occurred.

‡Within each type of run and for each column, differences are significant at the 5% level (Duncan's multiple range test) if the same letter does not appear.

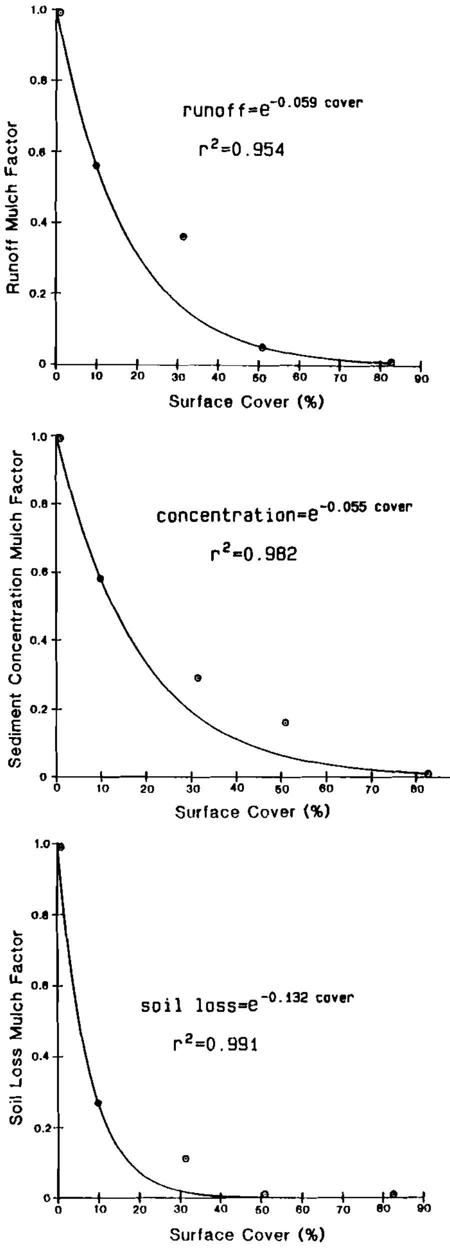

Fig. 3—The relationship between runoff, sediment concentration and soil loss mulch factor and surface cover.

cover given as a percentage, the following relation was obtained:

$$\text{Runoff mulch factor} = e^{-0.059\ \text{cover}} \quad \ldots\ldots\ldots\ldots [2]$$

which has a coefficient of determination, r^2, of 0.954. The reported runoff mulch factors are dependent upon study site soil characteristics, slope gradient and rainfall intensity and duration.

Sediment Concentration

Sediment concentration of runoff versus cumulative rainfall for the various corn residue treatments is presented in Fig. 2. Reductions in sediment content occurred with increased residue application. Average sediment concentration for each of the simulation runs is reported in Table 1.

Sediment concentration for each of the residue treatments was divided by sediment concentration for conditions without residue to obtain mulch factors. Fig. 3 contains sediment concentration mulch factors used to develop the following equation:

$$\text{Sediment concentration mulch factor} = e^{-0.055\ \text{cover}} \quad \ldots\ldots\ldots\ldots [3]$$

where surface cover is given as a percentage. The coefficient of determination, r^2, for the above equation is 0.982. Fig. 3 demonstrates the relative effectiveness of surface residue in reducing sediment concentration of runoff for the given experimental conditions.

Soil Loss

Cumulative soil loss versus cumulative rainfall for the various residue treatments is also presented in Fig. 2. Increased infiltration and reduced sediment concentration of runoff both contributed to decreased soil loss rates. Total soil loss and soil loss rate during the final 5 min of each simulation run are given in Table 1. Even a small addition of residue resulted in a substantial soil loss reduction. For the given experimental conditions, soil loss was essentially eliminated by a residue rate of 6.73 t/ha (surface cover of 51%).

The reported soil loss measurements were collected at the bottom of the runoff plots. These soil loss values were a composite of rill and interrill losses occurring in upslope areas. The upslope rill and interrill runoff and erosion components were examined by Gilley et al. (1986).

A soil loss mulch factor was obtained by dividing total soil loss for each of the residue treatments by soil loss for conditions without residue. The relationship between soil loss mulch factor and surface cover is presented in Fig. 3. For surface cover given as a percentage, the following relation was obtained:

$$\text{Soil loss mulch factor} = e^{-0.132\ \text{cover}} \quad \ldots\ldots\ldots [4]$$

which had a coefficient of determination, r^2, of 0.991. The effectiveness of surface residue in reducing soil loss for the given experimental conditions is shown in Fig. 3.

SUMMARY AND CONCLUSIONS

A rainfall simulator was used to measure runoff and erosion under uniform tillage conditions from plots having corn residue rates ranging from 0.00 to 13.45 t/ha. Increased rates of unanchored corn residue consistently resulted in reduced runoff, sediment concentration and soil loss. Erosion was minimal on plots with corn residue of 6.73 t/ha. No runoff occurred on the 13.45 t/ha residue treatment for the given soil and rainfall conditions.

A regression equation was derived that related surface cover to residue rate. Runoff, sediment concentration and soil loss mulch factors were determined by dividing the parameter values measured for a particular surface cover by corresponding values obtained for conditions without residue. Regression equations were identified that related runoff, sediment concentration and soil loss mulch factors to surface cover. Each of the mulch factors were found to be highly correlated to surface cover. Experimental results indicate that for a given rainfall rate, soil condition, and slope gradient, a mulch factor can be used to relate surface cover to runoff, sediment concentration and soil loss.

Surface mulch was shown to be beneficial in reducing runoff, sediment concentration and soil loss under uniform tillage conditions. The effectiveness of a particular conservation tillage system is influenced by the amount of crop residue maintained on the soil surface. Maintenance of adequate surface cover may serve to protect soil and water resources.

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