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Runoff and Erosion as Affected by Corn Residue: Prt II: Rill and Interill Components

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Runoff and Erosion as Affected by Corn Residue: Part II. Rill and Interrill Components

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ABSTRACT

HYDRAULIC and soil loss variables were measured under simulated rainfall conditions at selected downslope distances on plots with corn residue rates ranging from 0.00 to 6.73 t/ha. Application of corn residue produced substantial reductions in runoff rate, runoff velocity, sediment concentration and soil loss rate along the entire slope length. On those plots subject to rilling, runoff rate, sediment concentration and soil loss rate usually increased with downslope distance.

Rill and interrill sediment concentration and soil loss rate were also measured at selected slope lengths. Interrill sediment concentration changed little with downslope distance while greater interrill soil loss rates were observed with increasing slope length. Rill sediment concentration and soil loss rate increased rapidly near the bottom of the plots.

INTRODUCTION

Upland soil erosion is classified into rill and interrill components. Rill erosion consists of the removal of soil by concentrated flow in small, but well defined channels. The existence of rills indicates the potential for excessive erosion.

Interrill erosion in contrast, takes place in the region of shallow overland flow occurring between rills. Raindrop impact is the primary soil detaching mechanism on interrill regions. Soil particles detached by raindrop impact may be transported from the impact area by shallow overland flow.

Several studies have been conducted to characterize rill and interrill soil erosion components. Mosley (1972) examined the morphologic characteristics of small rill systems and their influence on soil loss rates. The relative importance of raindrop impact and flowing water to the erosion process was evaluated by Young and Wiersma (1973). Meyer et al. (1975) conducted field studies to measure rill erosion as affected by flow rate and canopy cover. The effect of slope length on soil loss for selected conservation tillage systems was determined by Laflen et al. (1978). Erosion resulting from added discharge and simulated rainfall on untilled soil with various rates of cornstalk mulch was determined by Foster et al. (1982). Dickey et al. (1983) measured rates of erosion for different slope lengths and tillage treatments on wheat fallow rotations. The effects of varying rates of unanchored corn residue on runoff, sediment concentration and soil loss under uniform tillage conditions were reported by Gilley et al. (1986).

Identification of hydraulic variables occurring in association with soil loss parameters along a slope could provide a more thorough description of the erosion process. Dye dilution techniques have been widely used to identify hydraulic variables in stream and river studies. Fluorescent dyes, utilized in dye dilution techniques, are economical, easy to handle and can be measured quantitatively in very low concentrations.

Information on fluorometric procedures for time-of-travel and discharge studies has been presented (Wright and Collings, 1964; Wilson, 1968; and Chase and Payne, 1970). Valiation of the dye-dilution technique for measurement of flow was described by Kilpatrick (1968) and Morgan et al. (1977). Kilpatrick (1970) also presented dye requirements for slug injections into streams. Eight fluorescent dyes were compared by Smart and Laidlaw (1977) in laboratory and field experiments to assess their suitability in quantitative tracing work.

In many of the previous erosion investigations, total runoff and erosion were usually measured at a single discharge location. Information concerning rill and interrill contributions to runoff and erosion along a slope is limited. The objective of the study was to quantify hydraulic variables and erosion rates on rill and interrill areas as affected by varying amounts of corn residue.

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 residue on the soil surface was first removed and stored for future use. The area was then disked and rototilled 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 and 6.73 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

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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 and total runoff (Meyer, 1960).

Runoff samples for determining sediment concentration were obtained once steady state runoff conditions had become established during the very wet simulation run. A stage recorder mounted on an HS flume was used to determine steady state runoff conditions. Samples approximately 800 mL in size were collected in polyethylene bags at the point where each rill (concentrated flow area in which soil scouring had occurred) or concentrated flow channel (area in which soil scouring had not occurred) discharged into the collection trough.

Additional upstream samples were obtained along two of the channels on each plot at approximately 3 m intervals. Samples were collected under uniform runoff conditions following two previous rainfall simulation events. As a consequence, it was assumed that rill and interrill soil loss rates had become uniform by this stage of simulation testing.

Once runoff samples had been collected from the rills, liquid paraffin was placed along the wetted perimeter of any rill in which scouring had occurred to prevent future rill development. Additional rainfall simulation testing was then performed and samples for runoff rate and sediment concentration determinations were again collected at the same locations used previously. Since the rill networks were sealed and therefore could no longer serve as source areas for soil detachment, sediment moving along the rills originated primarily from interrill regions. Sediment concentration and soil loss rate of the rill were obtained by subtracting interrill values from measurements obtained before rill stabilization. Sediment transport by raindrop splash was assumed to be negligible.

Samples for measuring discharge using dye dilution techniques were collected at each of the points used to sample sediment content. A known concentration of rhodamine WT fluorescent dye was continuously injected into the channel at a uniform rate. Runoff samples from the entire channel cross section were then obtained to determine the quantity of flow that had mixed with the tracer (Replogle et al., 1966). The runoff samples were filtered immediately after collection to minimize dye adsorption onto sediment materials. A fluorometer was used to determine dye concentration.

Some adsorption of dye onto soil materials was observed. Total plot discharge measurements were made using both an HS flume and the dye dilution technique. To correct for dye adsorption onto soil materials, each of the concentrated flow discharge measurements were multiplied by the ratio of total discharge obtained using the HS flume to discharge measured using the dye dilution technique.

A fluorometer was also used to measure mean flow velocity (Hubbard et al., 1982). A slug of dye was injected into the channel and the amount of time required for the concentration peak to pass a downstream point was determined. Continuous pumping of the sample through the fluorometer flow cell produced a time-concentration curve. Mean flow velocity was obtained by dividing travel distance by time of travel. Since dye adsorption onto sediment materials did not affect travel time of the concentration peak, no corrections to velocity measurements were required.

RESULTS AND DISCUSSION

Rills formed during the wet rainfall simulation run on the 0.00 and 1.12 t/ha residue treatments. Rill formation did not occur on the plots with residue rates of 3.36 t/ha or greater but well defined concentrated flow channels were present. It was within the rills or concentrated flow channels that hydraulic variables and soil erosion rates were determined.

The area contributing to runoff becomes greater with increased downslope distance. Thus, larger discharge quantities may result at greater slope lengths. Variations in runoff rates and associated water depth and velocity may affect soil detachment, deposition and sediment transport. In the following discussion, runoff rate, runoff velocity, sediment concentration and soil loss rate will be quantified.

Runoff Rate

Runoff rate at selected downslope distances is shown in Fig. 1. Each curve represents average values from four channels. Discharge measurements were made on the two largest channels on each of the two replicated plots.

Runoff rate usually increased with slope length on the 0.00, 1.12 and 3.36 t/ha residue treatments, but changed little with downslope distance on the 6.73 t/ha residue treatment. The largest rate of increase in runoff rate was usually found near the bottom on the plots where several channels converged.

For each of the downslope distances, discharge from the plot with 0.00 t/ha residue cover varied substantially from the other treatments. Runoff rates were similar on the 1.12 and 3.36 t/ha residue treatments. Infiltration was greatest on the plot with the largest amount of residue. Residue serves to protect the soil surface from raindrop impact. As a consequence, infiltration rate is maintained and runoff is reduced.

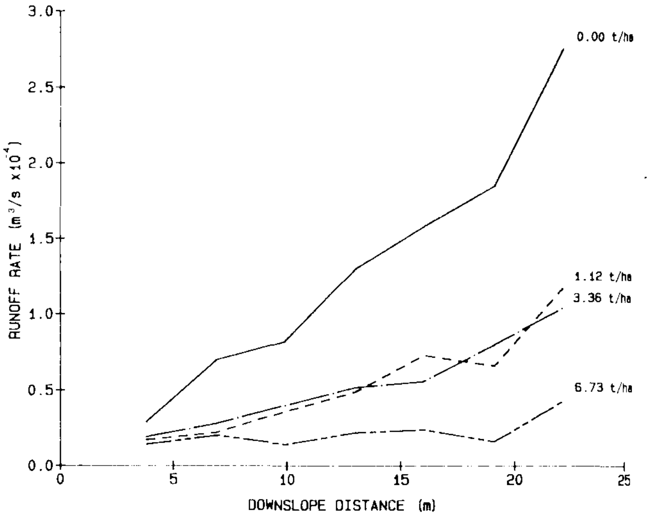

Fig. 1—Runoff rate at selected downslope distances for four corn residue treatments.

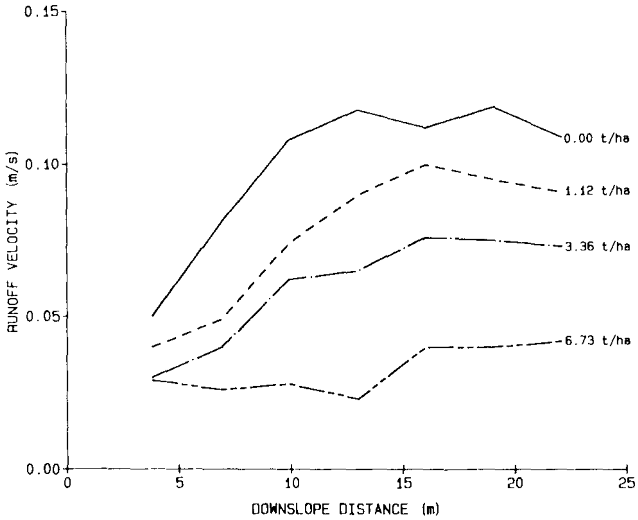

Fig. 2—Runoff velocity at selected downslope distances for four corn residue treatments.

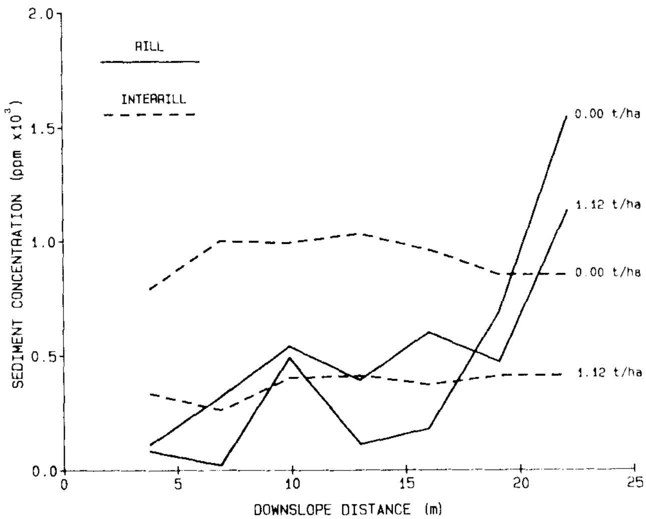

Fig. 4—Rill and interrill sediment concentration at selected downslope distances for two corn residue treatments.

Runoff Velocity

Runoff velocity as affected by slope length is shown in Fig. 2. Average values from four channels are represented by each curve. At a given downslope distance, reduced runoff velocity consistently resulted from increased residue rate. Little change in runoff velocity with downslope distance was found on the 6.73 t/ha residue treatment. For the other residue rates, runoff velocity increased rapidly in the upper plot area and then varied little with increased slope length.

Runoff rate was reduced on those plots with large rates of residue which would correspondingly decrease flow velocity. For a given discharge rate, smaller runoff velocity would result from increased hydraulic resistance caused by residue. Runoff followed a much more tortuous path on the plots with surface cover. The existence of numerous small ponds which formed behind the residue also served to reduce flow velocity. On those plots with large rates of residue, water movement occurs less frequently by concentrated flow. In contrast, on soil surfaces with little residue, water movement takes place at much greater flow velocities in well established, interconnected rill networks.

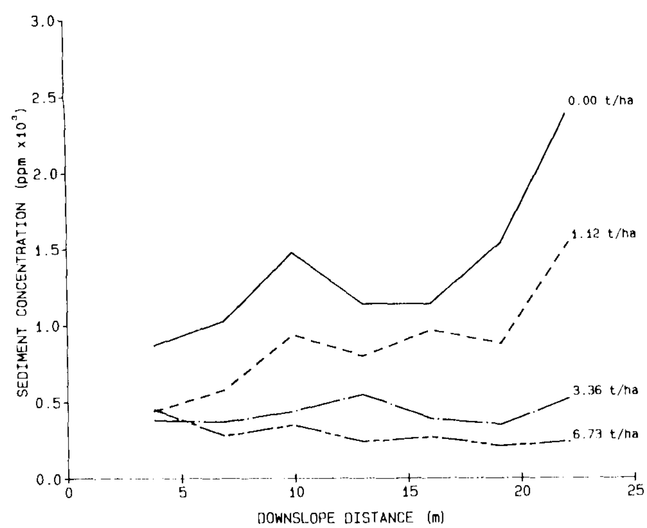

Fig. 3—Sediment concentration at selected downslope distances for four corn residue treatments.

Sediment Concentration

Sediment concentration at selected downslope distances is shown in Fig. 3. Each curve represents average values from four channels. For a given slope length, reduced sediment concentration usually resulted from increased residue rate. On the 3.36 and 6.73 t/ha residue treatments, runoff samples for determining sediment content were collected from concentrated flow channels in which soil scouring had not occurred. Little variation in sediment concentration was apparent from these areas. In contrast, well established rill systems were present on the 0.00 and 1.12 t/ha residue treatments. Substantial increases in sediment concentration occurred near the rill outlet locations.

Further evidence of rill and interrill contributions to sediment concentration is shown in Fig. 4. Average values from four channels are represented by each curve. The rill component of sediment concentration was obtained by subtracting total sediment content measurements obtained before rill stabilization from the interrill contributions. The interrill sediment concentration component showed little variation with downslope distance. Interrill sediment concentration contributions were greatest on the 0.00 t/ha residue treatment. Large increases in rill induced sediment concentration were found near the bottom of the plots.

Soil Loss Rate

Soil loss rate as affected by slope length is shown in Fig. 5. Each curve represents average values from four channels. For a given downslope distance, consistent reductions in erosion rate resulted from increased residue application. Soil loss rate for the 0.00 t/ha residue treatment was substantially larger than the other treatments for each of the downslope distances. On the 3.36 and 6.73 t/ha residue treatments, only minor variations in soil loss rate occurred with increased slope length. In contrast, for the other treatments, soil loss rate usually increased with downslope distance.

Rill and interrill erosion rate at selected slope lengths are presented in Fig. 6. Average values from four channels are represented by each curve. Interrill soil loss components were subtracted from total erosion measurements to obtain rill soil loss contributions. The

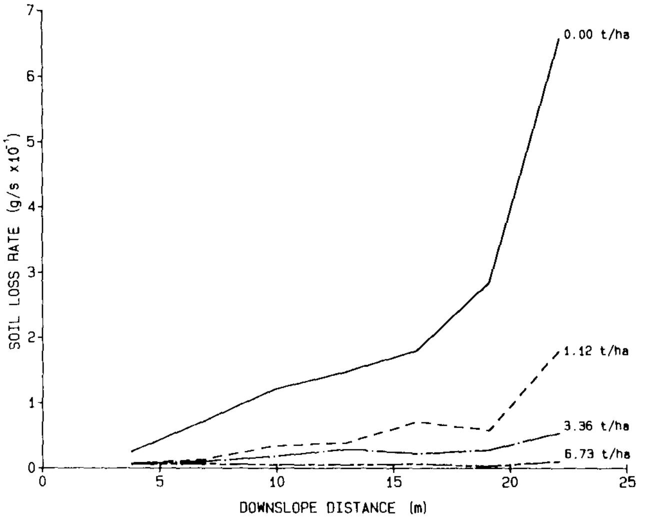

Fig. 5—Soil loss rate at selected downslope distances for four corn residue treatments.

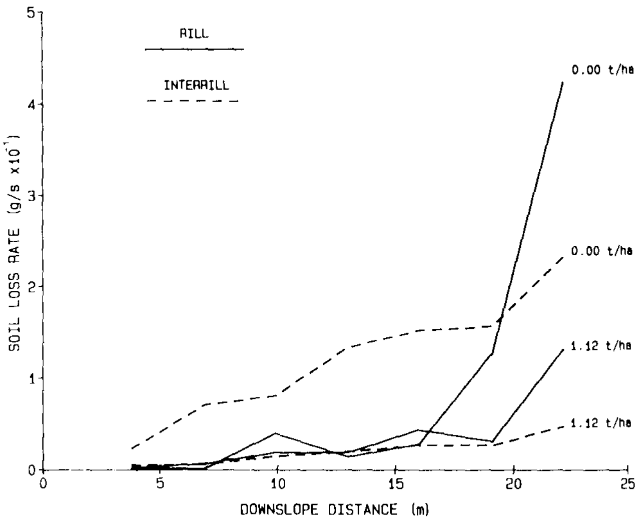

Fig. 6—Rill and interrill soil loss rate at selected downslope distances for two corn residue treatments.

smallest rill and interrill soil loss rates were found on the plots with greatest residue cover. In general, interrill erosion rate increased with slope length. Rill erosion was substantially larger near the bottom of the plots due to convergence of rills into larger channels.

SUMMARY AND CONCLUSIONS

Runoff rate, runoff velocity, sediment concentration and soil loss rate were measured on plots with corn residue rates ranging from 0.00 to 6.73 t/ha. Samples for runoff and soil loss determinations were collected during simulated rainfall events at various slope lengths. Dye dilution techniques were used to measure runoff rate and velocity at selected downslope locations.

Application of corn residue produced substantial reductions in runoff rate, runoff velocity, sediment concentration and soil loss rate along the entire plot length. For those plots on which rill formation occurred, runoff rate, sediment concentration and soil loss rate usually increased with downslope distance. Except for the 6.73 t/ha residue treatment where little change was noted, runoff velocity increased rapidly in the upper plot area and then varied little with slope length.

Only minor variations in interrill sediment concentration were observed on the 0.00 and 1.12 t/ha residue treatments. However, interrill erosion consistently increased with slope length due to greater interrill discharge rates. Large increases in rill sediment concentration and soil loss rate were measured near the bottom of the plots.

Many existing upland erosion models contain rill and interrill components. Detachment, deposition and sediment transport mechanisms occurring on both rill and interrill areas are frequently included as model elements. For the simulation models to function properly, runoff and soil loss variables throughout the eroding area must be predicted. If runoff, soil detachment, deposition and sediment transport can be reliably estimated at a particular slope length, downslope routing of water and sediment may be possible.

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