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Size Distribution of Sediment as Affected by Surface Residue and Slope Length

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Size Distribution of Sediment as Affected by Surface Residue and Slope Length

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ABSTRACT

RUNOFF samples for determination of size distribution of sediment were collected under simulated rainfall conditions at selected downslope distances on plots covered with sorghum and soybean residue at rates ranging from 0.00 to 6.73 t/ha. The effects of surface residue and slope length on size distribution of sediment were evaluated. Substantial movement of sediment in the form of aggregates was found for each of the residue treatments.

Significant differences in size distribution of sediment occurred between residue treatments. For a given residue rate, differences in sediment size distribution were found between sorghum and soybean residue. Size distribution of sediment was also determined to be significantly different at selected downslope distances.

INTRODUCTION

The transport of material eroded from cultivated croplands is greatly influenced by the size distribution of sediment. Flow channels provide the primary means for downslope transport of detached soil materials. Sediment eroded from cohesive soils usually consists of both primary and aggregated particles.

Agricultural chemicals are delivered to streams and reservoirs through sediment transport. Chemical transport capacity is influenced by the amount and type of clay present in sediment. Thus, not only the total quantity of sediment but also the size distribution of eroded material may be a water pollution concern.

The effect of residue cover on the size distribution of eroded soil was examined by Cogo et al. (1983). For smooth surfaces, a decrease in particle size with increasing residue cover was determined. However, the effect of cover on particle size was negligible on rough surfaces. For the relatively smooth surfaces which they examined, Gilley et al. (1986b) also found that increasing residue cover usually resulted in decreased particle size.

The degree of aggregation of sediment has received considerable attention. The effects of slope, rainfall intensity and crop cover on aggregation was examined by Weakley (1962). Swanson et al. (1965) found statistically different particle size distributions between aggregated sediment and surface soil. The size distributions of aggregates and primary particles eroded from simulated rainfall on different textured soils were compared by Gabriels and Moldenhauer (1978).

Meyer et al. (1980) found that much of the sediment from cohesive soils was in the form of aggregates, and some of the aggregates were much larger than the primary particles of which the soils were composed. Large differences in the size of soil aggregates and primary particles of sediment originating from rill and interrill areas were measured by Alberts et al. (1980). Alberts et al. (1983) further evaluated the physical and chemical properties of aggregates eroded from two fertile agricultural soils in southwestern Iowa. The densities of wet aggregates that exist during fluvial transport of sediment from agricultural soils was measured by Rhoton et al. (1983). Thus, it has been identified in previous studies that surface residue may influence the characteristics of eroded soil.

Size distributions of eroded materials are considered in some sediment transport models. A set of equations for predicting particle size distribution of eroded soil, based on soil surface area and texture and considering organic matter content and tendency of a soil to rill were developed by Young and Onstad (1976). Young (1980) suggested general guidelines on the characteristics of eroded soil for use in sediment production models. Existing sediment transport models can be more efficiently utilized if the factors affecting size distribution of sediment can be more accurately described.

Measurements of size distribution of sediment at a single discharge location were made in many of the previous investigations. However, limited information exists concerning sediment size distributions along a slope. The objective of this study was to determine size distribution of sediment as affected by surface residue and slope length.

PROCEDURE

The study was conducted at the University of Nebraska Rogers Memorial Farm in Lancaster County, approximately 18 km east of Lincoln, Nebraska. Average slope at the location was 6.4%. The Sharpsburg soil at the site (Typic Argiurdolls, montmorillonitic, mesic) formed on loess under prairie vegetation.

The entire study area had previously been planted to oats. Oat residue on the soil surface was first removed. The area was then plowed, disked and roto-tilled to depths of approximately 20, 13 and 8 cm, respectively. Plots 3.7 m wide and 22.1 m long were established in adjoining areas across the site. Following tillage, the plots were covered with plastic to maintain similarity in soil structure and water conditions.

A sample of the top 25 mm of surface soil was collected

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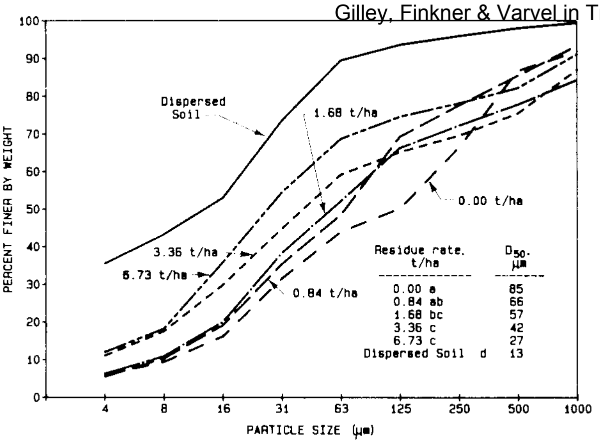

Fig. 1—Size distributions of eroded sediment for five sorghum residue treatments and dispersed soil. For the residue rates listed in the lower right table, differences in size distributions of sediment are significant at the 5% level (Pearson chi-square test) if the same letter does not appear.

following tillage. The primary particle size distribution of this soil after dispersing (Day, 1965) was determined and is shown in Fig. 1. The soil, classified as a silty clay loam, consisted of 11% sand, 54% silt, and 35% clay.

Prior to simulation testing, sorghum and soybean residue was placed uniformly on the plot surface in a random orientation at rates of 0.00, 0.84, 1.68, 3.36 and 6.73 t/ha. These residue rates produced average sorghum surface cover of 0, 4, 17, 26 and 44% and soybean surface cover of 0, 17, 27, 36 and 56%, respectively. There were two replications of each residue rate. Surface cover was measured using the point quadrant method (Mannering and Meyer, 1963).

The residue rates were selected to represent the broad range of conditions found under various cropping systems. Small amounts of surface residue may produce substantial reductions in runoff and erosion as compared to bare soil conditions (Mannering and Meyer, 1963). Consequently, several treatments with comparatively low residue rates were chosen.

A portable rainfall simulator designed by Schulz and Yevjevich (1970) was used to apply rainfall for a one hour duration at an intensity of approximately 48 mm/h. The first rainfall application (initial run) occurred at existing soil-water conditions, while the wet run was conducted approximately 24 h later. Average application rates were determined by collecting rainfall in 2.5 cm wide aluminum channels placed diagonally at four locations across each of the plots. A trough extending across the bottom of each plot gathered runoff, which was measured using an HS flume with stage recorder.

Samples for determining sediment size distribution were obtained once steady-state runoff conditions had become established during the 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 flume discharge location.

Runoff samples were also obtained on each plot at the point where the two largest rills (flow area in which soil scouring had occurred) or overland flow channels (flow area in which soil scouring had not occurred) discharged into the collection trough. Additional upstream samples were collected along these rills or overland flow channels at approximately 6-m intervals. These 800 mL runoff samples were obtained by placing a polyethylene bag across the channel cross section. A platform which extended over the entire plot width was used to prevent plot disturbance during sample collection.

The runoff samples were immediately wet sieved as suggested by Meyer and Scott (1983). Sand-sized sediment fractions were determined by washing the runoff samples through sieves with 1000, 500, 250, 125 and 63 µm openings. Each sieve was gently and thoroughly washed. The material passing through the 63 µm sieve was then stored for future analyses.

Sediment sizes of 31, 16, 8 and 4 µm were determined using pipette withdrawal procedures proposed by Guy (1969). Use of a special 25 mL pipette (Day, 1965) greatly facilitated withdrawal and dispensing of the sample. Guy (1969) suggested that particles greater than 62 µm be classified as sand, that silt-sized particles range from 4 to 62 µm, and that particles less than 4 µm be classified as clay.

RESULTS AND DISCUSSION

Increased sorghum and soybean residue cover was found by Gilley et al. (1986a) to cause reduced runoff, sediment concentration and soil loss. Runoff rate, runoff velocity, sediment concentration and soil loss rate were measured at the same locations at which samples for identification of sediment size distribution were collected (Gilley et al., 1987). However, only data on size distribution of sediment are reported here.

In the following discussion, the effects of varying sorghum and soybean residue cover on size distribution of sediment are examined. The degree of aggregation of eroded soil is discussed. Size distribution of sediment as affected by slope length is also described.

Size Distribution of Sediment as Affected by Surface Residue

Fig. 1 shows size distribution of sediment for five sorghum residue treatments and dispersed soil. The reported values were obtained from runoff samples collected during the wet simulation run on duplicated plots at the HS flume discharge location. The two sediment samples collected for each residue treatment were obtained once steady state runoff conditions had become established. Sediment found in the runoff was a composite of soil material transported from upstream areas.

The Pearson chi-square test (SAS Institute Inc., 1985) was used to determine the effect, if any, of surface residue on size distribution of sediment. This test allowed evaluation of the hypothesis that there was no difference in sediment size distribution due to different amounts of residue. In effect, the test identified whether the sediment composition of each particle class was drawn from the same population. Inherent in this evaluation is the concept that the test statistic has a limiting chi-square distribution with one less degree of freedom than the number of class intervals.

It can be seen from Fig. 1 that increasing amounts of sorghum residue produced consistent reductions in D_{50}, the size for which 50% of the sediment was smaller. Significant differences in the size distribution of sediment were found between selected residue treatments. Each of the sorghum residue treatments also

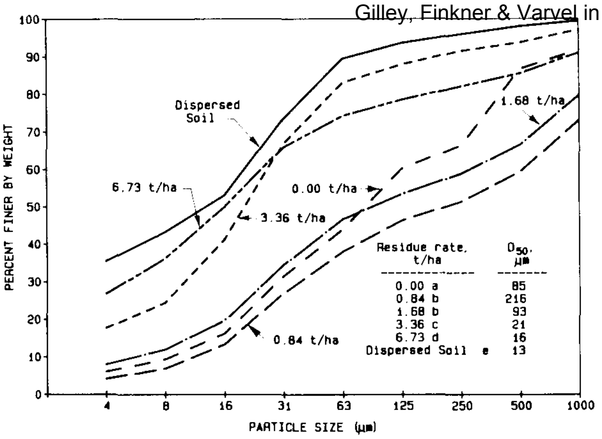

Fig. 2—Size distributions of eroded sediment for five soybean residue treatments and dispersed soil. For the residue rates listed in the lower right table, differences in size distributions of sediment are significant at the 5% level (Pearson chi-square test) if the same letter does not appear.

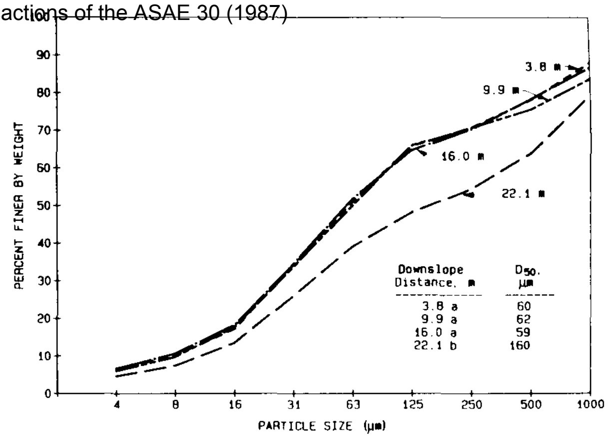

Fig. 3—Size distributions of eroded sediment at selected downslope distances for the no residue treatment. For the downslope distances listed in the lower right table, differences in size distributions are significant at the 5% level (Pearson chi-square test) if the same letter does not appear.

produced a sediment size distribution significantly different from dispersed surface soil.

Substantial movement of sediment in the form of aggregates was apparent from the distribution curves shown in Fig. 1 and the statistical analyses. For the dispersed surface soil, approximately 64% of the soil consisted of silt and sand particles. In comparison, the percentage of eroded silt and sand sized material ranged

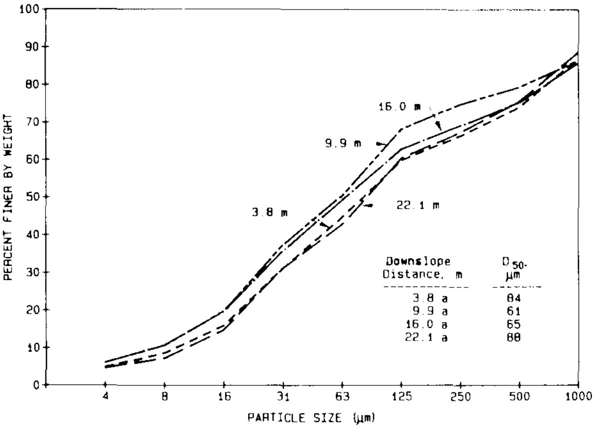

Fig. 4a—Size distributions of eroded sediment at selected downslope distances for the sorghum residue rate of 0.84% t/ha. For the downslope distances listed in the lower right table, differences in size distributions are significant at the 5% level (Pearson chi-square test) if the same letter does not appear.

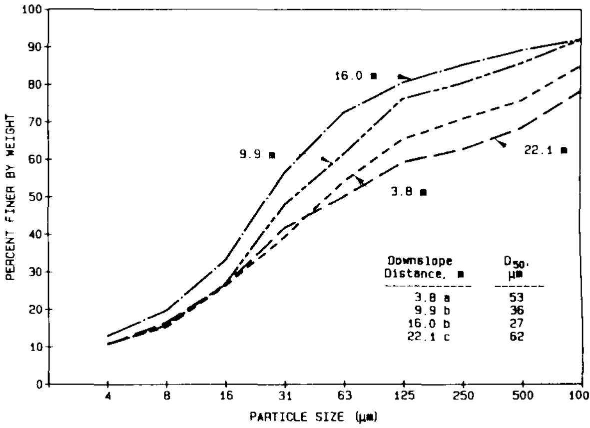

Fig. 4c—Size distributions of eroded sediment at selected downslope distances for the sorghum residue rate of 3.36 t/ha. For the downslope distances listed in the lower right table, differences in size distributions are significant at the 5% level (Pearson chi-square test) if the same letter does not appear.

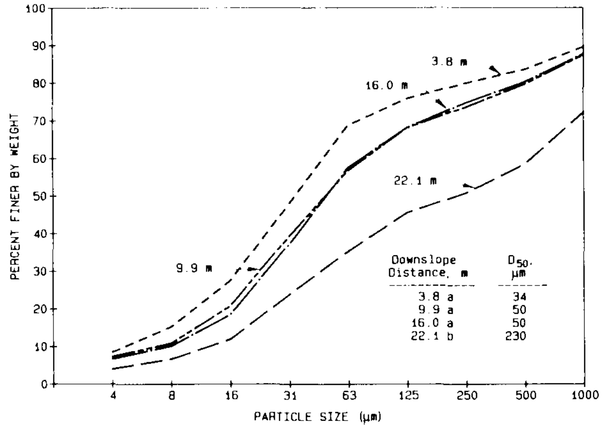

Fig. 4b—Size distributions of eroded sediment at selected downslope distances for the sorghum residue rate of 1.68 t/ha. For the downslope distances listed in the lower right table, differences in size distributions are significant at the 5% level (Pearson chi-square test) if the same letter does not appear.

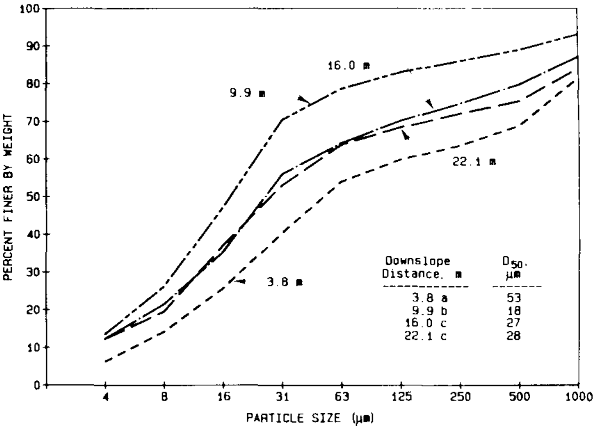

Fig. 4d—Size distributions of eroded sediment at selected downslope distances for the sorghum residue rate of 6.73 t/ha. For the downslope distances listed in the lower right table, differences in size distributions are significant at the 5% level (Pearson chi-square test) if the same letter does not appear.

from 94 to 88% for the 0.00 and 6.73 t/ha residue treatments, respectively.

Sediment sizes for the soybean residue treatments and dispersed soil are shown in Fig. 2. As was true with the sorghum residue plots, significant differences in sediment size distribution were found between selected residue treatments. Only the 0.84 and 1.68 t/ha soybean residue plots produced sediment size distributions which were not statistically different.

Movement of sediment in the form of aggregates also occurred on each of the soybean treatments. Approximately 10% of the dispersed surface soil contained sand. However, the percentages of sand sized material varied from 62 to 17% on the 0.84 and 3.36 t/ha residue treatments, respectively.

The Pearson chi-square test (5% confidence level) was also used to determine if, at a given residue rate, differences in size distribution of sediment occurred between sorghum and soybean residue. For residue rates of 0.84 and 3.36 t/ha no difference in sediment size distribution was found. However, differences in size distribution of sediment between sorghum and soybean residue treatments were determined at the 1.68 and 6.74 t/ha residue rates.

The results of the statistical analysis indicate that varying rates of sorghum or soybean residue may produce significant differences in size distribution of sediment. Substantial movement of sediment in the form of aggregates was found for each of the sorghum and soybean residue treatments. At a given residue rate, sediment size distribution may vary with different types of crop residue.

Size Distribution of Sediment as Affected by Slope Length

Fig. 3 shows sediment size distributions at selected downslope distances for the no residue treatment. Runoff samples for determination of size distribution of sediment were collected at approximately 6-m intervals along the entire plot length. The curves shown in Fig. 3 represent size distribution measurements for runoff collected from two channels on each of two plots. Sediment found in the runoff was a composite of soil material transported from upstream areas.

For the no residue treatment, no significant difference in size distribution of sediment was found between downslope distances of 3.8, 9.9 and 16.0 m. Sediment size distribution measurements at each of these three

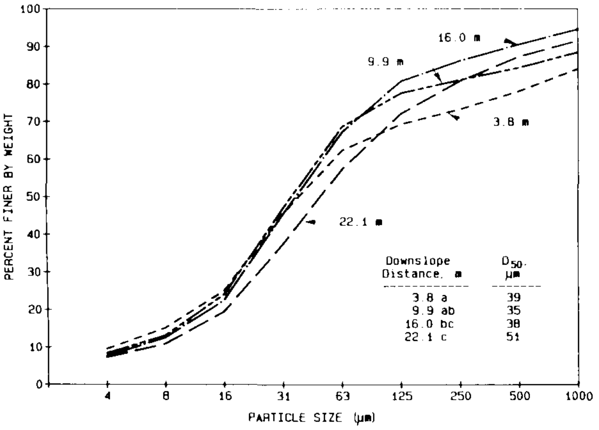

Fig. 5a—Size distributions of eroded sediment at selected downslope distances for the soybean residue rate of 0.84 t/ha. For the downslope distances listed in the lower right table, differences in size distributions are significant at the 5% level (Pearson chi-square test) if the same letter does not appear.

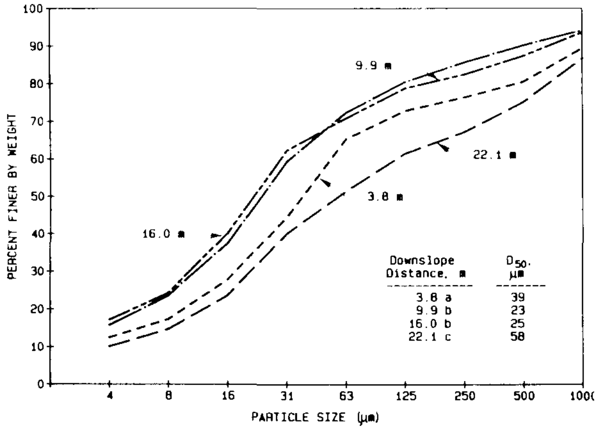

Fig. 5b—Size distributions of eroded sediment at selected downslope distances for the soybean residue rate of 1.68 t/ha. For the downslope distances listed in the lower right table, differences in size distributions are significant at the 5% level (Pearson chi-square test) if the same letter does not appear.

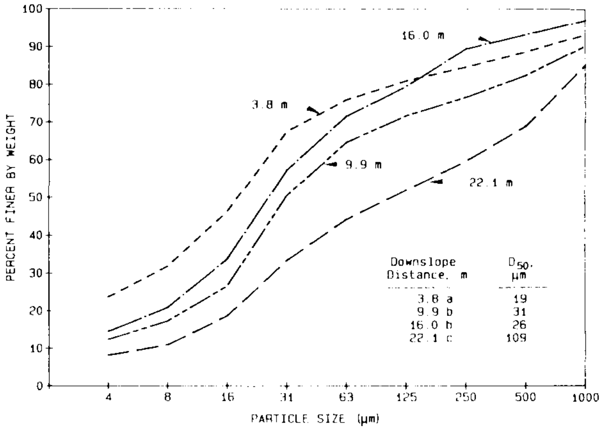

Fig. 5c—Size distributions of eroded sediment at selected downslope distances for the soybean residue rate of 3.36 t/ha. For the downslope distances listed in the lower right table, differences in size distributions are significant at the 5% level (Pearson chi-square test) if the same letter does not appear.

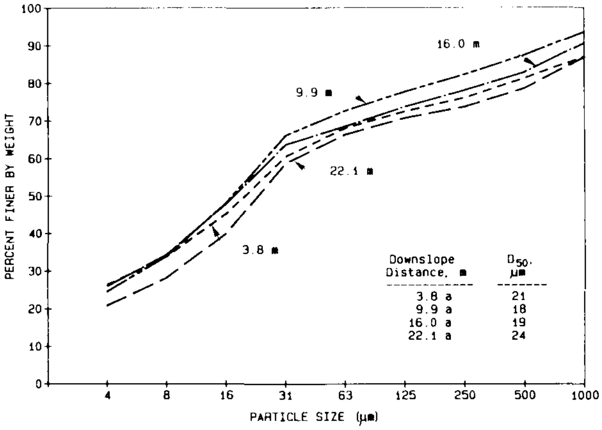

Fig. 5d—Size distributions of eroded sediment at selected downslope distances for the soybean residue rate of 6.73 t/ha. For the downslope distances listed in the lower right table, differences in size distributions are significant at the 5% level (Pearson chi-square test) if the same letter does not appear.

TABLE 1. TEST OF EQUALITY OF SIZE DISTRIBUTIONS OF SEDIMENT AT A GIVEN DOWNSLOPE DISTANCE FOR SELECTED SORGHUM RESIDUE RATES.

Residue rate, t/ha	Downslope distance, m			
	3.8	9.9	16.0	22.1
0.00	a	a	a	a
0.84	a	ab	a	b
1.68	b	ab	a	a
3.36	ac	b	b	c
6.73	c	c	c	d

Within a given column, differences in size distribution of sediment between selected sorghum residue rates are significant at the 5% level (Pearson chi-square test) if the same letter does not appear.

downslope distances were similar. In comparison, size distribution of sediment for the 22.1 m downslope distance was significantly different from values obtained for each of the other slope lengths.

Sediment size distribution curves at four downslope distances for sorghum residue rates of 0.84, 1.68, 3.36 and 6.74 t/ha are shown in Figs. 4a, 4b, 4c and 4d, respectively. No significant difference in size distribution of sediment was found with downslope distance for the 0.84 t/ha sorghum residue treatment (Fig. 4a). However, for each of the other sorghum residue rates (Figs. 4b, 4c and 4d), significant differences in sediment size distribution were found at selected downslope distances.

Figs. 5a, 5b, 5c and 5d show sediment size distribution curves for soybean residue rates of 0.84, 1.68, 3.36 and 6.73 t/ha, respectively. For the 6.73 t/ha soybean residue treatment (Fig. 5d), no significant difference in size distribution of sediment was found with downslope distance. However, significant differences in sediment size distribution were determined for each of the other soybean residue rates (Figs. 5a, 5b and 5c). The largest percentage of silt and sand sized material was found at a slope length of 22.1 m for each of the soybean residue treatments.

Additional statistical analysis was performed to determine if the size distribution of sediment at a given downslope distance varied with residue rate. Results of this analysis for sorghum and soybean residue are shown in Tables 1 and 2, respectively. It can be seen from Tables 1 and 2 that for a given downslope distance, significant differences in sediment size distribution occurred for varying sorghum and soybean residue rates.

TABLE 2. TEST OF EQUALITY OF SIZE DISTRIBUTIONS OF SEDIMENT AT A GIVEN DOWNSLOPE DISTANCE FOR SELECTED SOYBEAN RESIDUE RATES.

Residue rate, t/ha	Downslope distance, m			
	3.8	9.9	16.0	22.1
0.00	a	a	a	a
0.84	b	b	b	b
1.68	b	c	c	c
3.36	c	d	c	ac
6.73	c	c	d	d

Within a given column, differences in size distribution of sediment between selected soybean residue rates are significant at the 5% level (Pearson chi-square test) if the same letter does not appear.

It can be concluded from the statistical analysis that for a given sorghum or soyben residue rate, significant differences in sediment size distribuiton may occur with downslope distance. For both the sorghum and soybean residue treatments, the largest percentage of silt and sand sized material usually resulted at the greatest slope length. At a given downslope distance, significant differences in sediment size distribution were determined for varying sorghum and soybean residue rates.

SUMMARY AND CONCLUSIONS

Simulated rainfall was applied to a Sharpsburg silty clay loam soil located in southeastern Nebraska on which sorghum and soybean residue was placed at rates varying from 0.00 to 6.73 t/ha. Measurements were made of the percentages of eroded sediment over 10 size classes ranging from 4 to 1000 μm. Sediment size distributions were determined at selected downslope distances. These measurements allowed evaluation of the effects of surface residue and slope length on size distribution of sediment.

Significant differences in sediment size distribution were found between selected residue treatments for both sorghum and soybean residue. Substantial movement of sediment in the form of aggregates was found for each of the residue treatments. For selected residue rates, significant differences in size distribution of sediment were found between the sorghum and soybean residue treatments.

For a given sorghum or soybean residue rate, significant differences in size distribution of sediment may occur with downslope distance. The largest percentage of silt and sand size material usually appeared at the greatest slope length. At a given downslope distance, significant differences in sediment size distribution resulted from varying residue rates.

Differences in runoff rate, runoff velocity and sediment concentration between residue treatments may cause variations in size distribution of sediment. Due to differences in flow pattern and channel density, the drainage area contributing runoff to a particular flow channel may vary substantially with downslope distance. Surface residue may induce convergence or divergence of flow into the rill or overland flow channels.

Differences in infiltration rates caused by varying amounts of crop residue may greatly influence the quantity of water available for runoff at a given downslope distance. Crop residues may also produce small dams which cause deposition of soil materials. As additional information becomes available on the effects of surface residue and slope length on size distribution of sediment, improved sediment transport and deposition estimates will be possible.

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