11-1997

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Gilley, John E.; Kramer, L. A.; Cruse, R. M.; and Hull, A., "Sediment Movement Within a Strip Intercropping System" (1997). *Biological Systems Engineering: Papers and Publications*. 137.
https://digitalcommons.unl.edu/biosysengfacpub/137

Gilley, Kramer, Cruse & Hull in Journal of Soil and Water Conservation 52 (1997)

Sediment movement within a strip intercropping system

J.E. Gilley, L.A. Kramer, R.M. Cruse, and A. Hull

*ABSTRACT: This study was conducted to identify sediment movement within a strip intercropping system in southwestern Iowa during the third year of a three-year crop rotation. Soil loss, resulting from the application of simulated rainfall to a Monona silt loam soil, was measured from individual corn (*Zea mays *L.), soybean (*Glycine max *(L.) *Merr*), and winter wheat (*Triticum aestivum *L.) strips, and from multiple strips which included all three crops. Because of the crop rotation and residue management procedures used at the study site, a substantial amount of surface cover and vegetative mass was present on each of the strips. As a result, soil loss resulting from simulated rainfall applied for a one-hour duration at an intensity of approximately 64 mm/hr (2.5 in/hr) was less than or equal to 1.5 Mg/ha (0.67 tons/acre) from each of the individual and multiple strips. Thus, the strip intercropping system established on this highly erodible site provided effective erosion control.*

Strip intercropping is the practice of producing different crops in narrow alternating strips that are located throughout the length of the field. The strips are sufficiently wide that each can be managed independently, yet are narrow enough that the crops, which are rotated annually, can influence the microclimate and yield potential of adjacent crops (Van 1994; Sawchik 1994). Strip intercropping can provide important agronomic and environmental benefits. A well-managed strip-intercropping system could result in higher profitability and greater soil and water conserving potential than most monocropping operations (Cruse 1990; Davidson 1994).

Agronomic considerations. Strip intercropping can be tailored to individual farm needs and goals. Crop selection, strip width, planting direction, plant population, and crop strip orientation are management options that may vary from farm to farm. A corn, soybean, and winter wheat rotational strip intercropping system was examined in this study.

Corn provides strong yield response to field edge effects (Pendleton et al. 1963; Francis et al. 1986; Fortin et al. 1994). High sunlight levels are more efficiently utilized by corn than either wheat or soybeans. Strip-edge-rows frequently produce corn yields that are substantially larger than those occurring in strip centers. Improved crop yields are possible with greater corn populations within the edge rows.

For strips that are no wider than six rows, soybean yields typically increase with distance from the corn strip, with the highest yields occurring next to the

Interpretive summary

Strip intercropping systems are used to produce different crops in narrow alternating strips located throughout the length of the field. In addition to higher profitability, strip intercropping systems have been shown to provide important agronomic and environmental advantages. A rainfall simulator was used in this study to help identify possible soil conservation benefits of a strip intercropping system in southwestern Iowa which employed a corn, soybean, and winter wheat crop rotation. Rainfall simulation tests conducted under fallow conditions suggested that the Monona soil at the study location was highly erodible. As a result of the crop rotation and residue management practices used at the study site, a substantial amount of surface cover and vegetative mass was present throughout the field. Sediment movement within each of the individual strips was found to be minimal, indicating that the strip intercropping system provided effective erosion control.

Key words: conservation, erosion, intercrop, land management, rotation, runoff, sediment production, soil conservation, soil loss, tillage.

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J. Soil and Water Con. 52(6) 443-447

Table 1. Treatment designation, description and length*

Treatment	Description	Total Length (m)†
s	Winter wheat planted in soybean residue	3.9
w	Winter wheat residue	3.9
c	Corn residue	3.9
cws	Three 3.9 m strips containing corn residue, winter wheat residue, and winter wheat planted in soybean residue	11.7
swc	Three 3.9 m strips containing winter wheat planted in soybean residue, winter wheat residue, and corn residue	11.7
nns	Two strips—one containing no residue (7.8 m) and another containing winter wheat planted in soybean residue (3.9 m)	11.7
nnn	One 11.7 m strip containing no residue	11.7

* Each of the plots were 3.0 m wide

† Metric to English unit conversion: 0.305 m = 1 ft

small grain strip. The yield increases are attributed to a wind shelter effect from the taller corn plants. Generally, soybean yields are similar to or slightly lower than those obtained under monoculture systems (West and Griffith 1992; Ghaffarzadeh et al. 1994).

Small grain yield increases have been observed on strip edges compared to strip center positions (Ghaffarzadeh et al. 1994). Winter wheat is usually planted in the fall following soybean harvest. This results in less competition for winter wheat plants located along the strip edge than for plants in the strip center position. When corn and soybean are planted the following year and have begun to grow rapidly, winter wheat requirements for water, nutrients, and sunlight are substantially reduced. As the winter wheat crop matures, the taller adjacent corn plants may serve as a wind shelter which helps to minimize lodging.

Environmental considerations. Strip intercropping offers unique opportunities to manage soil and water resources within a high yielding crop production system. Ideal pesticide or fertilizer application periods vary between crops. Thus, since more than one crop is used within a strip intercropping system, the total load of pesticide or fertilizer applied to a field at a particular time is less than that which would occur if only one crop was present. This reduces the possibility for a large loss of pesticide or fertilizer as a result of heavy rainfall shortly after application. The small grain strips dispersed between the corn and soybean strips are suitable for summer manure application after small grain harvests. This reduces or eliminates the need for fall, winter, or spring manure applications when nutrient losses are more likely to occur and when soils are more susceptible to compaction. Some producers interseed a legume with the small grain for nitrogen fixation. As corn is rotated into this strip, nitrogen fertilizer requirements for corn are reduced.

Soil erosion could be substantially reduced within a strip intercropping system, particularly if the system contains small grain or forage strips. Three management factors help to reduce erosion potential; (1) Because strip position must be fixed from year to year, no-till or ridge tillage is best suited for strip intercropping systems. With these tillage systems, which have been shown to conserve soil, planting position is easily identified each year based on last year's residue and row location; (2) Contour planting on highly erodible land will further reduce soil erosion losses; (3) The small grain or forage strip could serve as an efficient vegetative filter for sediment removal from runoff.

A vegetative filter strip reduces the susceptibility for erosion through its extensive root system, which helps to hold soil in place. The plant vegetative material causes flow velocity to decrease which, in turn, reduces sediment transport capacity of flow (Tollner et al. 1976 and 1977). The backwater occurring upstream from the filter strip has been reported to cause substantial deposition (Dabney et al. 1995). The effectiveness of vegetative filters in trapping sediment is well documented (Hayes et al. 1984; Magette et al. 1989; Kemper et al. 1992; Robinson et al. 1996). Vegetative filters work best if runoff enters the strip as sheet flow (Dillaha et al. 1989). Placing the small grain strips on hillsides results in water entering the strip as sheet flow much more readily than if the vegetative filter were located only at the edge of the field. The objective of this study was to identify sediment movement within a strip intercropping system in southwestern Iowa during the third year of a three-year crop rotation.

Procedures

The study was conducted at the USDA-ARS Deep Loess Research Station approximately 19 km (12 mi) east of Council Bluffs, Iowa. A Monona (fine-silty, mixed, mesic typic Hapludolls) soil with a sand, silt, and clay content of 12, 63, and 25%, respectively, at the 0 to 15 cm (0 to 6 in) depth was used in this investigation. The Monona soil developed on a deep loessal mantle overlying glacial till. Annual precipitation at the study site averages 816 mm (32 in) and mean daily temperatures range from -7°C (19°F) in January to 24°C (75°F) in July. The average frost-free growing season extends for 145 days from May through September.

A strip intercropping system with 3.9 m (13 ft) wide strips was established at the study site in 1993 using no-till management. The rotation sequence was corn, soybeans, and winter wheat. Winter wheat was drilled using 0.17 m (0.56 ft) row spacings. Following harvest, the winter wheat straw was baled. Herbicide was applied to the winter wheat strip in late summer to reduce weed growth. The corn and soybean strips consisted of 4 0.97 m (3.2 ft) wide rows. When the rainfall simulation tests were conducted from May 20, 1995 to June 8, 1995, corn and soybeans, had been planted but seedlings had not yet emerged, and the winter wheat that had been drilled in soybean residue was beginning to head.

The following designations were used to identify individual strips (Table 1): winter wheat planted in soybean residue (s); winter wheat residue (w); corn residue (c); and no residue (n). Using sheet metal borders, two rainfall simulation plots, each 3.0 m (10 ft) wide, were established on uniform slopes for each of the experimental treatments (Table 1). Some of the treatments (s, w, c) covered only a single crop strip (3.9 m; 13 ft) while the other treatments (cws, scw, nns and nnn) extended over a length equivalent to 3 strips (11.7 m; 38.4 ft). Slope gradients for the individual treatments are shown in Table 2.

On the nns treatment, residue cover on the upper portion of the plots was removed immediately before rainfall simulation tests and the area was roto-tilled to a depth of approximately 13 cm (5 in). The tilled area served as a source of sediment to an actively growing winter wheat strip located at the bottom of the plot. The nnn treatment was established in October 1994. Surface residue was removed by hand raking. A tandem disc was used to till the area to a depth of approximately

Table 2. Slope, surface cover and vegetative mass for the experimental treatments[*]

Treatment[†]	Section	Slope (%)	Surface cover (%)	Vegetative mass (Mg/ha)[‡]
s	s	9.3	92	5.0
w	w	13.3	68	5.4
c	c	13.2	67	10.0
cws				
	c	13.6	69	7.6
	w	13.6	51	4.5
	s	13.6	79	5.1
scw				
	s	13.3	90	4.4
	c	13.3	76	8.7
	w	13.3	80	5.8
nns				
	n	13.5	25	0.0
	n	13.5	25	0.0
	s	13.5	91	5.2
nnn				
	n	13.6	33	0.0
	n	13.6	29	0.0
	n	13.6	14	0.0

[*] Values given are the average of two replications

[†] s (winter wheat planted in soybean residue), w (winter wheat residue), c (corn residue), n (no residue)

[‡] Metric to English unit conversion: 2.24 Mg/ha = 1 ton/acre

13 cm (5 in) and the surface was maintained free of vegetation by applying herbicide. The area was roto-tilled immediately before the rainfall simulation tests.

Surface cover was measured prior to the rainfall simulation tests using the point quadrant method (Mannering and Meyer 1963). Photographic colored slides were taken at three locations on each plot. The slides were later projected onto a screen containing a grid and the number of residue and crop elements intersecting the grid points were determined. The ratio of the number of intersection points over the total grid points is the fraction of the soil surface covered by residue. This ratio times 100 is the percent cover.

A circular frame covering a 0.589 m^2 (6.34 ft^2) area was used to obtain samples for measurement of above-ground biomasses. Standing vegetative material and residue lying on the soil surface within the frame were collected. The plant and residue material was oven-dried before calculating the weight of above-ground biomass per unit area.

A portable rainfall simulator based on a design by Swanson (1965) was used to apply rainfall at an intensity of approximately 64 mm/h (2.5 in/h). For the study area, this represents a storm with a recurrence interval of approximately 10 years. The first rainfall application (initial run) of 1 hour duration occurred at existing soil-water conditions. A second rainfall simulation run (wet run) was conducted approximately 24 hours later, again for a duration of 1 hour. A trough extending across the bottom of each plot gathered runoff, which was measured using an HS flume with stage recorder. Runoff samples for sediment content determinations were collected at five-minute intervals during the runoff events. Additional details concerning runoff and soil loss measuring procedures are given by Meyer (1960). Duncan's multiple range test was used to determine if differences in runoff, sediment concentration, and soil loss existed between the experimental treatments. Tests were run at the 5% confidence level.

Results and discussion

Slope, surface cover, and vegetative mass. It can be seen Table 2 that, with the exception of the treatment containing winter wheat planted in soybean residue (s), slope gradients for the plots in this study varied from 13.2 to 13.6%. Cropped areas with slopes in this range are typical of the loess hills of southwestern Iowa. Use of proper conservation measures are critical in this region because of the substantial slope gradients and slope lengths.

The plots with winter wheat residue (w) and corn residue (c) had surface cover values of 66% and 71%, respectively. Surface cover measurements on these plots were obtained soon after planting and, therefore, represent minimum values for the year. Surface cover within the strips that contained winter wheat planted in soybean residue (s) averaged 88%. The relatively large surface-cover values found within each of the three strips suggests excellent residue management practices were used on this farm.

Surface residues on the nnn treatment and the no residue section of the nns plots were removed by raking prior to tillage but the root material remained undisturbed. Some of the root material was detached and brought to the soil surface during tillage. As a result, root material covered from 14 to 33% of the surface on the no-residue section of these treatments.

A considerable amount of vegetative material was present within each of the narrow strips (Table 2). An average vegetative mass of 8.8 Mg/ha (3.9 tons/acre) was found within the corn residue (c) strips. The strips which contained winter wheat residue (w) and winter wheat planted in soybean residue (s) had average vegetative mass values of 5.2 and 4.9 Mg/ha, (2.3 and 2.2 Mg/ha), respectively. The vegetative mass measured on the strips containing winter wheat residue (w) consisted of material that remained after the bailing operation the previous summer.

The reduced surface cover and vegetative mass following harvest on fields planted to soybean is a concern in many cropping systems. For this strip intercropping system, winter wheat was seeded into the soybean strips in the fall soon after soybean harvest. The residual nitrogen produced by the previous soybean crop helped to reduce winter wheat fertilizer requirements. During the critical planting period in the spring when high intensity rainfall typically occurs, a substantial cover of winter wheat was present within the strips which formerly contained soybean.

The greatest amount of vegetative material was produced by the corn crop. The corn stalks are relatively large and resistant to decomposition. In this strip intercropping system, soybeans, are planted into the strip which was used for corn production the previous year. The residual corn residue, therefore, served to reduce erosion potential until a protective soybean canopy became established.

Runoff, sediment concentration, and soil loss. Runoff, sediment concentration, and soil loss values are reported (Table 3) on a unit area basis so that results obtained from both the single strip and multiple strip treatments can be compared. For both the initial and wet rainfall simulation runs, runoff, in general, did not increase significantly where the residue cover was removed and tillage took place (nns and nnn). The tillage operations appeared to have brought enough root material to the soil surface to help reduce raindrop-induced, surface-sealing during both rainfall simulation runs. However, because of the fragile nature of the root material, its ability to provide protection against surface sealing would be expected

Table 3. Runoff, sediment concentration, and soil loss from the initial and wet rainfall simulation runs[*]

Treatment[†]	Run	Runoff (mm)[‡]	Sediment conc. (ppm × 10 ^ 3)	Soil loss (Mg/ha)[§]
s	Initial	24 ab	1.9 b	0.4 b
w	Initial	39 a	3.4 b	1.3 b
c	Initial	33 ab	4.8 b	1.5 b
cws	Initial	38 a	2.0 b	0.8 b
scw	Initial	18 b	4.4 b	0.8 b
nns	Initial	30 ab	5.5 b	1.9 b
nnn	Initial	37 a	133.2 a	51.5 a
s	Wet	33 c	0.9 e	0.3 c
w	Wet	51ab	2.6 dc	1.3 c
c	Wet	43 bc	3.2 c	1.4 c
cws	Wet	49 ab	1.5 de	0.7 c
sew	Wet	40 bc	2.7 dc	1.0 c
nns	Wet	56 a	5.7 b	3.2 b
nnn	Wet	49 ab	47.4 a	23.2 a

[*] Values given are the average of two replications. Runs lasted for a 60 min duration. Average rainfall intensity was 64 mm/h

[†] s (winter wheat planted in soybean residue), w (winter wheat residue), c (corn residue), n (no residue)

[‡] 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

[§] Metric to English unit conversion: 25.4 mm = 1 in; 2.24 Mg/ha = 1 ton/acre

to rapidly diminish.

The 51.5 Mg/ha (23.0 tons/acre) of soil loss measured during the initial rainfall simulation run on the no-residue treatment (nnn) was significantly larger than on any of the other plots. Residue cover on this treatment was removed the previous fall. The area was then disked and maintained in a fallow condition until immediately before the rainfall simulation tests when it was tilled again. The nnn plots were, therefore, in a highly erodible condition, and the excessive sediment movement from this site should be considered as a soil-loss extreme. It is apparent that appropriate soil conservation measures are needed on the Monona soil located at the study site.

The 23.2 Mg/ha (10.3 tons/acre) of soil loss, measured during the wet rainfall simulation run on the nnn treatment, was also significantly larger than the other experimental plots, but less than that obtained during the initial run on this site. The rills on this treatment appeared to have progressed to the bottom of the tillage zone by the end of the initial run. A diminished sediment supply could have caused the reduction in soil loss measured during the wet run on this treatment.

The nns plots were established to help determine the effectiveness of a narrow winter wheat strip as a sediment filter. The 0.4 Mg/ha (0.2 tons/acre) of soil loss measured during the initial rainfall simulation run on the 3.9 m (13 ft) long winter wheat strip (s) suggests that the amount of sediment generated within the section of the nns treatment containing winter wheat was probably minimal. However, since 51.5 Mg/ha (23.0 tons/acre) of sediment was measured during the initial run on the nnn treatment, the amount of sediment moving into the winter wheat strip from the upper area of the nns plot would be expected to have been substantial. For the initial rainfall simulation run, there was no significant difference in soil loss between the nns treatment and the undisturbed treatments. Thus, the winter wheat strip proved to be an effective sediment filter.

For the wet rainfall simulation run, soil loss was significantly larger on the nns treatment than the undisturbed plots. The total amount of runoff was almost twice as large during the wet rainfall simulation run on the nns treatment as compared to the initial run, and this could have contributed to the increased soil loss values.

For both the initial and wet rainfall simulation runs, no significant differences in soil loss were found among the cropped treatments (s, w, c, cws, and swc). Even though runoff volumes were greater on the longer plots (cws and swc), soil loss on a unit area basis was similar. It can be seen (Table 3) that soil loss from each of the cropped treatments was minimal. Thus, the strip intercropping system was found to provide effective erosion control on this highly erodible site.

Summary and conclusions

A strip intercropping system has been shown to result in higher profitability than most monocropping operations (Cruse 1990). However, the soil conservation benefits of intercropping systems have not been thoroughly evaluated. Therefore, this study was conducted to identify sediment movement within a strip intercropping system located in southwestern Iowa during the third year of a three-year crop rotation.

A rainfall simulator was used to measure soil loss from individual corn, soybean, and winter wheat strips, and from multiple strips which included all three crops. The rainfall simulator applied rainfall for a one hour duration at an intensity of approximately 64 mm/hr (2.5 in/hr). Soil loss measurements were made during both initial and wet runs which were separated by approximately 24 hours. For the initial rainfall simulation run, a soil loss of 51.5 Mg/ha (23.0 tons/acre) was measured from a fallow-tilled area. This rainfall simulation test indicates the Monona soil at this location is highly erodible and appropriate conservation measures are, therefore, needed.

Narrow strips of winter wheat have been successfully employed as sediment filters. Soil loss during the initial rainfall simulation run from a 3.9 m (13 ft) winter wheat strip located below a 7.8 m (26 ft) tilled area was 1.9 Mg/ha (0.85 tons/acre). This soil-loss rate was similar to values obtained from both individual- and multiple- cropped strips. Thus, if necessary, the 3.9 m (13 ft) winter wheat strip, on this site, could serve as an effective sediment filter.

As a result of crop rotation and residue management practices used at the study site, a substantial amount of surface cover and vegetative mass was present on each of the individual cropped strips. Soil loss values less than or equal to 1.5 Mg/ha (0.67 tons/acre) were measured from individual and multiple cropped strips during both the initial and wet rainfall simulation runs. Thus, in addition to providing important agronomic and economic benefits, the strip intercropping system was also found to furnish effective erosion control.

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