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Sorghum Residue Reduction in a Stubble Mulch Fallow System[1]

B. W. Greb and A. L. Black[2]

SYNOPSIS. Sorghum residues on the soil surface were preserved at 30 to 45% of original material in a summer fallow system with maximum use of subsurface tillage. Climatic weathering and tillage burial were nearly equally responsible for residue reduction.

STUBBLE-MULCHING and soil cloddiness in western Kansas, western Nebraska, and eastern Colorado are practical methods for controlling wind erosion in summer fallow systems of farming. Acreage reductions in wheat have promoted the use of a wheat-sorghum-fallow rotation as a replacement for alternate wheat-fallow in many farming units of the above region. However, a wheat-sorghum-fallow rotation involves sorghum residue instead of wheat as the primary plant cover during the critical erosion periods.

The use of crop residues, particularly small grain stubble, for control of soil erosion has been critically evaluated for the dryland areas of the Western States by Zingg and Whitfield (8). Most residue measurement studies involve only total weight of plant cover in relation to soil erosion, nitrification, etc. Other attributes of wheat residues such as height, distribution, orientation, and quality also have been shown to influence erosion (3).

Sorghum residues, as a source of vegetative cover, have received little attention to date. The quantities produced in the semi-arid region are known to be generally low, from 1/2 to 2 1/2 tons per acre (4, 5). Zingg and Englehorn (9) found a significant reduction in wind erodibility of soil when standing sorghum stubble was oriented at right angles to wind produced by a wind tunnel. High weathering losses of standing forage sorghum were obtained by Webster and Davies (6). They found that losses of dry matter began shortly after frost and continued until spring with losses ranging from one-third to one-half of the original weight of forage.

The purpose of this investigation was to evaluate the survival of sorghum residues under various fallow tillage methods with natural weathering.

EXPERIMENTAL PROCEDURE

Three field experiments were conducted. Two experiments involved methods of tillage for measurement of sorghum residue preservation and one experiment measured the survival of residues by subsurface tillage as a function of rotation and row width of grain sorghum.

1958–1959 Tillage Experiment

Nineteen acres of grain sorghum were grown after millet during 1958 as a source of residues for subsequent tillage treatments for the 1959 fallow season. Field dimensions were 322 feet by 2600 feet and included 4 quadrants, 2 of which were seeded to Reliance and 2 to RS 501 sorghum varieties, each in 2 row widths as shown in Table 1. As no apparent differences in residue reduction were obtained in the planting quadrants as the result of varieties or row width, the quadrants were used as four replications in calculating means of residue reduction by the tillage treatments involved (see Table 3). Individual planting blocks were 161 feet by 1300 feet oriented lengthwise east to west and were subdivided into plots 80 feet by 400 feet for tillage treatments.

Various methods of fallow and residue treatments included a fall *versus* spring comparison of the primary (first operation) of tilling with 48-inch V-type sweep blades on 43-inch centers, one-way disk, mowing upright stubble 2 inches above ground level, or tandem disk pulled once at 45° angle to stubble row. Two sweep and two rod weed operations were performed successively after the primary fall operation for the remainder of the fallow season on all plots except one tandem-disked plot which was tandem disked again instead of sweeped in the first spring operation. Following the spring applied primary treatments all plots were treated with 1 and 2 rod weed operations except 1 tandem disked plot which was disked instead of sweeped in the second spring operation. Fall tillage was conducted October 24 and the spring-summer tillages on May 18, June 15, July 23, and August 21, respectively, the latter 2 being rod weed operations.

The soils on the experimental plots included equal areas of Ascalon fine sandy loam and Sligo loam. These soils covered 65% of the area involved. Small patches of Goshen loam, Haxtun fine sandy loam, Platner loam, and Rago silt loam made up the other 35% of the field. These soils are typical of cultivated land in northeastern Colorado, southwestern Nebraska, and northwestern Kansas. In most cases, each soil type involved covers a larger field area than the area represented in the experiment. In terms of residue loss by tillage, variability of soil did not appear to be an influence within the confined experimental area. Variability of soil is more likely to affect production of residues than to affect loss by weathering or tillage.

1959–1960 Tillage Experiment

This experiment was conducted adjacent to the 1958–1959 tillage experiment with sorghum residues provided by RS-501 variety which succeeded winter wheat in a wheat-sorghum-fallow rotation. Ten tillage treatments with 3 replications in randomized blocks were laid out on a field 320 feet by 2600 feet and subdivided into 60 feet by 400 feet plots exclusive of alleys. No fall tillage was involved. All tillage treatment combinations, as shown on Table 4, involved the use of a primary operation on April 25 and were succeeded by 2 secondary operations performed on June 12 and July 6. A final seed bed preparation treatment of rod weeding was applied to all plots August 3.

The soils included Ascalon fine sandy loam occupying the center half of the field with the east 25% composed of Rago silt loam. The western quarter had 20% Sligo loam and 5% Goshen loam.

1958–1959 Sorghum Rotation and Row Width Experiment

Reliance grain sorghum was grown on Weld silt loam in row width plantings of 14, 28, and 42 inches drilled and 42 inches listed in rotations of alternate fallow-sorghum (F-S) and fallow-wheat-sorghum (F-W-S). The 8 treatment plots, 50 feet by 150 feet, were replicated 3 times in randomized blocks. The stubble remaining in the fall of 1958 was used for measurements of winter stalk breakage and weight of residues remaining from stubble-mulch tillage during the 1959 fallow period. The order of subtillage was as follows: sweep with 48-inch V-blades on 43-inch centers on May 18 and June 16 succeeded by rod-weeding July 22 and August 22.

Table 1—Experimental conditions in November 1958 of grain sorghum grown on 4.5-acre blocks, 1958–59 tillage experiment.

Sorghum variety	Quadrant position	Planting row width, inches	Stalks per acre	Stalk ht., inches
Reliance	NW	42	24,000	17
RS 501	SW	28	49,000	22
RS 501	NE	42	42,000	25
Reliance	SE	28	56,000	17

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[2] Soil Scientists, Western Soil and Water Management Branch, SWCRD, ARS, USDA, Central Great Plains Field Station, Akron, Colorado.

Residue and Stalk Breakage Estimation

Sorghum residue samples in all experiments were taken in the following manner:

1. A 3- by 7-foot wooden frame was placed across a minimum of 2 rows of sorghum stalks.
2. Anchored stalks were cut at base level with a linoleum knife.
3. Roots were cut off unanchored stalks.
4. Three samples per plot in each of 3 plots gave 9 samples per treatment for weight averages.
5. Residues were shaken free of soil particles except for fine dust.
6. Samples were air dried and weighed.

Positions were selected in stubble during the fall of 1958 to determine winter damage to stalks. Six sets of 2 rows 16 feet long per treatment were sampled for calculation of percent of lodged stalks the following spring. In this manner, several hundred stalks were counted per treatment.

RESULTS

Weather conditions—The climatic summary of the 1958–1960 period is shown in Table 2. Production of residues and total pounds preserved by tillage favored the 1958–1959 season compared with 1959–1960. The 14.4 inches of precipitation in 1958, combined with sub-soil moisture reserves from a more favorable 1957 season resulted in nearly 2½ times as much residue produced in 1958 as with 13.4 inches of precipitation in 1959. The pattern of spring and summer rainfall during 1959 and 1960 did not include any long period of moist surface soil conditions. Consequently, the decomposition of larger stalks was slow.

Wind velocities and snowfall were higher in the latter season (Table 2). A total of 19 inches snowfall was received in 4 storms the first winter and 39 inches snowfall in 12 storms were received in the second winter. Snowcover persisted for 68 consecutive days during the 1959–1960 winter compared with only 18 days the previous season. Periods of prolonged snow cover reduce residue exposure to wind.

Over-winter losses of undisturbed residues were large (Tables 3, 4), averaging 31% and 34% for the two winters involved. One mechanism of loss included wind transportation of dry leaves and loose shredded upper portions of the sorghum plant scattered by combine harvest. Observations indicated that partial surface decomposition and leaching of soluble materials may also cause some reduction of sorghum residue weight.

Evidence of transportation of residues by water was negligible as no rainstorm produced runoff during the experimental period. Runoff from snowmelt in the spring of 1960 was confined largely to north sloping fields with frozen soils. Soils on the experimental plots were generally not frozen and consequently runoff of snowmelt was low.

Tillage experimentation—The reduction of sorghum residues by tillage is summarized in Tables 3 and 4. No difficulty was experienced in carrying out any of the tillage treatment combinations.

Results of both years' tillage operations (Tables 3, 4)

Table 2—Climatic summary of 1958–59 period, USDA Central Great Plains Field Station, Akron, Colo.

Year	Rainfall, inches	Rainfall, in. Mar. – Sept.	Snowfall, in.* Oct. – Apr.	Wind vel., mph. – 24 hr. Oct. – Apr.
1958	14.38	10.09	28	–
1959	13.77	9.97	19	6.2
1960	8.94†	7.96†	39	6.8
Average, 1909-1959	17.1	11.51	32	5.9

* Period beginning fall of previous year. † Period of Jan. 1 to Sept. 30, 1960.

Table 3—Sorghum residues remaining during fallow season as percent of initial residues as a result of fall and spring operations in the 1958–59 tillage experiment.

Tillage implement* and dates used: Fall 1958, Oct. 24	Spring 1959†, May 18	Spring 1959†, June 15	Initial residues, fall 1958, lb./A.	Percent residues remaining: April 12, after winter	June 23, end tillage variable	August 24, end of fallow
Primary	Secondary	Secondary				
S	S	S	3370	61	43	32
M	S	S	3520	39	31	29
O-D	S	S	3390	37	36	27
T-D	S	S	3000	52	44	32
T-D	T	S	3680	52	9	15
	Means		3390	48	32	27
	Primary	Secondary				
None	S	S	3620	62	52	37
None	M	S	3220	72	47	31
None	O-M	S	3540	69	26	20
None	T-M	S	3560	64	24	19
None	T-M	T	2890	78	13	15
	Means		3370	69	33	25
	LSD .05					8

* Tillage symbols: S - Sweep 48" V-blade on 43" centers, M - Mow, O - One-way disk, T - Tandem disk, D - Dry soil, M - Moist soil.
† All plots had rod weed operations on July 23 and August 21.

Table 4—Sorghum residues remaining during fallow season as percent of initial residues in the 1959–60 tillage experiment.

Tillage implement* and dates used, 1960: May 16	June 12	July 6	Initial residues, fall 1959, lb./A.	Percent residues remaining: April 12, after winter	June 23, end tillage variable	September 2, end of fallow
Primary	Secondary	Secondary				
O	S	S	1320	60	30	22
O	O	S	1160	66	17	21
T	S	S	1250	61	30	26
T	T	S	1320	65	20	17
S-16	S-16	S-16	1440	65	47	30
S	S	S	1390	70	64	41
C	S	S	1230	67	45	38
C	C	S	1380	70	50	36
B	S	S	1280	65	58	41
B	B	S	1330	67	62	45
	Means		1310	66	43	32
	LSD .05					11

* Tillage symbols: O – One-way disk; T – Tandem disk; S-16 – Sweep blade, 16" V-blade on 13" centers; S – Sweep blade, 48" V-blade on 43" centers; C – Chisel; B – Rotating bar with attached shovels.

were similar even though total quantities of initial residue differed greatly. Subsurface tillage with wide V-blade sweeps, straight bars, and chiseling (with row) preserved the maximum quantities of residue. These averaged 35–45% of the initial fall harvest residues. In no case was the quantity of residue at the end of fallow considered sufficient for prolonged wind erosion protection by itself.

In the tillage experiment of 1958–1959 there was no essential difference between sorghum residue preservation as a function of variety, row width (28 inch versus 42 inch), or fall versus spring tillage. However, there were trends (Table 3) which indicated greater preservation by delayed use of sweeps in the spring.

There were apparent disadvantages in fall cultivation. Cultivation in the fall of 1958 with dry surface soil produced a hazardous situation with respect to wind erosion. A complete breakdown of clods resulted from all disking treatments. Timely precipitation prevented soil blowing but wind losses of loose residues occurred. Actual wind losses were difficult to determine because of relocation within disturbed areas. Mowing residues in the fall resulted in some deposition of residues in areas of low microtopography and in nearly complete removal on higher exposures. Residues tended to be deposited into furrows in some of the plots. Snow was blown off plots where residues were completely leveled such as was produced by one-way disk and mowing. Tandem disk at 45° angle to rows preserved some upright stalks for partial snow retention, as did sweep cultivation.

Failure to bury residues by disking in the fall of 1958 under dry soil conditions gave artificially less residue loss than would be normally expected (Table 3). Residue reduction for spring disking under moist soil conditions are considered normal.

Double disking tended to reduce the percentage of residue survival when compared with single disking (Tables 3, 4). A portion of large stalks temporarily buried by disking were later brought up to the surface by succeeding sweep and rod weed treatments. These stalks showed little evidence of decomposition since the surface soil conditions were dry during both fallow seasons.

Stalk breakage during fallow appeared to be a function of time, weathering, and tillage. Stalks became increasingly brittle and discolored on the surface. Residue particles at the end of fallow averaged 2 to 5 inches in length under disk treatment compared with 4 to 10 inches with subtillage.

There was some variation in weed control by tillage when the fallow seasons were considered as a whole. Early spring weeds undercut by subtillage tended to re-root when tillage was conducted shortly before additional precipitation was received. Disk tillage tended to cause volunteer sorghum to germinate but it was later controlled by sweep and rod weed operations. Weed species included lambs quarter early in the season, succeeded by volunteer sorghum, pigweed, Russian thistle, and late season grassy weeds in that order.

Rotation and row width experiment—The results of this experiment are summarized in Table 5. Survival of surface residues for the 1959 fallow season was a function of both row width and rotation. Significantly higher percentages of initial residues were preserved when sorghum was grown in wider rows than narrower and where sorghum succeeded fallow compared with sorghum grown after wheat. Use of the 48-inch V-sweeps tended to wind-row residues regardless of initial row width. This was caused by pushing residues away from the shank furrow.

Wider rows produced taller stalks initially. Consequently residue stalk length at the end of the fallow season was a function of original plant height. For example, stalk residue lengths of 14- and 42-inch row widths averaged 3–6 and 4–10 inches, respectively.

Stalk breakage, over-winter—Stalk breakage was high for the one season in which counts were taken (Table 6). Between 23 to 70% of the stalks were broken during the winter months. Although no definite conclusions could be drawn, observations indicated that stalk collapse during the dormant fall and winter season was a function of many factors: incidence of charcoal rot at base of stalks, height, position in relation to exposure to snow drifting, plant population, row width, maturity of stalk, distribution of stalks within rows, orientation of rows to a particular storm and severity of storms. In all cases where stalk counts were taken, the lodged stalks were still attached to the base of the plant, indicating very little wind removal of the primary stalks. Leaves and shredded materials were removed by wind if the plant population was less than 18–20 thousand stalks per acre as in the case of the listed plots in the sorghum row width-rotation experiment (Table 6).

Table 5—Survival of sorghum residues under subtillage during fallow as affected by row width and rotation in 1959.

Treatment: Row width	Treatment: Rotation	Initial residues, fall 1958, lb./A.	Plant population	% residues at end of fallow, 1959
14 inches Drilled	F-W-S	1950	33,000	22
	F-S	2000	34,000	26
28 inches Drilled	F-W-S	2300	38,000	21
	F-S	2550	36,000	31
42 inches Drilled	F-W-S	2050	36,000	32
	F-S	2750	37,000	35
42 inches Listed	F-W-S	1750	12,000	21
	F-S	1750	17,000	26
All*	F-W-S	2000	30,000	24
All*	F-S	2250	31,000	30
All treatment LSD .05		610	8,000	10
Rotation LSD .05		NS	NS	6

* For over-all comparison of F-W-S with F-S.

Table 6—Percent broken stalks at end of 1958–59 winter season in the 1958–59 tillage and the row width and rotation experiments.

Treatment	Stubble height, in.	Stalks per acre	% stalks broken
	1958-1959 tillage experiment		
Reliance, 28 inch	17	56,000	23 north plots 29 south plots
RS 501	25	42,000	70 north plots 40 south plots
	Row width and rotation experiment		
Drilled, 14 inch	11	33,500	32
Drilled, 28 inch	15	37,000	40
Drilled, 42 inch	16	36,500	49
Listed, 42 inch	16	14,500	34
LSD .05			11

DISCUSSION

Any analysis of the importance of sorghum residues in a fallow system in areas of limited rainfall must integrate a number of major variables for final interpretation. Among these are climate, nature of stubble, date of first primary tillage, and soil cloddiness.

Climate helps determine the production of residues and also plays a role in loss of residues after production. Normal weathering can be responsible for reducing residues by wind and water transportation, surface decomposition, and leaching of soluble compounds. The total loss of residues during the dormant season can be high, as found in the experiments reported in this paper and by the results in Oklahoma (6).

The effect of the nature of stubble is related to plant population, maturity, and height of cutting. There can be nearly 100% loss of all materials cut above the combine cutter bar if plant populations are low. There appears to be greater resistance of larger and more robust stalks grown in wide rows to transportation, burial, or decomposition than weaker stalks often produced in narrow rows (Table 5).

Under no circumstances is fall disturbance of sorghum residues considered advantageous for the semi-arid regions. Loosening sorghum residues in the fall, either by cultivation or grazing, greatly magnifies the wind erosion hazard. In this manner clods are shattered, residues transported off the field by wind, and snow retention potential is reduced. Experience indicates that the first primary tillage on undisturbed sorghum stubble can begin one to two weeks later in the spring than for the primary tillage on wheat stubble. Water consumption by volunteer growth and spring weeds usually begins earlier in wheat stubble than in sorghum.

Soil cloddiness is needed under sorghum stubble-mulch to supplement lower quantities of residue and lower surface area covered per unit of residue at the end of summer fallow tillage. The weight-surface area ratio of sorghum residues is not comparable to that of small grain stubble. The results of Chepil and Woodruff (2) have shown that as much as 75% of the variability of wind erosion can be attributed to soil cloddiness, surface roughness, and crop residues. Thus, in semi-arid areas of low sorghum weight-surface coverage, major consideration must include a method for providing optimum sized (½- to 3-inch diameter) mechanically stable clods.

The importance of soil texture in relation to clod structure has been pointed out by Chepil (1). The potential wind erodibility of the sandier textured soils as found in his work was not encouraging. A moderate portion of sorghum production in the West Central Plains is on sandy soils and constitutes a major wind erosion hazard.

Woodruff and Chepil (7) have shown that for emergency wind protection it may be necessary to create maximum surface roughness by listing, which would bury all residues. A drastic treatment of this type would only be needed when the production of residues is generally insufficient to provide over-winter land protection.

Strip cropping of sorghums in rotation with winter wheat and fallow would increase field protection and supplement the influence of residues and soil cloddiness in reducing wind erosion. Research is now underway to study the role of sorghum residue strips for strategic decomposition of snow for moisture conservation and reduction of surface wind velocities.

SUMMARY

Cultivated sorghum acreage ranks second to wheat as a source of vegetative material for wind and water erosion control in the Central and Southern Great Plains of the United States. Its importance is magnified in a wheat-sorghum-fallow rotation where vulnerability to erosion is highest during the fallow year. Results of three sorghum stubble management experiments showed that residue was lost by two mechanisms: (a) climatic weathering, and (b) tillage burial. Climatic weathering included loss of residues by wind, decomposition, and possibly leaching of carbohydrate materials. Losses by tillage burial were a function of type of implement, frequency of use, timing, and soil moisture conditions. Undisturbed stubble lost 31 to 34% of the residue weight by over-winter weathering. Combinations of various experimental fallow tillage practices preserved 15 to 45% of original sorghum residues at wheat seeding time. Of several tillage methods attempted, subsurface tillage, including wide blades and bar implements, preserved residues more effectively than the use of disk type implements during the two years of comparisons.

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