SORGHUM RESIDUES IN A SUMMER FALLOW SYSTEM:

I RESIDUE REDUCTION BY TILLAGE

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ABSTRACT

Sorghum residue ranks second to wheat as source of vegetative material for wind and water erosion control in the Central Plains of United States. Its importance is magnified in a wheat-sorghum-fallow rotation where vulnerability to erosion is highest during the fallow year. Results showed that residue preservation was a function of loss by two primary mechanisms; (1) climatic weathering and (2) tillage burial. Climatic weathering included loss of residues by wind removal, decomposition, and possibly leaching of carbohydrate materials. Losses by tillage burial was a function of type implement, frequency of use, timing, and soil moisture conditions. Undisturbed stubble lost 33% weight by over-winter weathering. Combinations of various tillage implements preserved quantities of original residues ranging from 15-45%. Subsurface tillage with wide blades and bars was the most effective method for residue maintenance.

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Stubble-mulching in western Kansas, western Nebraska, and eastern Colorado is primarily a supplement with soil cloddiness for wind protection during the summer fallow period and also for the succeeding winter-wheat planting. Acreage reductions in wheat has necessitated the substitution of a wheat-sorghum-fallow rotation as a replacement for alternate wheat-fallow in many farming units of the above region. A wheat-sorghum-fallow rotation therefore, involves sorghum residue as the primary plant cover for the critical erosion seasons.

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 (9). Most residue measurements involve only total weight of plant cover in relation to other soil-plant interactions. Other attributes of wheat residues such as height, distribution, orientation, and quality also have influence (3). The same should be true of sorghum residues.

Sorghum residues as a source of vegetative cover has received little attention to date. The quantities produced in the semi-arid region is known to be generally low, from ½ - 2½ tons per acre (4, 5). Zingg, Woodruff, and Englehorn (8) found a significant reduction in wind erodibility of soil when standing sorghum stubble was oriented at right angles to the wind. High weathering losses of standing forage sorghum was 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 forage by weight.

The purpose of this investigation was to obtain partial evaluation of sorghum residues under various tillage methods of fallow and measurements of natural weathering losses.

EXPERIMENTAL PROCEDURE

Three field experiments were conducted, two experiments involving methods of tillage on fallow for measurement of sorghum residue preservation and one experiment on the survival of residues by stubble-mulch tillage as a function of rotation and row width of grain sorghum. The experimental treatments for the years 1958-1960 are summarized as follows:

1958-1959 Tillage Experiment

An eighteen acre field of grain sorghum was grown succeeding millet during 1958 as a source of residues for subsequent tillage treatments for the 1959 fallow season. The soils on the experimental plots included equal areas of Ascalon fine sandy loam and Sligo loam making up 66% of the area involved. Small patches of Goshen loam, Haxtun fine sandy loam, Platner loam, and Rago silt loam made up the other 34% of the field. Field dimensions were 302 feet by 2500 feet and included four planting blocks:

Variety Sorghum	Acres	Position	Row Width Planting Inches	Stalks Per Acre 000	Stalk Height Inches
Reliance	4.5	NW	42	24	17
RS 501	4.5	SW	28	49	22
RS 501	4.5	NE	42	42	25
Reliance	4.5	SE	28	56	17

Individual planting blocks were 161 feet by 1300 feet oriented lengthwise east to west and were subdivided into six plots 80 feet by 400 feet for tillage treatments. A proposed sweep-spray, sweep plot was abandoned from the original design when dry weather eliminated the need for spraying during the summer of 1959.

Tillage Treatments, Fall versus Spring

<u>Initial</u>

Initial	
Sweep, 48 inch V blade (1)*	One sweep and two rod weed operations were used successively after initial tillage for the remainder of the fallow season on all tillage plots.
Mow, 2 inches high (1)	
One-way disk (1)	
Tandem disk 45^o angle to rows (1)	
Tandem disk 45^o angle to rows (2)	

( )* refers to number of times implement was used.

Dates of Tillage

October	24	-	Fall treatment
May	18	-	1st. spring
June	15	-	2nd. spring
July	23	-	Miller rod
August	21	-	Miller rod

1958-1959 Sorghum Rotation and Row Width Experiment

Reliance grain sorghum was grown on Wald silt loam in row width plantings of 14, 28, and 42 inches in rotations of alternate fallow-sorghum (F-S) and fallow-wheat-sorghum (F-W-S). Plots of 50 feet by 150 feet dimension were replicated three 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 tillage was as follows: sweep 48 inch V blades on May 18 and June 16 succeeded by Miller rod-weeding July 22 and August 22.

1960 Tillage Experiment

A series of ten tillage treatments with three replications in randomized blocks were included for the 1960 season. Residues were provided by growing nineteen acres of bulk RS 501 grain sorghum succeeding winter wheat parallel to the 1958-1959 tillage experiment. The soils included Ascalon fine sandy loam occupying the center half of the field with the east 25% composed of Rago silt loam and the west 20% primarily Sligo loam. A limited area of 5% of the field west of center was Goshen loam. The field was 320 feet by 2600 feet and subdivided into 30 plots 60 feet by 400 feet. No fall tillage was involved.

Tillage Treatments

1. One-way disk (1) - Sweep (2)
2. One-way disk (2) - Sweep (1)
3. Tandem disk (1) - Sweep (2)
4. Tandem disk (2) - Sweep (1)
5. Sweep blade, 16 inch V (3)
6. Sweep blade, 48 inch V (3)

Sweep blades, 48 inch V type were used for treatments 1-4 and 7-10. All treatments include (3) primary tillages. A rod weeder was utilized for the last field operation on all plots.

	Dates of Tillage
7. Chisel (1) - Sweep (2)	April 25 - 1st spring operation
8. Chisel (2) - Sweep (1)	June 12 - 2nd spring operation
9. 12 foot Bar (1) - Sweep (2)	July 6 - sweep 48 inch V
10. 12 foot Bar (2) - Sweep (1)	August 3 - Miller rod-weed

Residue Sampling

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

As large drying ovens facilities were not available, samples taken during the fall and early spring were air dried a minimum of two months before weighing. Large variation in sampling can occur because of several factors: movement of residues by tillage, movement of residues by wind, natural production variation, and small sampling area within large plots.

Stalk Breakage

Positions were selected in stubble during the fall of 1958 to determine winter damage to stalks. Two rows by 16 feet sample areas repeated six times per treatment were used for calculation of percent down stalks the following spring. In this manner, several hundred stalks were included per treatment. Percentage of lodged stalks in the fall were low and subtracted out.

RESULTS

Weather Conditions

The basic weather which prevailed during the experimental period is shown on table I. Production of residues and total pounds preserved by tillage favored the 1958-1959 season compared with 1959-1960. Although precipitation in 1958 for production of sorghum amounted to only 14.4 inches, this rainfall combined with sub-soil moisture reserves from the favorable 1957 season resulted in nearly 2½ times the residue production as 13.4 inches precipitation produced in 1959. The pattern of spring and summer rainfall during 1959 and 1960 did not include any long periods of moist surface soil conditions. Consequently, the decomposition of larger stalks appeared slow.

Over winter losses of undisturbed residues were large (tables 2, 3), averaging 31% and 34% for the two winters involved. Wind velocities and snowfall were higher in the latter season (table 1). A total of 19 inches snowfall was received in four storms the first winter and 39 inches snowfall in twelve storms were received in the second winter. Snow-cover prevailed in the 1959-1960 winter for 68 consecutive days which reduced the time element in residue exposure to wind compared with the previous season by 50 days.

There was no evidence of transportation of residues by water. No single rainstorm produced runoff during the experimental period. Snow melt runoff in the spring of 1960 was confined largely to north slope fields and silt loam soils. Soils on the tillage plots were generally not frozen and consequently runoff of snow melt was low.

Tillage Experimentation

The reduction of sorghum residues by tillage are summarized on tables 2, 3, and 4. No difficulty was experienced in carrying out any of the proposed tillage treatments except for spraying in 1959.

Cultivation in the fall of 1958 with dry surface soil produced a hazardous situation with respect to wind erosion. A complete breakdown of clods was created by disking. Timely precipitation prevented soil blowing but wind losses of loose residues occurred. Actual wind losses were difficult to determine because of re-orientation within disturbed areas. Residues tended to be deposited into furrows in some of the plots.

Mowing residues in the fall resulted in some deposition of residues in areas of low micro-topography and near complete removal on higher exposures.

Results for both years tillage experimentation (tables 2, 3) were similar even though total quantities of initial residue were greatly different. 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 quantities of residues at the end of fallow considered sufficient for prolonged wind erosion protection by itself.

Double disking tended to reduce the percentage of residue survival when compared with single disking in most cases (tables 2, 3). Disking residues when the surface soil was dry did not bury as much residues as when the surface soil was moist (table 2). A portion of large stalks temporarily buried by disking were later brought up to the surface by succeeding sweep and rod weed treatment. These stalks showed little evidence of serious decomposition because of relatively dry soil conditions for much of 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 average 2-5 inches in length under disk treatment compared with 4-10 inches with subtillage by sweeps and bars, and chiseling parallel to the rows.

In the tillage experiment of 1958-1959 there was no essential difference between sorghums residue preservation as a function of variety, row width (28 inch versus 42 inch), or fall versus spring when all plots were averaged (table 2). However, there were trends which indicated greater preservation by delayed use of sweeps in the spring. Failure to bury residues by disking in the fall under dry soil conditions gave an artifically high value for spring tillage comparisons.

There was little 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 if tillage was conducted shortly before additional precipitation was received. Disk tillage tended to plant volunteer sorghum which was later controlled by sweep and rod weed operations. Weed species included lambs quarter early in season succeeded by volunteer sorghum, pigweed, Russian thistle, and late season grassy weeds in that order.

The formation and preservation of soil clods during fallow as a function of tillage treatment was of particular interest. Upon the drilling of wheat after fallow there appeared to be a much greater quantity of optimum size wind resistant clods on the drill ridge when plots had received subtillage as compared with single or double disking. Samples for sieve analysis were taken from the 1960 treatments to determine erodibility and mechanical stability of the clods. The results will be presented in a later paper.

Rotation and Row Width Experiment

The results of this experiment are summarized on table 4. 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 with wider rows and where sorghum succeeded fallow. Use of the 48 inch V sweeps wind-rowed residues regardless of initial width. This was caused by pushing residues away from the shank furrow. Residue particles were longer in length at the end of fallow where they were longer originally as in the case of the two 42 inch row plantings. Residual stalks averaged 3-6 inches in the 14 inch and 4-10 inches in the 42 inch width row plantings.

Stalk Breakage, Over-Winter

Stalk breakage was high for the one season in which counts were taken (table 5). Between 23-70% of the stalks were broken during the winter for the treatment plots checked. Although no definite conclusions can be drawn, it appeared that the cause of stalks to 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 of 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 down stalks were still attached to the base of the plant, indicating very little wind removal of the primary stalk although leaves and shredded materials were removed if the plant population was less than 18-20 thousand stalks per acre as in the case of the listed plots (table 5).

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:

1. <u>Climate</u>: as related to production of residues and its role in loss of residues after production. Normal weathering can be responsible for reducing residues by wind removal; 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 at Oklahoma (6).
2. <u>Nature of Stubble</u>: as related to plant population, maturity, and height of cutting. There is nearly a hundred percent 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 mature stalks to resist transportation, burial, or decomposition than smaller immature stalks.
3. <u>Soil Cloddiness</u>: as related to quantity of residue and surface area covered by the 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 percent of the variability of wind erosion can be attributed to soil cloddiness, surface roughness, and crop residues. Thus, in areas of low sorghum residue production confounded by a low ratio of weight-surface coverage for sorghum, major consideration must then be given to providing optimum sized (½-3 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 as assistance with surface residues and soil cloddiness. Research is now underway to study the role of sorghum residue strips for strategic deposition of snow for moisture conservation and reduction of surface wind velocities.

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Table 1 - Climatic Summary of 1958-1960 period
U.S.D.A. Central Great Plains Field Station, Akron, Colorado

Year	Total Rainfall	Rainfall Mar.-Sept.	Total Snowfall* Oct.-Apr.	Wind Velocities* Oct.-Apr.
	Inches	Inches	Inches	MPH - 24 hour
1958	14.38	10.09	28	
1959	13.77	9.97	19	6.2
1960	8.94**	7.96**	39	6.8
1909-1959	17.1	11.51	32	5.9

* Period beginning fall of previous year

** Period of January 1 - September 30, 1960

Table 2 - Reduction of sorghum residues during fallow season as percent of initial residues.

1958-1959 Tillage Experiment

Tillage Treatment		Initial Residues	April 12 Residues after winter		June 23 End tillage variable	August 24 End of fallow		
		Lbs./A	Lbs./A	%	%	Lbs./A	%	
Fall	Spring							
Sweep	S-S	3370	2060	61	43	1080	32	
Mow	S-S	3520	1370	39	31	1010	29	
One-way	S-S	3350	1260	37	36	920	27	*
Tandem	S-S	3000	1560	52	44	960	32	*
Tandem	T-S	3680	1910	52	9	570	15	
Means		3390	1630	48	32	910	27	
	S-S	3620	2230	62	52	1350	37	
	M-S	3220	2320	72	47	1010	31	
	O-S	3540	2440	69	26	720	20	**
	T-S	3560	2280	64	24	680	19	**
	T-T	2890	2260	78	13	430	15	
Means		3370	2310	69	33	840	25	
Comparisons						$LSD_{.05}$ for tillage	8	
Varieties - all tillage								
Reliance		2950				760	25	
RS 501		3810				990	26	
Row Width								
28 inch		3670				980	27	
42 inch		3090				770	25	

* Dry soil
** Moist soil

Table 3 - Reduction of sorghum residues during fallow season as percent of initial residues.

1959-1960 Tillage Experiment

Tillage : Implement and times used Symbol*			Initial Residues Lbs./A	April 12 Residues after winter Lbs./A	%	June 23 End tillage variable %	September 2 End of fallow Lbs./A	%
O_1	-	S_2	1320	790	60	30	290	22
O_2	-	S_1	1160	770	66	17	240	21
T_1	-	S_2	1250	760	61	30	330	26
T_2	-	S_1	1320	860	65	20	230	17
Sweep	-	16 V_3	1440	930	65	47	430	30
Sweep	-	48 V_3	1390	970	70	64	570	41
C_1	-	S_2	1230	820	67	45	470	38
C_2	-	S_1	1380	970	70	50	500	36
Bar_1	-	S_2	1280	830	65	58	520	41
Bar_2	-	S_1	1330	890	67	62	600	45
Means			1310	860	66	43	420	32
							$LSD_{.05}$ all treatments	11

* Symbol

O - One-way disk
S - Sweep
T - Tandem disk
C - Chisel

Table 4 - Reduction of sorghum residues by subtillage during fallow as function of row width and rotation in 1959.

Treatment Row Width	Treatment Rotation	Initial 1958 Residues Lbs./A	Plant Population 000	End of fallow Residues Lbs./A	End of fallow Residues %	Row Width Average
14 Inches	F-W-S	1950	33	420	22	
Drilled	F-S	2000	34	520	26	24
28 Inches	F-W-S	2300	38	480	21	
Drilled	F-S	2550	36	790	31	26
42 Inches	F-W-S	2050	36	660	32	
Drilled	F-S	2750	37	950	35	33
42 Inches	F-W-S	1750	12	370	21	
Listed	F-S	1750	17	460	26	24
Rotation	F-W-S	2000	30	480	24	
Means	F-S	2250	31	680	30	
All treatment $LSD_{.05}$		610	8	150	10	
Rotation	$LSD_{.05}$	N.S.	N.S.	75	6	5

Table 5 - Percent broken stalks, end of 1958-1959 winter season.

Treatment	Height Stubble	Stalks Per Acre	Down Stalks	
	Inches	000	%	
		1958-1959 Tillage Experiment		
Reliance, 28 inch	17	56	23	north plots
			29	south plots
RS 501, 42 inch	25	42	70	north plots
			40	south plots
		Row Width and Rotation Experiment		
Drilled, 14 inch	11	33.5	32	
Drilled, 28 inch	15	37.0	40	
Drilled, 42 inch	16	36.5	49	
Listed, 42 inch	16	14.5	34	
		$LSD_{.05}$	11	