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Effect of Wind-Row Orientation on Erodibility of Land in Sorghum Stubble[1]

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THE planting of sorghum in rows running at right angles to the direction of the prevailing winds has long been a recommended practice for reducing the wind erosion hazard. Critical studies of the practice, however, have not been made.

This study is in the nature of a pilot experiment dealing with only a portion of the variables involved. Specifically, it is confined to one field of Ellis sorghum which was cut at a uniform 9-inch height with a field cutter. The field was located on the Munjor soil at the Fort Hays Branch Experiment Station near Hays, Kans. Wind tunnel studies of the field were made on November 15–16, 1950. A view of the field with the tunnel oriented parallel to the rows is shown in figure 1.

PROCEDURE

The equipment and procedures used in this study have been described in detail previously (1, 2, 3) and need not be repeated here. The tunnel was operated at each location in the usual manner, wherein four levels of wind force were applied to the surface at each setting of the tunnel. The total weight of soil material eroded from the tunnel was determined for each level of wind force by the use of a differential-type sampler. The ridge roughness equivalent, K, and the level of surface drag, τ, pertaining to the tests of each surface were determined from pressure relationships derived in tunnel calibration procedures (2).

Eight wind tunnel sets were made wherein the 30-foot duct of the tunnel was oriented over and parallel to a sorghum row. The row spacing was 40 inches while the duct width was 36 inches.

An equal number of sets was carried out at right angles to the rows. In this case the 30-foot length tunnel was equal to 9 row spacings. It was oriented to cover 8 rows of stubble with the ends of the duct placed at the center of the space between rows.

The number of stalks and the weight of residue were determined for each test location of the tunnel.

The clod structure was considered to be a constant for the field. Six samples of the immediate surface were secured to give a measure of the size distribution of clods and the variation within the field. The size distribution was obtained by rotary sieving.

Statistical methods were used as a tool to present and interpret the data which were subject to the usual large experimental error associated with field experiments of this type.

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RESULTS

Surface Roughness

Since the height of sorghum stubble was a constant for the experiment, the roughness of the surfaces was governed by the density of stubble and the wind-row orientation. The sorghum stalks are concentrated in the center of the test surface width when an artificial air stream is applied parallel to the row. They are distributed more or less uniformly throughout the width of a test surface when wind is applied at right angles to the rows. Any ridging within the rows causes greater resistance to air flow over the surface, particularly when wind is applied at right angles to them.

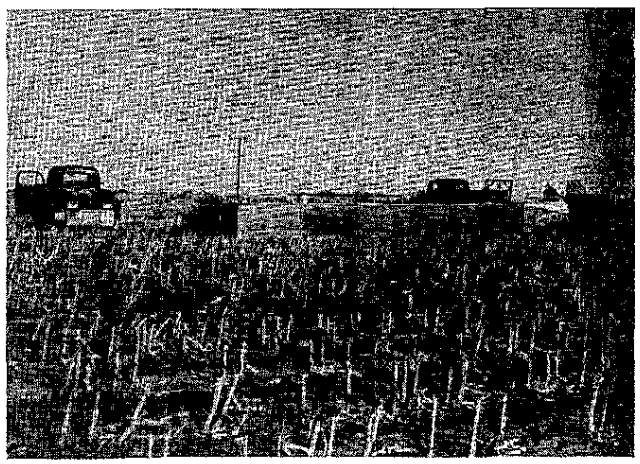

FIG. 1.—View of sorghum stubble field at the Fort Hays Branch Experiment Station near Hays, Kans. The wind tunnel used for evaluation of the wind-row orientation is in this instance placed over the center of a sorghum drill row.

The relationship of the ridge roughness equivalent, K, to the dry weight of sorghum residue, R, for the two wind-row orientations is shown in figure 2. It will be noted that values of K are higher per unit weight of residue where the wind was applied at right angles to the sorghum rows. For example, where the dry weight of sorghum, R, is 400 pounds per acre, K is approximately 3 inches where the rows are transverse to the wind. It is 1.5 inches where they are parallel to the wind. Where the value of R equals 1000 pounds per acre values of K equal 5 when the wind is at right angles to the row, and 3.5 when parallel to the

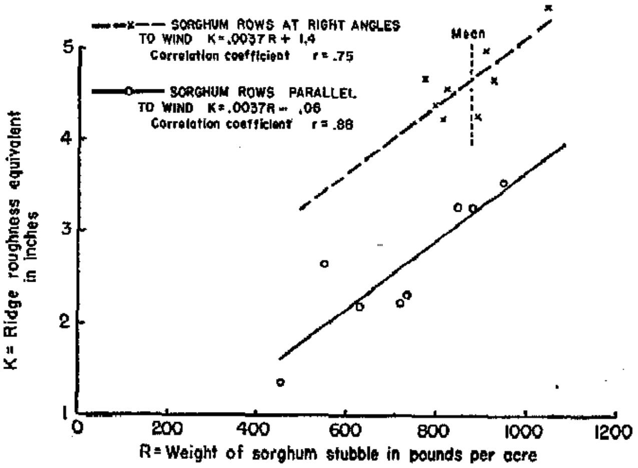

FIG. 2.—Relationships of K, the ridge roughness equivalent, to R, the weight of sorghum residue, for variable wind-row orientation.

row. A direct relationship is shown by the straight lines of the figure. It is probable, however, that the true relationship is a curvilinear one with the curves projecting to greater than indicated values on the K-axis.

It will be noted that values of R where the sorghum rows parallel the wind direction range from 400 to 1,000 pounds per acre. This range for the eight tests was obtained by a partial control of the stand by clipping out a portion of the sorghum stalks at the ground surface. The relatively small variation of residue for the transverse condition is natural variation within the field. The average weight of dry residue was 875 pounds per acre which may be considered a representative value for the field.

The number of stalks, N, per 90-square-foot test area, was equivalent to $N = \frac{R}{13.34}$. The moisture content of the stalks was 55%. Sorghum leaves comprised only 4.5% of the total weight of sorghum residue, and their moisture content was 9%.

Structure of Soil

An average of the dry sievings of six surface soil samples from the field gave clod size distributions as follows:

Clod size mm	Total weight percent
<0.42	28.3
0.42– 0.84	13.7
0.84– 2.0	9.8
2. 0– 6.4	12.7
6. 4–12.8	15.6
12. 8–38.0	18.3
>38.0	1.6

Past experience has shown that a soil of this structure is only moderately erodible. A small amount of soil movement by atmospheric wind occurred during the first day of the tests, demonstrating that it was susceptible to drifting.

Quantities of Soil Material Eroded

Multiple regression methods were used to obtain an average relationship of soil loss to the levels of wind force and amounts of residue. Assuming an exponential relationship, the equations obtained from the eight tunnel settings for each condition were:

$$\log x = 3.41959 \log \tau - 1.55756 \log R - 4.66046 \quad (1)$$
$$\log x = 2.91593 \log \tau - 2.05213 \log R - 1.98894 \quad (2)$$

where equation (1) represents the relationship when the wind was applied parallel to the row direction, and equation (2) represents the relationship for the soil eroded when the wind was applied at right angles to the rows. In the above equations, x equals the material eroded in pounds per acre, τ is the surface drag of the wind in units of force intensity of pounds per acre, and R is the weight of sorghum residue (oven dry basis) in pounds per acre. The indices of multiple correlation are 0.81 and 0.89 for equations (1) and (2), respectively.

A surface drag of 3,000 pounds per acre has been used previously to compare the erodibility of field surfaces (3). This value approximates the force of a wind of 1- to 2-year occurrence frequency in the month of April. By substituting a value of $\tau = 3{,}000$ pounds per acre in equations (1) and (2) the relationships of x to R may be obtained and the results presented in simple graphical form. These relationships are shown by the two curves of figure 3. From this figure it will be noted that quantities of soil material eroded when the rows parallel the wind are much greater than those from the transverse wind-row orientation. For example, for the average quantity of residue on the field, R = 875 pounds per acre, the losses are approximately 420 and 130 pounds per acre respectively, or a little over three times as large. When the quantity of residue is 400 pounds per acre, comparable figures for soil eroded are 1,500 and 650 pounds per acre.

By looking at the subject in another way, it is seen that lesser quantities of residue are required to cut erosion to a given level where the rows are at right angles to the

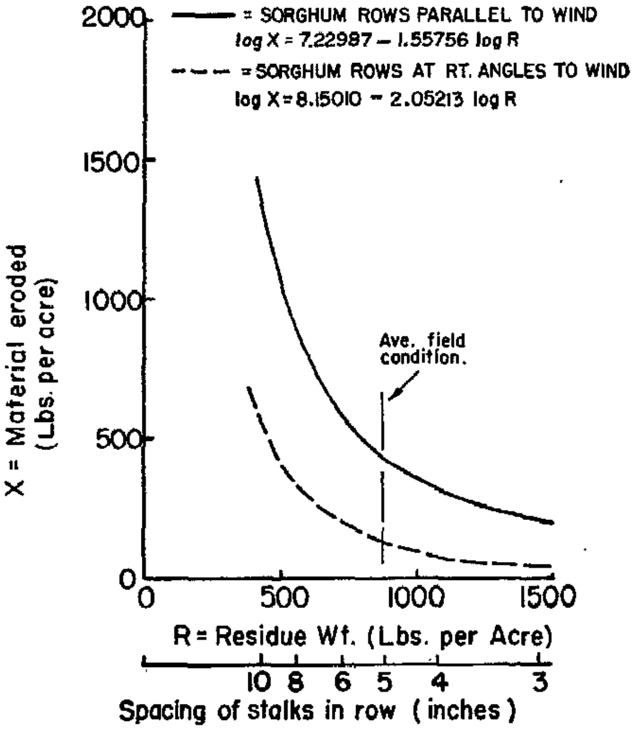

FIG. 3.—Relationship between amount of sorghum residue and material eroded at a surface drag of 3000 pounds per acre for (1) sorghum rows paralleling the wind direction and (2) sorghum rows at right angles to the wind direction. Data from 9 inch sorghum stubble field at Hays, Kans.

wind. As an illustration, 500 pounds of residue in rows transverse to the wind are as effective as 900 pounds of residue where the wind blows down the rows.

Retardation of Wind Velocity and Drag on the Soil Surface

The pattern of wind velocity above the soil surface for the wind-row orientation conditions is shown in figure 4. The ratio $\frac{V}{V_c}$ is the ratio of V, the velocity of the wind at a given height, to V_c, the velocity at an 18-inch height in the center of the tunnel duct. A third curve, representing the distribution of wind velocities over a fallow field on which the sorghum stubble has been obliterated through fallowing operations, is shown also for purposes of contrast. These latter data were secured at Amarillo, Tex. Assuming that this third curve is a reasonable representation of the field condition at Hays were no sorghum stubble present, some concept of the effect of the stubble in reducing the wind velocity within the height of stubble and near the ground surface can be gained.

A rather detailed consideration of the relative velocities and drag at the 1-inch height, which is near the projecting irregularities of the soil surface, will be given. From the curves of figure 4 values can be tabulated as shown in table 1. The ratios of wind velocity, $\frac{V_1}{V_c}$, for the three wind-residue-row conditions are shown under (a) of the table. Relative values of this ratio where condition (1) is considered to be unity are shown under (b). It is therein noted that the relative velocities for conditions (2) and (3) are 0.82 and 0.68 of those for condition (1). Again in column (c), the relative velocity for condition (3) is shown to be 0.83 of that for condition (2); in other words, the relative velocity at the 1-inch height in sorghum with rows at right angles to the wind is 83% of that for rows parallel to the wind. The relative drag taken by the portion of the surface below 1 inch is approximately proportional to the square of the relative velocities as shown in column (d). In column (e) the relative drag of the wind below the 1-inch level in sorghum stubble at right angles to the wind is 0.69 of that where the wind direction parallels the row.

Another approach can be used to approximate the relative protection of the stubble to the soil for the two wind-row directions. By equating equations (1) and (2) for

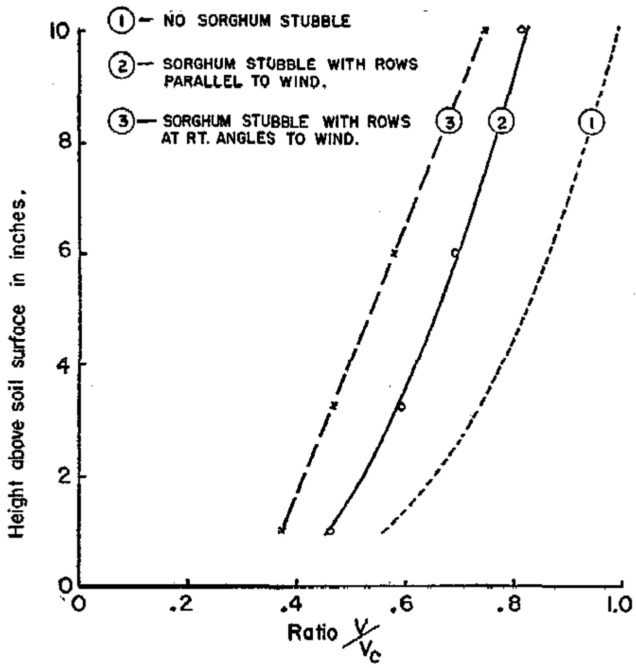

FIG. 4.—Ratios of $\frac{V}{V_c}$ at various heights above the soil surface for varying wind-residue-row conditions.

equal values of soil loss x, the values of drag required to produce equal soil losses over the two surfaces can be estimated. Limiting the comparison to the average residue of 875 pounds per acre for the field, an expression is derived as follows:

$$\log \tau_1 = 0.85271 \log \tau_2 - 0.35577$$

where τ_1 and τ_2 are the levels of drag in pounds per acre for the parallel and the transverse wind-row orientations, respectively. When $\tau_2 = 3{,}000$ pounds per acre, $\tau_1 = 2{,}093$ pounds per acre as determined from the above relationship. At this specific regimen of drag levels, approximately 50% more drag is required to cause as much erosion where the rows are transverse to the wind as where they are parallel to the wind. From the nature of the equation, $\frac{\tau_1}{\tau_2}$ is a variable.

Table 1.—Values of relative wind velocity at a 1-inch height above the ground surface and relative drag of the wind taken by the soil-cover complex at or below a height of 1 inch.

Wind-residue-row condition	$\frac{V_1}{V_c}$	$\frac{V_1}{V_c}/0.56$	$\frac{V_1}{V_c}/0.46$	$\left(\frac{V_1}{V_c}/0.56\right)^2$	$\left(\frac{V_1}{V_c}/0.46\right)^2$
	(a)*	(b)†	(c)‡	(d)§	(e)‖
(1) No sorghum stubble	0.56	1.00	—	1.00	—
(2) Sorghum stubble (rows parallel to wind)	0.46	0.82	1.00	0.67	1.00
(3) Sorghum stubble (rows at right angles to wind)	0.38	0.68	0.83	0.46	0.69

* Ratio of velocity of wind at 1-inch height to its velocity at 18-inch height.
† Relative velocity ratio of wind at 1-inch height based on condition (1).
‡ Relative velocity ratio of wind at 1-inch height based on condition (2).
§ Relative drag of wind below 1-inch height based on condition (1).
‖ Relative drag of wind below 1-inch height based on condition (2).

Characteristics of Eroded Material

The wind-row orientation was found to affect the distribution and size of material eroded from the tunnel. Averages of these data are summarized in table 2. Where the rows parallel the wind direction the percentage of the material moving below a height of 1 inch comprised about 22% of the total. Where the rows were transverse to the wind direction a comparable figure was 9%. Similar differences were obtained at all heights as shown in columns 2 and 3 of the table. A simple breakdown of the materials eroded into the percentage <0.044 mm indicates they are smaller in size where the wind is applied transversely to the row. There is also some tendency for the transported material to decrease in size with height above the soil surface as shown in columns 3 and 4 of table 2. The lesser size of eroded material for the transverse wind-row orientation is apparently associated with decreased wind force on the soil due to the orientation of the sorghum stalks.

Interpretation of Field Value of Results

When wind is applied parallel and wind is applied at right angles to the row direction the relative losses of soil represent the largest possible contrast. Under field conditions the best that can be done is to place the rows at right angles to the prevailing winds. In this case atmospheric winds will come from all directions. The benefits creditable to the practice therefore will be governed by the proportions of the time the rows are more or less at right angles to the wind direction.

Table 2.—Soil material eroded from the leeward end of the tunnel in relation to height above the ground surface.

Height above ground surface	Material transported below given heights in relation to total removal from plots		Soil material finer than 0.044 mm	
	Rows parallel to wind	Rows at right angles to wind	Rows parallel to wind	Rows at right angles to wind
Inches	Percent	Percent	Percent	Percent
1	22.2	8.9	24.4	27.9
3½	48.9	26.9	21.5	26.3
6	68.2	42.2	25.0	31.8
10	87.3	60.3	25.8	38.9
12*	89.6	68.0	—	—
18*	99.2	85.0	—	—

* Estimated.

The prevailing wind directions in western Kansas are from the north and south quadrants of the compass. Sorghum rows are, therefore, usually planted in an east-west direction. At Dodge City, Kans., approximately 80% of the wind in excess of 15 miles per hour comes from the north and south, and 20% from the east and west quadrants.

An example of the benefit to be derived from running rows east-west over north-south at Dodge City can be made using the following assumptions:

(1) Winds in excess of 15 miles per hour are equal in erosive characteristics.

(2) Wind blowing from the east-west or north-south quadrant will be considered to yield losses with respect to row direction equal to those obtained for average conditions of the experiment at Hays, Kans., i.e.,

$$\frac{\text{Loss from rows at right angles to wind}}{\text{Loss from rows parallel to wind}} = \frac{1}{3}$$

Under these conditions the net effect on soil loss from placing rows east-west over placing them north-south is as follows:

$$\text{Ratio} = \frac{\text{Soil loss from rows E–W}}{\text{Soil loss from rows N–S}} = \frac{(80\% \times 1) + (20\% \times 3)}{(80\% \times 3) + (20\% \times 1)} = 0.54$$

In round figures the soil lost from rows drilled east-west would, therefore, be about one-half that from rows in a north-south direction.

The scope of the present experiment should be expanded subsequently to evaluate the variable of stubble height and to cover a range of soil structure conditions. Broadening the experiment to include these factors did not appear advisable at the time the presently reported experiment was undertaken. Now that an understanding of the variability of results associated with stubble density and the magnitude of the experimental error is at hand, an expansion to include these variables is feasible.

SUMMARY

The results of an experiment designed to evaluate soil erosion by wind with respect to the wind-row orientation of sorghum stubble are presented. The data are limited to one field of 9-inch sorghum stubble at Hays, Kans.

Relationships describing the roughness of the surface in relation to stubble density and row direction are developed. Equations for estimating the amount of soil eroded for varying drag levels of the wind and for varying quantities of sorghum stubble are presented. These equations describe the losses experienced with a wind tunnel operated both parallel and transverse to the row direction.

When the rows of sorghum stubble were transverse to the wind, the relative velocity and the drag of the wind on the soil surface were decreased; consequently, amounts of erosion were decreased. These decreases were in comparison to values obtained when wind was applied parallel to the row direction. Measured differences were interpreted in terms of relative soil losses expected for field conditions.

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