

Wind Erosion as Influenced by Row Spacing, Row Direction, and Grain Sorghum Population¹

E. L. SKIDMORE, N. L. NOSSAMAN, AND N. P. WOODRUFF²

ABSTRACT

Replicated plots of grain sorghum (*Sorghum vulgare*) with 21- and 42-inch row spacings and three plant spacings within each row spacing were established on Dalhart sandy loam in 1963 and yield data were obtained. In March 1964, four wind tunnel tests were conducted on each plot, two with wind blowing parallel to row direction and two perpendicular. Sorghum stubble residue was sampled and analyzed. The results were interpreted in terms of natural wind conditions for sample locations in the Great Plains by applying previously developed procedures to determine prevailing wind erosion direction and preponderance of wind erosion forces in the prevailing wind erosion direction.

Soil loss was reduced by narrow row spacing, high plant population, and rows perpendicular to wind direction. Nearly three times as much erosion occurred with wind blowing parallel to row direction.

The combined advantage of narrow row spacing (21-inch) and rows perpendicular to prevailing wind erosion direction reduced soil loss from 29 to 55%. Greater reductions result when a larger proportion of wind erosion forces occur in the prevailing wind erosion direction.

Plant residue and grain yield increased significantly with higher plant population. Grain yield was not significantly affected by row spacing.

Based on the results of this study and for similar conditions, for decreased wind erosion and maintenance of grain yields one should (i) plant high plant populations within the recommended range, (ii) plant in narrow row spacings, and (iii) where field layout permits, plant perpendicular to prevailing wind erosion direction.

GRAIN SORGHUM (*Sorghum vulgare*) generally has been grown in 42-inch rows. In recent years interest has developed in narrow row spacing in grain sorghum (1, 2, 3, 6, 7). Wide spacing is unduly susceptible to soil erosion by wind, especially when the wind blows parallel to the rows. Considerable interest appears to be developing among farmers and farm technicians as to the value of narrow row spacing of grain sorghum stubble to control wind erosion, especially on sandy soils. This study is an attempt to provide information on the problem.

PROCEDURE

Experimental

Plots were established in southwest Kansas on Dalhart fine sandy loam. One 50-foot-wide strip throughout the length of the

¹Contribution from the Soil and Water Conservation Research Division, ARS, USDA, the Garden City Branch Exp. Sta., Contribution no. 81, and the Kansas Agr. Exp. Sta., Department of Agronomy Contribution no. 940. Received Jan. 10, 1966. Approved April 6, 1966.

²Research Soil Scientist, USDA, Manhattan, Kansas; Instructor, Dryland Investigations, Garden City Branch Exp. Sta.; Research Investigations Leader, Soil Erosion, USDA, Manhattan, Kansas.

field was planted to 'RS-610 hybrid' grain sorghum in rows spaced 21 inches apart. Another similar adjacent strip was planted in rows spaced 42 inches apart. One month after planting, the sorghum was thinned to give plant populations of one plant every 9, 18, and 36 inches in the rows with 21-inch spacing (33,000, 17,000, and 8,000 plants/acre) and one plant every 4.5, 9, and 18 inches in the rows with 42-inch spacing (3,000, 17,000, and 8,000 plants/acre), respectively. These row and plant spacings give areas of 189, 378, and 756 square inches/plant for the 33,000, 17,000 and 8,000 plants/acre populations. The thinnest population in 21-inch rows had one plant in each row inside the 36-inch wind tunnel placed at right angles to the rows. The thinnest population in 42-inch rows had two plants in each row inside the tunnel.

Plot size for each population was 40 by 50 feet. Each population was triplicated.

Grain yields were evaluated by sampling two rows 20 feet long from each individual plot. Paired samples were taken side-by-side for 21- and 42-inch row spacings to avoid variation due to topography and soil changes. The entire plot area was harvested with a combine cutting at uniform height of 16 inches.

Four wind tunnel tests were conducted on each plot—two with wind blowing parallel to row direction and two perpendicular. The portable wind tunnel (8) was operated 3 min at the same fan pitch and engine speed for all tests. Based on the calibration of Zingg and Woodruff (9), the average windspeed at the center of the tunnel at the leeward end was approximately 37 miles/hour.

A typical view of sorghum stubble and an insert of the portable wind tunnel are shown in Fig. 1.

Since the different row spacings required different types of cultivation, resulting in different degrees of soil surface roughness, all plots were smoothed with a rake before tunnel tests. Amount of soil loss was determined by the amount of soil collected by two 3/8-inch Bagnold catchers at the leeward end of the tunnel.

Quantity of vegetative matter was determined by sampling two 1-square-yard areas, washing, oven-drying, separating the leaves from the stems, weighing each, and computing each in accordance with standard procedure (USDA-ARS, 41-68, July 1962.).

Analytical

This section describes the method of combining salient findings of this study with the results of a previous study (4) to illustrate merit and application of both. The effect of row spacing, row direction, and preponderance of wind erosion forces in the prevailing wind erosion direction on soil loss are evaluated.

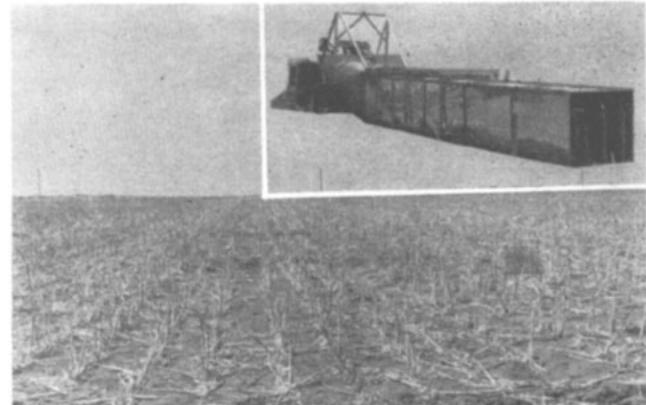


Fig. 1—A typical view of sorghum stubble and an insert of the portable wind tunnel.

The results of the experimental wind tunnel study give the amount of erosion that occurred with all wind blowing either parallel or perpendicular to row direction. Under natural conditions some wind erosion forces may occur at all angles with row direction. However, the wind erosion forces at a location can be resolved into two orthogonal erosion forces that are parallel and perpendicular to any particular direction.

The previous study (4) provided a method of estimating wind erosion forces parallel and perpendicular to a particular direction as follows:

$$F_{11} = \sum_{j=0}^{15} r_j \left| \cos(j \times 22.5 - \theta) \right| \quad [1]$$

$$F_{\perp} = \sum_{j=0}^{15} r_j \left| \sin(j \times 22.5 - \theta) \right| \quad [2]$$

where F_{11} and F_{\perp} are the parallel and perpendicular wind erosion forces, respectively; r is the magnitude of a wind erosion force vector in j th direction; the j 's indicate direction and take on values from 0 to 15, inclusive, corresponding to the 16 principal compass directions; θ is the angle between reference direction and direction in question.

The analysis is made from record of frequency of occurrence of direction by windspeed groups. It is assumed that winds will occur in the future according to their recorded history.

The percent of wind erosion forces parallel and perpendicular to a particular direction in terms of equations [1] and [2] is:

$$\%F_{11} = \frac{100 F_{11}}{F_{11} + F_{\perp}} \quad [3]$$

and

$$\%F_{\perp} = \frac{100 F_{\perp}}{F_{11} + F_{\perp}} \quad [4]$$

The percent of wind erosion forces parallel and perpendicular to the prevailing wind erosion direction in terms of the ratio of wind erosion forces parallel to perpendicular to the prevailing wind erosion direction R_m is:

$$\%F_{\perp} = \frac{1}{R_m + 1} \times 100 \quad [5]$$

and by difference

$$\%F_{11} = 100 - \%F_{\perp}. \quad [6]$$

From the percent of wind erosion forces parallel and perpendicular to a particular direction and information of soil losses from 21- and 42-inch rows parallel and perpendicular to row direction, soil losses for various combinations of row spacing and row direction were evaluated for sample locations by various arrangements of equation [7]. For example, the ratio of soil loss (21- or 42-inch row spacing) with rows perpendicular to prevailing wind erosion direction was found by:

Table 1—Components of variation and level of significance of soil removed from sorghum stubble by portable wind tunnel tests

Components of variation	Level of significance
Plant population	.025
Row spacing	.25
RS \times PP	.10
Orientation of wind tunnel	.0005
O \times PP	NS*
O \times RS	.25
O \times RS \times PP	NS*

* Nonsignificant at .25.

$$\text{Ratio (21- vs. 42-inch)} = \frac{E_{11}^{21} \%F_{\perp} + E_{\perp}^{21} \%F_{11}}{E_{11}^{42} \%F_{\perp} + E_{\perp}^{42} \%F_{11}} \quad [7]$$

where E_{11}^{21} and E_{11}^{42} are soil losses from 21- and 42-inch rows parallel to prevailing wind erosion direction. Similarly, E_{\perp}^{21} and E_{\perp}^{42} are soil losses from 21- and 42-inch rows perpendicular to prevailing wind erosion direction. If we assume:

- 1) That when wind erosion forces occur perpendicular to row direction the soil losses from 21- and 42-inch rows are 2 and 3, respectively;
- 2) when the erosion forces occur parallel to row direction, the soil losses from 21- and 42-inch rows are 2 and 4, respectively; and
- 3) the percent of wind erosion forces that occurs parallel and perpendicular to row direction is 40 and 60, respectively, then

$$\text{Ratio (21- vs. 42-inch)} = \frac{(2)(60) + (2)(40)}{(3)(60) + (4)(40)} = .588 \quad [8]$$

Based on the assumptions of the hypothetical example, soil loss from 21-inch rows was 59% of soil loss from 42-inch rows.

RESULTS AND DISCUSSION

Experimental

Soil loss data were analyzed as a split-split-plot design with plant population, row spacing, and orientation of wind tunnel with respect to row direction as main plot, subplot, and sub-subplot, respectively. Components of variation and level of significance are presented in Table 1.

More soil was lost from plots with 42-inch row spacing than from plots with 21-inch row spacing when the tests were made with the wind blowing parallel to row direction, but when wind was perpendicular the results show that losses were equal from the two row spacings (Fig. 2).

Analysis of yield data showed that yield was not significantly influenced by row spacing. However, as plant population increased, yield increased. The relation between yield and plant population is shown in Fig. 3. Each datum

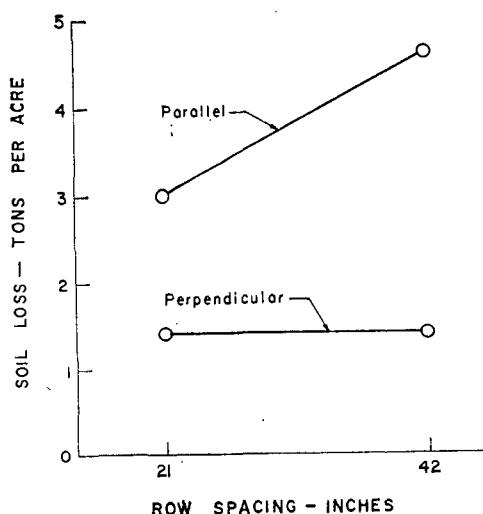


Fig. 2—The effect of row spacing on soil loss with portable wind tunnel tests conducted parallel and perpendicular to row direction.

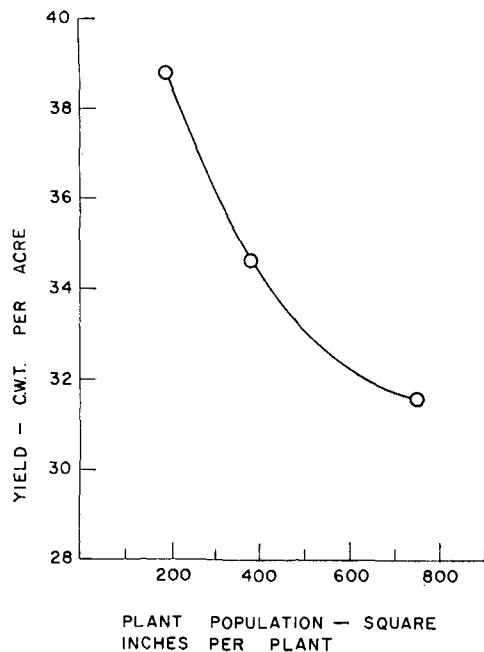


Fig. 3—The effect of plant population on sorghum yields (average of 21- and 42-inch rows).

point is the average yield of the two row spacings and three replications.

In some studies (2, 6), narrow row spacing produced larger yield. Ross and Laude (3) emphasized the necessity of not increasing the number of seeds per acre over that normally planted in 40- to 42-inch rows when planting in narrow rows with a grain drill. Stickler et al. (7) pointed out that the yield superiority of narrow rows in many tests when high plant populations were used was due to a high plant population and not to row width effects per se.

Erosion of the soil decreased as plant population increased (Fig. 4). The rate of increase of soil loss with increase of area per plant levels off at the upper end of the curve. At that point the load limit of the wind was being approached.

The recommended planting rate for grain sorghum in the area of the tests is from 240 to 480 square inches/plant (5). Soil loss at 480 square inches/plant was 178% of soil loss at 240 square inches/plant.

Amount of stubble residue was statistically highly significant with plant population. Interaction of row spacing and plant population with total stubble residue also was significant. Rate of increase of residue with increased plant population was greater for the 21-inch than for the 42-inch row spacing (Fig. 5).

Sorghum stem diameter increased with wider row spacing and thinner plant population. The ratio of leaf weight to stem weight was greatest for wide (42-inch) row spacing and high plant population (189 square inches/plant) and smallest for narrow (21-inch) row spacing and low plant population (756 square inches/plant). This suggests that leafiness is more closely related to the dimension of space per plant than to total area per plant.

Orientation of the wind tunnel with respect to sorghum row direction was the most highly significant component of the study. Nearly three times (2.8) as much soil was removed

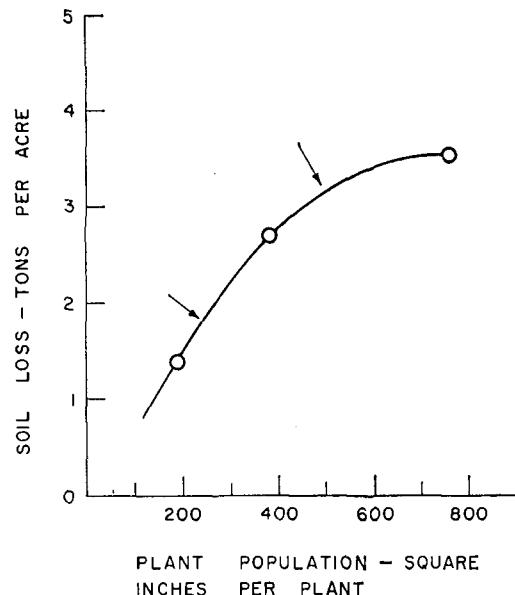


Fig. 4—The effect of plant population on soil removed from sorghum stubble by portable wind tunnel tests. Arrows in curve indicate range of recommended plant spacings for the geographic area studied.

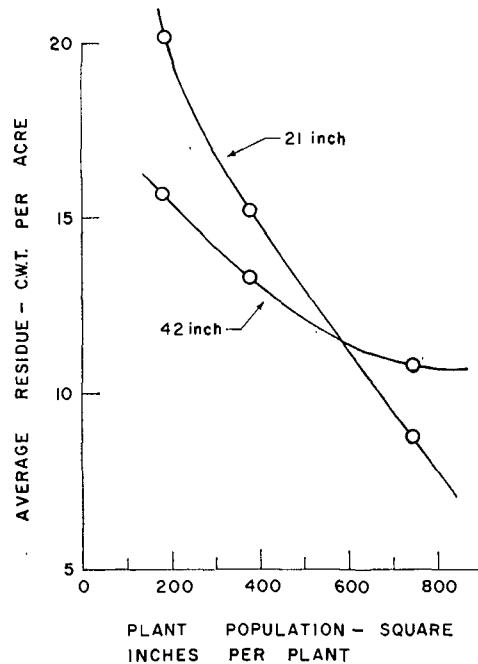


Fig. 5—Grain sorghum residue as affected by plant population and row spacing interaction.

with the wind blowing parallel as blowing perpendicular to row direction, which confirms results by Zingg et al. (10) for average field conditions.

Analytical

The effect of row spacing on soil loss when rows run parallel and perpendicular to prevailing wind erosion direction was estimated by applying equation [7] to results of this experiment and wind erosion forces at sample locations. The sample locations (Albuquerque, New Mexico; Great Falls, Montana;

Table 2—The effect of row spacing on soil loss when rows run parallel or perpendicular to prevailing wind erosion direction for sample locations

Month	Rm^*	Ratio of soil loss		
		21 \perp /42 \perp inch	21 \parallel /42 \parallel inch	21 \perp /42 \parallel inch
<i>Albuquerque</i>				
February	1.50	0.77	0.71	0.61
March	1.45	.76	.71	.62
April	1.43	.76	.71	.62
<i>Great Falls</i>				
February	3.30	.85	.67	.45
March	1.85	.79	.70	.56
April	1.63	.77	.70	.59
<i>Midland</i>				
February	1.10	.74	.73	.71
March	1.20	.75	.72	.67
April	1.06	.74	.73	.71
<i>Salina</i>				
February	1.93	.79	.69	.55
March	1.84	.79	.70	.56
April	1.63	.77	.70	.59

* Ratio of the wind erosion forces parallel to perpendicular of the prevailing wind erosion direction.

Midland, Texas; and Salina, Kansas) represent a variety of wind conditions in the Great Plains.

The advantage of 21-inch row spacing is less when both row spacings are perpendicular than when parallel to prevailing wind erosion direction (Table 2). The advantage lessens as a greater preponderance of wind erosion forces occur in the prevailing wind erosion direction (Fig. 6, curve c). This does not mean that less erosion occurs when rows are parallel to prevailing wind erosion direction but that the advantage of narrow row spacing is greater as a larger proportion of the wind erosion forces occur parallel to row direction.

At some locations a prevailing wind erosion direction essentially does not exist. The wind erosion forces parallel to

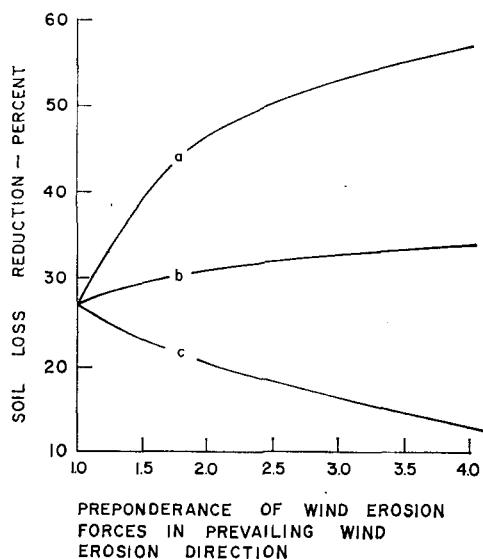


Fig. 6—Erosion as affected by preponderance of wind erosion forces in the prevailing wind erosion direction. Curve a is for 21-inch row spacing with rows perpendicular to prevailing wind erosion direction compared with 42-inch row spacing with rows parallel to prevailing wind erosion direction. Curves b and c are for 21- vs. 42-inch row spacing with rows parallel and perpendicular, respectively, to prevailing wind erosion direction.

Table 3—Ratio of north-south to east-west wind erosion forces for sample locations

Month	Ratio			
	Albuquerque	Great Falls	Midland	Salina
February	0.85	0.89	0.90	2.0
March	0.79	0.97	0.99	1.84
April	0.91	0.86	0.98	1.64

row direction will be as great as those perpendicular regardless of row direction. At other locations winds may blow consistently from one direction.

The combined advantage of narrow row spacing (21-inches compared with 42-inch) and row direction (perpendicular compared to parallel to prevailing wind erosion direction) is shown in Table 2, last column, for wind conditions at the sample locations. Soil loss reduction varies from 55% for February at Great Falls to 29% for February at Midland. The difference is caused by the preponderance of the wind erosion forces in the prevailing wind erosion direction. Soil loss reductions in relation to preponderance of wind erosion forces in the prevailing wind erosion direction for various comparisons of row spacing and orientation are shown in Fig. 6.

When rows run perpendicular to prevailing wind erosion direction, the advantage of 21- over 42-inch row spacing decreases as "prevailing wind erosion direction" becomes more pronounced (Fig. 6, curve c). However, if row direction is parallel to prevailing wind erosion direction, the advantage of 21- over 42-inch row spacing increases as the "prevailing wind erosion direction" becomes more pronounced.

Narrow rows perpendicular to prevailing wind erosion direction are best for erosion protection, but such orientation is not always feasible unless the prevailing wind erosion direction is north-south or east-west. If it is not obvious whether a north-south or east-west direction is better, a simple method of making this decision follows. Let a reference direction be east, and θ of equations [1] and [2] equal 90 degrees. The ratio of equation [1] to equation [2] evaluated for data at a respective location will give the ratio of erosion forces north-south to east-west direction. If the ratio is > 1.0 , it would be better to run the row east-west. If the ratio is < 1.0 , run the row north-south. If the ratio is 1.0, it won't matter whether rows are east-west or north-south.

This ratio was obtained for the sample locations and is presented in Table 3. The data indicate a slight advantage of north-south over east-west at Albuquerque and Great Falls. Row direction essentially would make no difference at Midland but there would be a distinct advantage for east-west rows at Salina.

LITERATURE CITED

- Brown, Paul L., and W. D. Shrader. 1959. Grain yields, evapotranspiration, and water use efficiency of grain sorghum under different cultural practices. *Agron. J.* 51:339-343.
- Laude, H. H., A. W. Pauli, and G. O. Thorneberry. 1959. Row spacing of dwarf grain sorghum. *Crops and soil field data report. Kansas Agr. Exp. Sta. Circ.* 323:21-23.
- Ross, W. M., and H. H. Laude. 1955. Growing sorghums in Kansas. *Kansas Agr. Exp. Sta. Circ.* 319.

4. Skidmore, E. L. 1965. Assessing wind erosion forces: Directions and relative magnitudes. *Soil Sci. Soc. Amer. Proc.* 29:587-590.
5. Stickler, F. C. 1964. Grain sorghum yields from 20- to 40-inch rows at various stand densities in Kansas. *Kansas Agr. Exp. Sta. Bull.* 474.
6. Stickler, F. C., and H. H. Laude. 1960. Effect of row spacing and plant population in performance of corn, grain sorghum, and forage sorghum. *Agron. J.* 52:275-277.
7. Stickler, F. C., A. W. Pauli, H. H. Laude, H. D. Wilkins, and J. L. Mings. 1961. Row width and plant population studies with grain sorghum at Manhattan, Kansas. *Crop Sci.* 1:297-300.
8. Zingg, A. W. 1951. A portable wind tunnel and dust collector developed to evaluate the erodibility of field surfaces. *Agron. J.* 43:189-191.
9. Zingg, A. W., and N. P. Woodruff. 1951. Calibration of a portable wind tunnel for simple determination of roughness and drag on field surfaces. *Agron. J.* 43:191-193.
10. Zingg, A. W., N. P. Woodruff, and C. L. Englehorn. 1952. Effect of wind-row orientation on erodibility of land in sorghum stubble. *Agron. J.* 44:227-230.