Wind erosion: Uniformly spacing nonerodible elements eliminates effects of wind direction variability

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ABSTRACT—Wind tunnel studies suggest that equidistant spacing of nonerodible elements, such as plants at various populations, provides equal protection from wind erosion, regardless of wind direction. The protection equals that of elements in rows oriented normally (perpendicular) to wind direction (row spacing in experimental data did not exceed 61 cm). These observations assume equal numbers of elements per unit area for any orientation.

WIND direction varies widely—during the same wind, among winds, and at various geographical locations. Monthly wind information is available on (a) relative magnitude, (b) prevailing wind (erosion) direction, and (c) preponderance of wind erosion forces in prevailing wind (erosion) direction (*8*). Such information indicates where and when protection from wind erosion is needed and the proper orientation of barriers or strips to reduce wind erosion forces.

Because of management practices, such as contouring, or farmer preference, crop rows may be oriented without consideration of wind erosion protection. Studies show that crops planted in rows perpendicular (normal) to wind direction give the most protection against wind erosion (*7, 12*). But few studies have compared the erosion protection provided by uniformly spaced elements (plants, stubble, etc.) with the protection provided by rows perpendicular or parallel to wind direction.

Experimental Procedure

We placed wood dowels (0.66 and 1.59 cm in diameter), with axes normal to a wind tunnel floor, in uniformly spaced diagonal arrays or in rows normal or parallel to wind direction (*4*). The same number of elements per unit area—387, 97, 24, or 11 per square meter (36, 9, 2.25, and 1 per square foot)—were used for two or three orientations. We covered the spaces between the dowels with erodible particles, 0.15- to 0.42-mm or 0.42- to 0.59-mm-diameter sand, and determined the loss rates for values greater and smaller than 0.01 g/cm-width/min. The windspeed associated with the 0.01 g/cm/min loss rate (determined graphically) for each height was defined as the stable surface windspeed.

We obtained the mean velocity profile parameters (Z_o, D, u_*) with the equation

$$\frac{\bar{u}_z}{u_*} = \frac{1}{k} \ln \left(\frac{Z - D}{Z_o}\right) \qquad [1]$$

where $\bar{u}_z$ is mean windspeed at height Z above some reference plane; u_* is the friction velocity, defined as $(\tau_o/\rho)^{1/2}$, where τ_o is the shear stress at the boundary and ρ is air density; k is von Karman's constant (0.4); D is an effective roughness height; and Z_o is a roughness parameter.

Data and Observations

We presented our experimental results in terms of a dimensionless parameter u_*/u_{*t}, as influenced by average height (H) of nonerodible elements (Figures 1-4). Earlier (*4*), u_*/u_{*t} was called the critical friction-velocity ratio (CFVR) because erosion began when it was exceeded. u_* is the total friction velocity when a surface stabilizes at a given free-stream velocity. u_{*t} is the threshold friction velocity for the erodible particles in question.

The CFVR value indicates the soil protection provided by nonerodible elements (stubble, clods, etc.). The greater the CFVR, the greater the protection provided. A CFVR of 1.0 indicates that no protection is provided by the nonerodible elements—either because none exists (H = 0) or because they are too few to influence particle movement. A CFVR of 3 indicates that total friction velocity (u_*) could rise to 3 times the threshold (u_{*t}) before erosion starts.

Several observations are obvious from figures 1-4. Rows normal to flow (wind direction) offer more protection against wind erosion than rows parallel to flow. The advantage of normal over parallel rows increases directly with element height, size (diameter), and number per unit area. Elements uniformly spaced in diagonal arrays and in rows normal to flow provided equal protection against wind erosion (for the same number of elements per unit area). This equality relationship appears valid between 11 and 387 elements per square meter (maximum row spacing of 61 cm) and for heights less than or equal to 43 cm (Figure 4).

The condensed height scale toward the right of figure 3 indicates that u_*/u_{*t} is related linearly to H for heights between 1 and 38 cm. However, the effect of element height on u_*/u_{*t} appears to diminish as H increases and as the number of elements per unit area decreases to some value less than 97 but greater than 24 (Figure 4).

Practical Considerations

Crop rows cannot be oriented to provide equal protection from wind from all directions unless all erosive winds come from the same or opposite direction. Our data suggest that equidistant spacing of plants provides equal protection regardless of wind direction. Furthermore, the protection equaled the protection provided by plants in rows normal to the wind direction.

Limited research (mostly in the Corn Belt) suggests that equidistant plant spacing may increase corn yields (*1, 2, 3, 6*). Such yield increases are attributed to shading of

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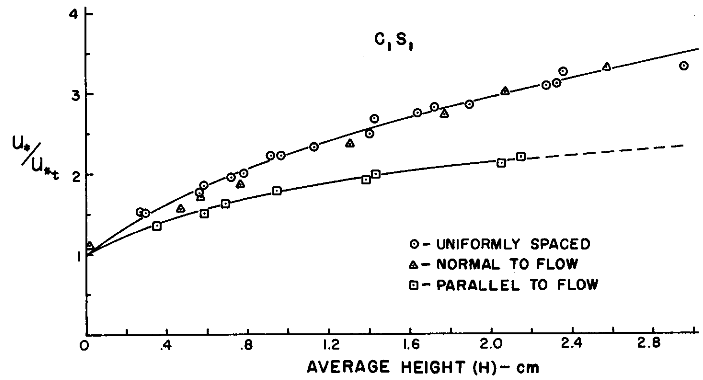

Figure 1. Effect of nonerodible element height and orientation to flow on wind-erosion protection: 0.66 cm diameter cylindrical elements (C_1); 387 elements per square meter (S_1).

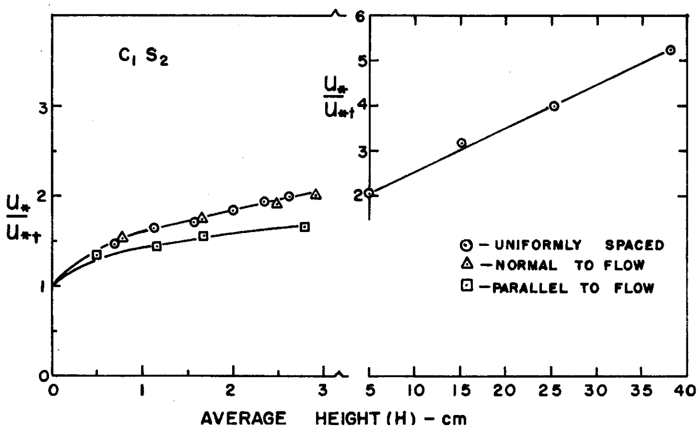

Figure 3. Effect of nonerodible element height and orientation to flow on wind-erosion protection: 0.66 cm diameter cylindrical elements (C_1); 97 elements per square meter (S_2).

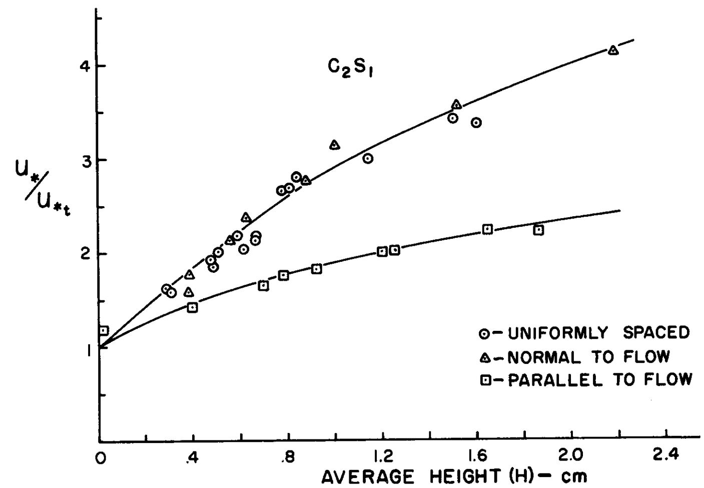

Figure 2. Effect of nonerodible element height and orientation to flow on wind-erosion protection: 1.59 cm diameter cylindrical elements (C_2); 387 elements per square meter (S_1).

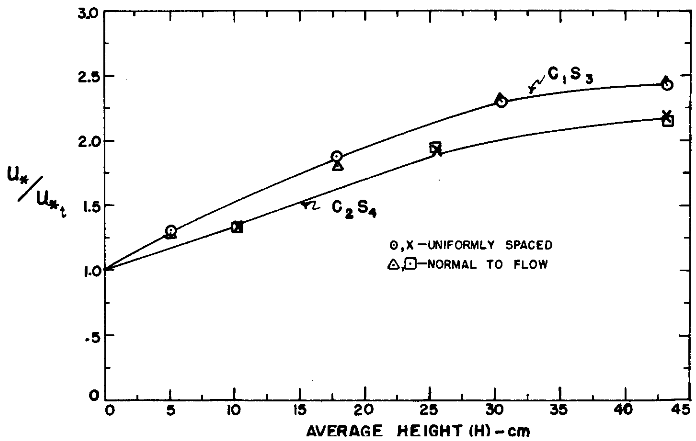

Figure 4. Effect of nonerodible element height and orientation to flow on wind-erosion protection: 0.66 (C_1) and 1.59 (C_2) cm diameter cylindrical elements; 24 (S_3) and 11 (S_4) elements per square meter.

the soil surface and uniform competition for soil moisture and solar energy.

We found no planned equidistant spacing studies of grain sorghum. A few stand density studies, involving some row spacings and plant spacings within rows so plants were approximately equidistant in all directions (*9, 10*), do not indicate yield increases for equidistant spacing. Apparently, by tillering, many crops (grain sorghum, barley, and wheat) adjust their yield and stalks per unit area over a wide range of plant populations.

Yields of soybeans (for the same number of plants per unit area) in two studies were maximum with plant spacings nearly equidistant (*5, 11*). Shibles and Weber (*5*) suggested the most efficient arrangement of soybeans is one that presents the most canopy surface during the growth cycle. Equidistant plant spacings appear to meet this criterion.

Disadvantages of equidistant plant spacings may be more difficult planting, harvesting, and weed control. However, omnidirectional protection against wind erosion and possible yield increases should stimulate additional study and perhaps development of equidistant plant spacing systems.

REFERENCES CITED

1. Dungan, G. H. 1946. *Distribution of corn plants in the field.* J. Am. Soc. Agron. 38: 318-324.
2. Fery, Richard L., and Jules Janick. 1971. *Response of corn (*Zea mays L.*) to population pressure.* Crop. Sci. 11 (2): 220-224.
3. Hoff, D. J., and J. H. Medereski. 1960. *Effect of equidistant corn plant spacing on yield.* Agron. J. 42: 295-297.
4. Lyles, Leon, R. L. Schrandt, and N. F. Schmeidler. 1974. *How aerodynamic roughness elements control sand movement.* Trans., ASAE 17(1): 134-139.
5. Shibles, R. M., and C. R. Weber. 1966. *Interception of solar radiation and dry matter production by various soybean planting patterns.* Crop Sci. 6(1): 55-59.
6. Shubeck, F. E., and H. G. Young. 1970. *Equidistant corn planting.* Crops and Soils 22(6): 12-14.
7. Skidmore, E. L., N. L. Nossaman, and N. P. Woodruff. 1966. *Wind erosion as influenced by row spacing, row direction, and grain sorghum population.* Soil Sci. Soc. Am. Proc. 30(4): 505-509.
8. Skidmore, E. L., and N. P. Woodruff. 1968. *Wind erosion forces in the United States and their use in predicting soil loss.* Agr. Handbook No. 346. U. S. Dept. Agr., Washington, D. C. 42 pp.
9. Stickler, F. C., and H. H. Laude. 1960. *Effect of row spacing and plant population on performance of corn, grain sorghum, and forage sorghum.* Aron. J. 52: 275-277.
10. Stickler, F. C. 1964. *Grain sorghum yields from 20- and 40-inch rows at various stand densities in Kansas.* Bul. 474. Kans. Agr. Exp. Sta., Manhattan.
11. Wiggans, R. G. 1939. *The influence of space and arrangement on the production of soybean plants.* J. Am. Soc. Agron. 31: 314-321.
12. Zingg, A. W., N. P. Woodruff, and C. L. Englehorn. 1952. *Effect of windrow orientation on erodibility of land in sorghum stubble.* Agron. J. 44(5): 227-230. □