Soil Ridging for Reduction of Wind Erosion from Grass Seedbeds[1]

W. E. MARLATT AND D. N. HYDER

Associate Professor of Atmospheric Science, Colorado State University; and Range Scientist, Crops Research Division, Agricultural Research Service, U.S. Department of Agriculture, Fort Collins, Colorado.

Highlight

In the wind tunnel, styrofoam ridges 2 inches high and 12 inches apart reduced wind velocities as much as 90% below the free wind velocity. In the field, ridging of a sandy loam soil by packing with a heavy packer wheel prevented wind erosion from the modified seedbed. High-intensity rain and hail can eliminate the ridges.

During several periods between 1880 and 1940, attempts were made to convert the grassland region of eastern Colorado into a dryland farming economy. Most attempts were unsuccessful; consequently, many thousands of acres were abandoned after 1 to 3 years of successive crop failures. Unfortunately, even though the land has lain idle for 3 or 4 decades, many fields have not reverted to the native blue grama (*Bouteloua gracilis* (HBK) Lag. ex Steud.) sod. The vegetation on these fields consists primarily of weedy species of grass and broadleaf plants (Fig. 1).

Over the years, a number of techniques for seeding these abandoned fields back to grass were tested (Bement et al., 1965). Seeding trials at the Central Plains Experimental Range generally were unsuccessful, due to the combination of low rainfall and strong winds in this region. Numerous strong winds cause severe erosion and prevent grass seedling establishment. The removal of several inches of soil by wind from unprotected seedbeds is not uncommon.

The erodibility of bare soil by wind is a function of wind velocity and turbulence, soil texture and structure, roughness of the soil surface, moisture content of the surface soil, and the size of the bare soil area. Reduction of wind velocity at the soil surface is one of the main principles in the control of wind erosion, because the force of the wind varies as the square of its velocity (Chepil, 1957). Therefore, even a slight reduction in wind velocity near the surface provides a marked reduction in erosion potential.

One of the most effective methods for reducing wind velocity at the soil surface is to prepare the seedbed so that the surface has a maximum roughness. A rough ground surface is more resistant to wind erosion than a smooth one because the rough surface reduces the wind velocity and traps dislodged particles before they attain enough velocity to become abrasive (Chepil, 1957). Maximum roughness often is obtained by deep plowing. The effectiveness of deep plowing is determined by its success in reducing the erodibility of surface soil particles (Chepil et al., 1962). Rough plowed soils are seldom good seedbeds, however, due to poor moisture holding capacity of the exposed clods. Deep plowing stops wind erosion, at least temporarily, if the subsoil turned up to the surface is cloddy and contains more than 12% clay (Hobbs, 1957). With a soil containing less than about 15% clay, additional treatments designed to increase surface roughness and bulk density are needed. Therefore, we theorized that resistance to wind erosion can be increased by packing ridges in freshly-plowed sandy soils.

A technique for modifying the surface of sandy soils to reduce the amount of wind erosion was developed in 1965 (Hyder and Bement, 1969). This technique consists of plowing when the soil is moist and packing with a heavy packer wheel. The first model of the roller was designed to make flat bottom furrows 4 inches wide separated by ridges 2.25 inches high. The packed ridges had a top angle

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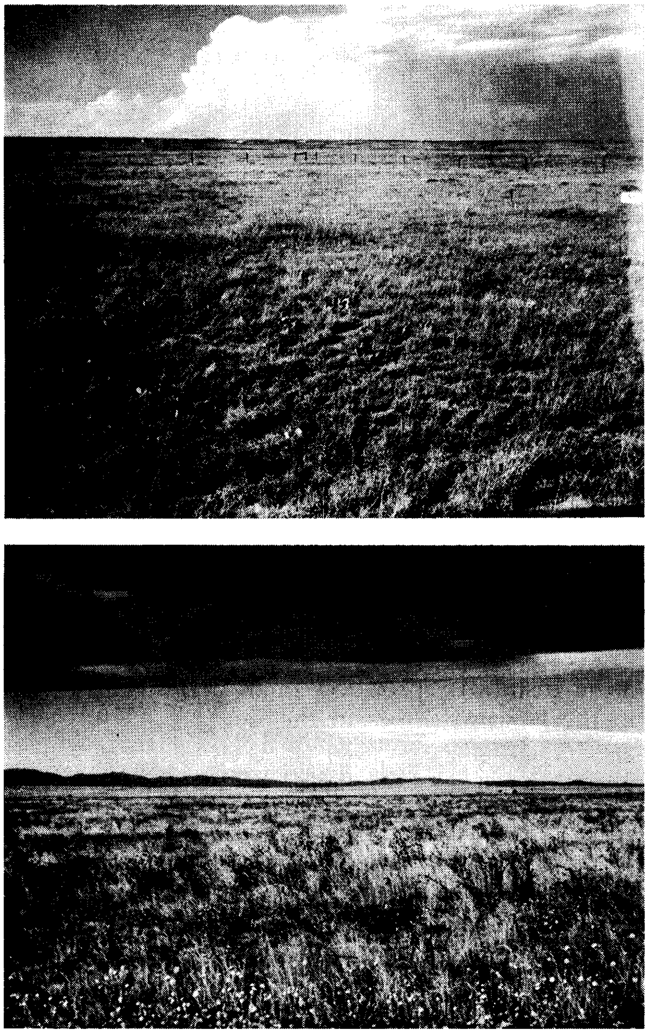

FIG. 1. Unplowed blue-grama sod (top) and adjacent abandoned field (bottom) as it appears more than 35 years after unsuccessful cropping.

of 120° and a spacing of 12 inches. Field testing in 1965 indicated that the roller firmed moist soil adequately but left the ridges with a great deal of lateral cleavage. After additional field testing in 1966, a second model was built. This roller was designed to form a succession of adjacent ridges having a height of 4 inches, a top angle of 113°, and a spacing width of 12 inches (Hyder and Bement, 1969).

The usefulness of ridging for erosion control was studied in the field, and the influence of ridges on vertical wind profiles was investigated by wind tunnel modelling in 1967. The results obtained evaluate the durability and windbreak effectiveness of small ridges.

Methods

The effectiveness of the ridges for protecting seedbeds from wind erosion was studied in the field at the Central Plains Experimental Range in northcentral Colorado and in the wind tunnel facility at the Colorado State University Engineering Research Center.

To determine the effect of ridges on the low level wind velocity profile, a stryrofoam model of the relief produced by the 1965-model roller was constructed in the Colorado State University micro meteorological wind tunnel. The model was placed in the tunnel with ridges at a right angle to wind flow. Wind velocity measurements at heights from 0.04 to 20 inches above the surface at each of 4 positions were made, using a nondirectional miniature hot wire anemometer. Two free-wind velocities of 13.6 mph (20 fps) and 34.1 mph (50 fps) were evaluated. The measurements were recorded on an X-Y analog plotter and graphed as profile envelopes of observations between mean minimum and mean maximum wind velocities. Mean wind velocities then were plotted as isotachs of equal velocity above the ridges. Time-lapse movies were taken of the model during tests under varying wind velocity using small yarn "flags" to indicate wind direction and turbulence on top of and between ridges.

The field experiments were located on a McGrew sandy loam soil that contains 10% clay. Other characteristics of this soil are given by Everson et al. (1969). Five test plots, each measuring 100 by 100 feet, were plowed to a depth of about 10 inches with a moldboard plow on March 28, 1967. Soil moisture was near field capacity in the plow layer. One plot was left in the rough-plow condition. The other four plots were packed with the 1966-model roller on March 29, 1967. Ridges, oriented to directions of 0, 45, 90, and 135 degrees, were measured five times to determine ridge erosion and furrow fill.

One-half-inch hardwood dowels 12 inches long were established in the furrows of the ridged relief (and in the rough-plowed soil) as elevational references for determining subsequent relief erosion. Five sets of 4 dowels each were established in each plot. All dowels were set with an exposed height of 4.0 inches. Thereafter, dowel heights were measured to determine furrow fill, and the heights of ridges (or plowed soil) between dowels were measured to determine ridge erosion.

Soil bulk densities of the surface 3 inches of soil in the furrows and ridges were obtained from cores cut while the soil was wet to near field capacity.

Daily amounts of wind movement and precipitation were measured by standard U.S. Weather Bureau instruments as factors relevant to erosion.

Results

Wind Tunnel Experiments

The degree of reduction in wind velocity near the surface of ridges varies with position on the ridges and with free wind velocity. The least reduction, with a free wind velocity of either 13.6 mph (20 fps) or 34.1 mph (50 fps), is directly above the ridge tops (Figures 2 and 3). This reduction is about 50 and 60% of free wind velocities of 13.6 and 34.1 mph, respectively. The greatest reductions, amounting to 75 and 90% of the low and high wind velocities, respectively, are above the furrows. Minimum wind velocities above the furrows are about the same (< 4 mph) for both free wind velocities.

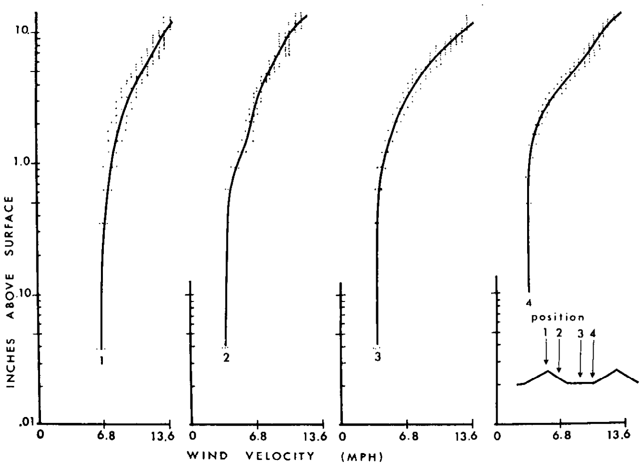

FIG. 2. Wind velocity profiles above 4 positions on ridges when the free wind velocity was 13.6 mph (20 fps).

Minimum wind velocities prevail to a height of ½ inch or less above the surfaces. Above these heights, the mean velocity increases geometrically with additional height, and attains the free wind velocity at about 10 to 20 inches. Since the erosive force of wind varies according to the square of velocities, the wind-tunnel model of ridges reduces the erosive force to about ¼ at minimum effect and to about ⅟₈₀ at maximum effect.

Vertical fluctuations of the isotach lines indicate wind turbulence near the soil surface (Figures 4 and 5). Turbulence is primarily a matter of vertical displacement with a free wind velocity of 13.6 mph. However, at a free wind velocity of 34.1 mph, the turbulence creates a reversal in wind direction between some of the ridges. This reversal in direction, as indicated by the yarn flags, forms a rotary movement that is very transient. It increases between a pair of ridges until it can no longer be contained, then disintegrates only to reform—usually between the next leeward pair of ridges. In the rotary movement, the greatest instability occurs on the leeward slope of a ridge.

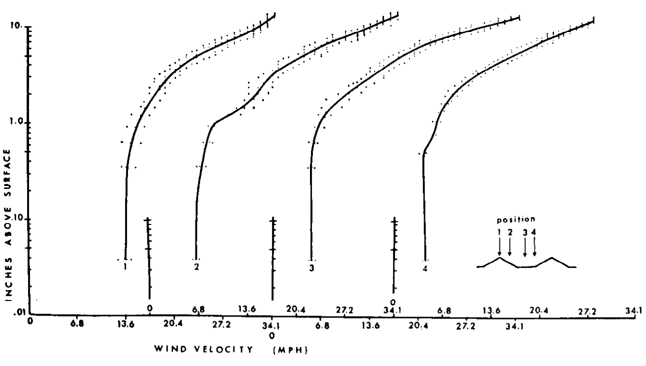

FIG. 3. Wind velocity profiles above 4 positions on ridges when the free wind velocity was 34.1 mph (50 fps). Each position is plotted separately, but wind velocity scales overlap to conserve space.

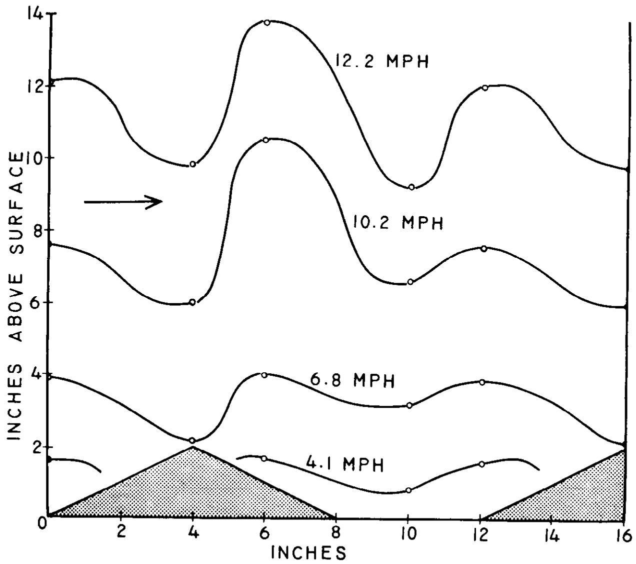

FIG. 4. Isotachs of wind velocity across ridges for a free wind velocity of 13.6 mph. (20 fps).

Wind instability produces small depositions of silt on the leeward slopes in the field.

Field Experiments

Ridge erosion and furrow fill for different ridge directions changed from one period of observation to the next; but these effects were independent of ridge direction when averaged over all periods of observation (Table 1). The directional effect within periods of observation is attributed to wind driven rain and hail, and is interpreted as an essentially random variable among storms. High-intensity rain (often with hail) falls from thunderstorms that normally move eastward from the Rocky Mountains. Nevertheless, the wind movement associated with these storms has no uniform direction over fixed ground positions.

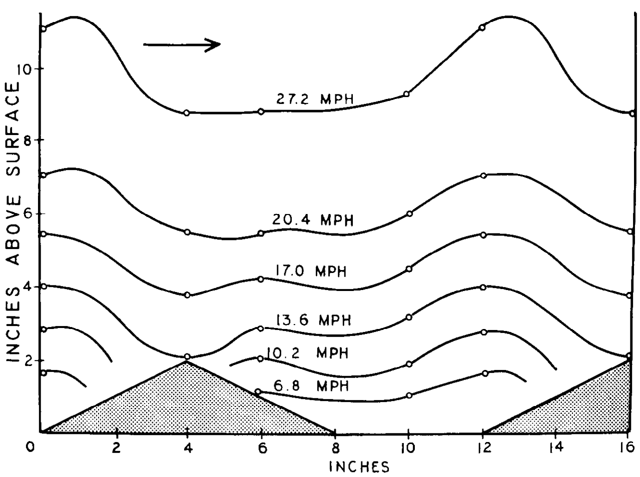

FIG. 5. Isotachs of wind velocity across ridges for a free wind velocity of 34.1 mph (50 fps).

Table 1. Erosion (inches) of ridged soil reliefs.

Ridge direction	Position and effect	Periods of observation 4/4–14	4/14–5/24	5/24–6/7	6/7–7/17	Sum
0°	Ridge erosion	.18	.27	.36	.63	1.44[a1]
	Furrow fill	.36	.04	.23	.35	.98
45°	Ridge erosion	–.09	.25	.32	.83	1.31
	Furrow fill	.13	.15	.32	.47	1.07
90°	Ridge erosion	.13	.09	.53	.61	1.36
	Furrow fill	.15	.13	.35	.37	1.00
135°	Ridge erosion	.07	.25	.53	.82	1.67
	Furrow fill	.22	.09	.33	.42	1.06
0°	Mean	.27[b]	.16	.30	.49	1.22[c]
45°	Mean	.02	.20	.32	.65	1.19
90°	Mean	.14	.11	.44	.49	1.18
135°	Mean	.15	.17	.43	.62	1.37
Mean	Ridge erosion	.07[d]	.22	.44	.72	1.45[e]
Mean	Furrow fill	.22	.10	.31	.40	1.03
Grand mean		.14[f]	.16	.37	.56	1.23
Precipitation (inches)		1.37	3.03	3.90	9.01	17.31
Wind (miles)		2320	8060	2130	4180	16,690

[1] L.S.D. at .05: a = not significant; b = .09 inch; c = not significant; d = .06 inch; e = .03 inch; f = .04 inch.

Furrow fill exceeded ridge erosion in the first period of observation (April 4 to 14) because initial furrow fill required only small amounts of soil compared with that required to reduce the height of ridges (Table 1). Over all four periods of observation, ridge erosion amounted to 1.45 inches and furrow fill amounted to 1.03 inches.

Among the four periods of observation, the amounts of ridge erosion and furrow fill increased in approximate relation to the amounts of precipitation (Table 1). The effects were more closely related to the amounts of high-intensity precipitation. In each of the first two periods of observation (April 4 to 14 and April 14 to May 24), the erosive effects were associated with a single high-intensity rain (Figure 6). In periods 3 and 4 (May 24 to June 7 and June 7 to July 17), which included 3 and 7 high-intensity rains, respectively, the erosive effects were correspondingly greater than in the earlier observation periods. Since high-intensity winds were encountered primarily in the second period of observation, and not at all in the fourth period, it is obvious that the erosion of the surface-soil relief was caused by rain. On the other hand, wet soil is more resistant to wind erosion than dry soil.

The ridged relief was almost completely eroded down by July 17. Precipitation in the period from April 4 to July 17 amounted to a total of 17.3 inches; however, this amount was greater than for corresponding periods in any of 28 previous years. Mean precipitation amounts for the last 29 years are 12.2 inches annually, and 7.5 inches in the 4 months April through July. With reference to the high-intensity rains in the 4 months April through July, the mean annual count is 4.3 storms producing precipitation in excess of 0.5 inch and 1.8 storms producing precipitation in excess of 1.0 inch. Consequently, a packed soil relief generally would last longer than in this example. Even with the excessive precipitation in 1967, the ridges withstood erosion long enough for grass establishment.

Although the roller was designed to produce

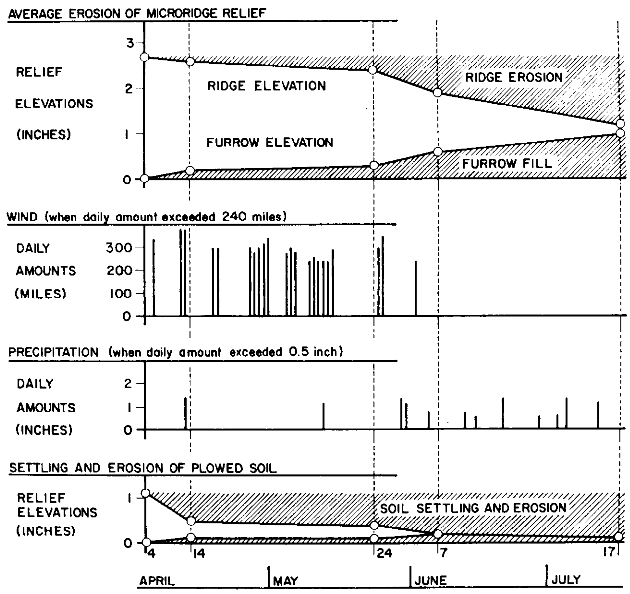

Fig. 6. The erosion of ridged and plowed soil reliefs as related to high-intensity precipitation and wind.

ridges 4.0 inches high, the mean ridge elevation attained was only 2.7 inches. The plowed-soil relief had an average elevational profile of 1.1 inches, but the dowel system of measurement was less well adapted to the plowed than to the packed relief. Nevertheless, the greater durability of the packed relief is readily apparent.

Soil bulk densities are relevant to the study of soil erosion as well as to the study of seed-soil and plant-soil systems. Soil bulk densities in the surface 3 inches were 1.15 gm/cm^3 in freshly plowed soil, 1.25 gm/cm^3 in the ridges of packed soil, and 1.45 gm/cm^3 in the furrows of packed soil. The bulk density of unplowed soil (1.43 gm/cm^3) was considerably lighter by the "coring technique" than was obtained previously by the "clod technique" (Everson et al., 1969).

Discussion

Although the importance of surface soil roughness for the control of wind erosion has been known and applied for many years, the mathematical characterization of the effects of systematic patterns of roughness has not been completely formulated. Our results indicate a great potential value of such information for seedbed preparation and grass establishment. Various ridge heights, shapes and spacings need to be considered; and will be evaluated in subsequent work at the Colorado State University Engineering Research Center.

Although the packing of ridges has prevented wind erosion in the field, we recognize some deficiencies with present implementation. The lateral cleavage of soil in the ridges has been described in a previous paper (Hyder and Bement, 1969). We would like to reduce lateral cleavage and increase soil bulk density in the ridges. Both of these effects would make the ridges more durable against the forces of both high-intensity precipitation and wind. The movement of soil from ridges to furrows presents some hazard with respect to covering grass seeds (planted in the furrows) too deeply.

In subsequent experiments on grass establishment, soil physical conditions and moisture relations need to be defined more completely. Some revision of ridge configuration may be needed to facilitate the seeding operation. The prospect of stopping wind erosion by packing ridges in soils that cannot be controlled by deep plowing alone appears entirely feasible.

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SECOND CALL FOR PAPERS

24th Annual Meeting
February 15–18, 1971
Reno, Nevada

Theme: *Rangeland Environments and Man*

Plan now to attend the 1971 annual meeting of the American Society of Range Management and participate in the program. The meeting is an opportunity for scientists, technicians, ranchers, teachers, administrators and others interested in rangeland resources to report the results of their work, to air their views on current problems, and to exchange ideas.

Voluntary papers are an expression of the areas of work currently underway and represent many of the interests of society members. Your 1971 program committee would like to receive offered papers from people working in all aspects of rangeland resource management—ecology, livestock, watersheds, wildlife, economics, recreation, scenic beauty, land use, etc.

The 1971 theme, "Rangeland Environments and Man" will emphasize the role of man in rangeland resource use but particularly how the range manager is concerned with environmental quality. Papers from all potential contributors, whether members of the society or not, will be considered. Where possible it is desired that authors develop and discuss their papers in the context of relevance to the total range environment.

Administrators and supervisors are urged to facilitate preparation of papers by promising younger members of their organizations who have information that would be of value to Society members and the general public.

Procedure—the following list of *proposed* session topics indicates the areas to be featured in the 1971 program and the subcommittee chairmen responsible for development of each session. Those wishing to present papers should submit to the Program Chairman by June 20, 1970:

(1) title of paper
(2) preliminary abstract of not over 200 words
(3) a supporting statement explaining the significance of the paper, whether it is new work, a literature review, or a philosophical point of view. The statement should also specify how the paper would be presented—reading, charts, slides, etc. Indicate session for which paper is intended.

The program chairman will forward

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