Soil Physical Conditions after Plowing and Packing of Ridges[1]

D. N. HYDER AND R. E. BEMENT

Range Scientists, Crops Research Division, Agricultural Research Service, U.S. Department of Agriculture, Fort Collins, Colorado.

Highlight

A system of seedbed preparation by moldboard plowing and packing small ridges appears to fulfill two requirements for successful seeding—control wind erosion and eliminate competing vegetation. The percentage by weight of soil aggregates larger than 0.833 mm increases greatly with an increase in the moisture content of soil at the time of packing. A sandy loam soil should contain 9 to 12% moisture when packed to obtain a surface condition greatly resistant to wind erosion.

Soil erosion by wind has prevented the development of reliable methods of seeding grasses on abandoned croplands in the shortgrass plains of Colorado. Previous work has shown that a successful method must control wind erosion and competing vegetation while seeded grasses are becoming established. Unfortunately, direct seeding, interseeding, seeding in narrow strips after a year of mechanical fallow, and seeding after chemical fallow have not completely fulfilled these two requirements (Bement, et al., 1965; Hyder and Everson, 1968; Everson, et al., 1969). Competing vegetation is eliminated most thoroughly by moldboard plowing, which cannot be practiced unless wind erosion can be controlled. Previous work also suggests that seedbed preparation and planting should be completed as quickly as possible after soil moisture and temperature have become favorable for seed germination and seedling emergence.

These considerations have led to a new approach that includes moldboard plowing for control of competing vegetation. The procedure requires plowing, packing, and seeding when soil conditions are favorable. Attention has been directed to the packing operation, because temporary soil stability against wind must be created immediately after plowing (Marlatt and Hyder, 1968). For this purpose, we have developed a roller for seedbed modification (Hyder and Bement, 1969). Wind-tunnel and field studies show the value of a ridged surface for protection against wind (Marlatt and Hyder, 1970). Most recently, field work has been directed to the measurement of soil physical conditions that are important to the control of wind erosion and to seed-soil and plant-soil relations.

This paper summarizes results on soil aggregate size, bulk density, field capacity, drying rate, temperature, and movement from ridges to furrows.

Methods

Four plots, each measuring 100 by 100 feet, were located on a McGrew sandy loam that was last plowed for crop production about 1929. This soil has a particle-size distribution of about 80% sand, 10% silt, and 10% clay in the surface 8 inches. Consequently, the soil is loose and erodible after plowing. Its erodibility is witnessed by a large accumulation of windblown soil at the south border of the field.

The plots were plowed to a depth of about 10 inches with a moldboard plow on July 17, 1967, and packed with the roller on July 18 (Fig. 1). On the separate plots, the ridges were oriented to directions of N–S, NE–SW, E–W, and SE–NW. Soil moisture was near field capacity at plowing time as a result of precipitation amounting to 3.6 inches in the previous 2 weeks.

Small areas about 20 feet in diameter within plots were wetted by sprinkling, covered with plastic for 24 hours to permit the measurement of soil bulk density and field capacity, then uncovered and sampled daily to determine drying rates. Soil cores were taken to a depth of 3 inches in the ridges and to a depth of 15 inches in the furrows. Two drying sequences were sampled in this manner, and a third sequence omitted the 24 hours with plastic cover. Similar wetted areas on adjacent unplowed soil were sampled for soil bulk density and field capacity. Moisture-tension relations for unplowed soil were obtained in a previous study (Everson, et al., 1969).

To provide for the measurement of soil movement from ridges to furrows, one-half inch hardwood dowels 12 inches long were established in the furrows as elevational references. 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 determined the amount of furrow fill; and the heights of ridges between dowels determined the amount of ridge cut. Measurements were taken on July 18, 1967, September 13, 1967, and April 8, 1968, to encompass a complete winter season. A previous study evaluated soil movement during a spring season (Marlatt and Hyder, 1970).

An area was plowed while the soil was moist (9% moisture content), sprinkled to wet, and packed at different times during natural drying in July 1969. When all packed soils were very dry, samples of the surface inch of soil were cut away and screened through a 20-mesh (0.833 mm) screen to determine the proportions of non-erodible particles as required by the universal equation for measuring

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FIG. 1. A ridged seedbed prepared by plowing and packing.

wind erosion (Agricultural Research Service, 1961).

Soil temperatures were measured with a mercury thermometer. Records of precipitation and wind movement were summarized as erosive forces.

Results

Soil Bulk Density and Field Capacity

The bulk density of the surface 3 inches of soil after plowing and packing was 1.25 gm/cm^3 in the ridges and 1.45 gm/cm^3 in the furrows (Table 1). Bulk densities by 3-inch segments to a depth of 15 inches in the furrows were not significantly different from those of unplowed soil. However, the moisture percentages at field capacity (that is, when covered with plastic for 24 hours after wetting) were about 2% greater (significant at .01) to a depth of 9 inches in the furrows of packed soil than in unplowed, unpacked soil. Small differences in the clay content of the plowed and unplowed areas could account for the difference in water content, which amounted to 0.4 inch in 15 inches of soil.

Drying Rate

In the first 2 drying sequences the soil was covered with plastic for 24 hours after wetting (Fig. 2). The moisture percentage (13.3%) of 3 inches of soil in the furrows after 24 hours of drainage under plastic was not significantly different from that obtained for unplowed soil at a moisture tension of 1/10 atmosphere. Consequently, the moisture percentages at tensions of 1/10, 1/3, and 15 atmospheres are shown in Figure 2 as approximate moisture tension levels for the soil cores taken in the furrows. In each drying sequence the soil dried more quickly in the ridges than in the furrows. The average moisture content of the surface 3 inches of soil in the furrows continued at a level that was satisfactory for seed germination for about 10 days; however, at a seeding depth of 1/2 to 1 inch the moisture supply must have become critical at an earlier time.

In the second drying sequence the plastic was removed at 11 AM on day 1, when the moisture percentages of the surface 3 inches of soil were 9.6 and 13.3 in the ridges and furrows, respectively. Three hours later, at 2 PM, the moisture percentages were 8.9 and 10.4, respectively.

After we had applied 2 inches of water on August 21, 1967, the soil below the furrows was sampled for water content and drying rates to a depth of 15 inches. The soil contained 3.4 inches of water immediately after wetting (Table 2). One day later the soil contained 2.9 inches—a loss of 0.5 inch of

Table 1. Soil bulk density (gm/cm^3) and field capacity[a] (%) of McGrew sandy loam—mean of 15 determinations and standard deviation of the mean.

Soil treatment	Location on soil relief	Soil characteristic	Soil depth (inches) 0–3	3–6	6–9	9–12	12–15	Sum
None	Random	Bulk density, wet	1.43 ± .01	1.52 ± .01	1.59 ± .01	1.58 ± .01	1.57 ± .02	
		Field capacity	11.3 ± .5	10.9 ± .3	10.8 ± .4	10.6 ± .4	10.4 ± .5	
		Water content (inches)	.48	.50	.51	.50	.49	2.5
Plowed and packed	Furrow	Bulk density, wet	1.45 ± .02	1.52 ± .03	1.58 ± .01	1.61 ± .02	1.63 ± .02	
		Field capacity	13.3 ± .3	13.4 ± .3	12.7 ± .2	11.7 ± .4	10.5 ± .5	
		Water content (inches)	.58**	.61**	.60**	.57	.51	2.9
	Ridge	Bulk density, wet	1.25 ± .04					
		Field capacity	9.6 ± .4					
		Water content (inches)	.36**					

[a] Bulk density and moisture content at field capacity were determined for 2-inch i.d. soil cores removed 24 hours after wetting and covering the soil with plastic.

** Value is different from that of non-plowed soil at 99% probability.

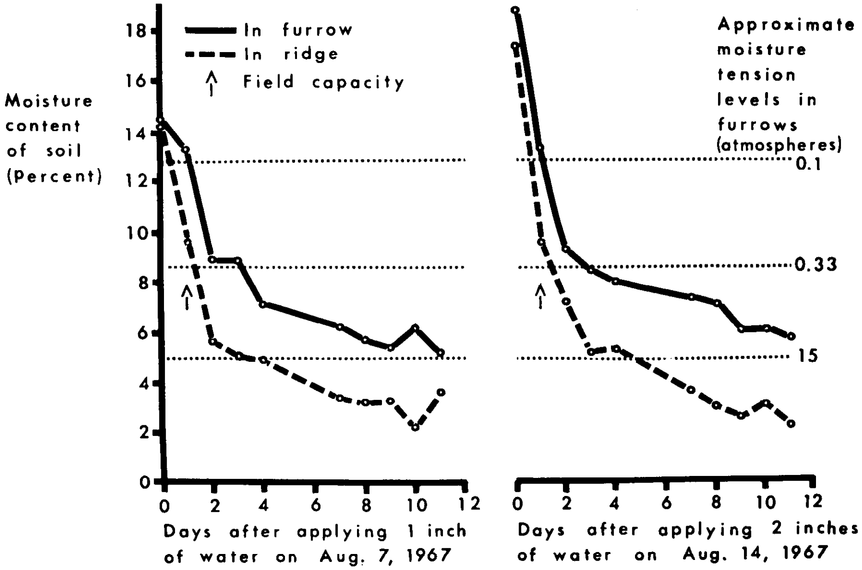

FIG. 2. Moisture loss from the surface 3 inches of soil after wetting by sprinkler. The surface was covered with plastic for 24 hours after sprinkling to allow the attainment of field capacity, which was 13.3% in the furrows and 9.6% in the ridges.

water. All of this loss appeared in the surface 6 inches of soil. In addition, a small amount moved downward to increase the water content at a depth of 12–15 inches. On subsequent days the losses from 15 inches of soil continued at a diminishing rate. Since the water contents at depths of 0–3 and 12–15 inches were less than those at intermediate depths, it appears that the losses were due to water movement downward as well as upward. All water movement after the second day presumably was by unsaturated flow. Total water loss from 15 inches of soil amounted to nearly an inch in 3 days.

Table 2. Water content (inches) in and loss from 15 inches of bare soil taken in the furrows after applying 2 inches of water by sprinkling on August 21, 1967.

Soil depth (inches)	Days after wetting 0	1	2	3	6	7
0–3	.8	.5	.4	.4	.4	.4
3–6	.8	.6	.6	.5	.6	.5
6–9	.7	.7	.6	.5	.5	.5
9–12	.7	.6	.6	.5	.5	.5
12–15	.4	.5	.4	.5	.4	.4
Sum	3.4	2.9	2.6	2.4	2.4	2.3
Water loss (cumulative)		.5	.8	.9	1.0	1.1

Soil Temperature

Minimum soil temperatures were higher and maximum soil temperatures were lower in the furrows than in the ridges (Table 3). At a depth of 1 inch below the surface the diurnal range on warm, clear days was 28 F in the furrows and 38 in the ridges.

Soil Movement from Ridges to Furrows

The ridges established in July 1967 had an average height of 3.1 inches, and the remaining ridge height in April 1968 was 1.2 inches (Table 4). Ridge cut (the reduction in ridge elevation) exceeded furrow fill by about 2 to 1. Total precipitation amounted to 5.3 inches, but there were no high-intensity rains.

In all the work to date there has been no evidence of soil movement away from treated plots until the ridges have been washed down by high-intensity precipitation. The ridges appear to be unaffected by wind, but in a previous study conducted in April, May, June, and July, 1967, 12 high-intensity rains (each exceeding 0.5 inch) eliminated the ridged relief (Marlatt and Hyder, 1970). Even in that trial, wind erosion was controlled long enough to prevent abrasion of grass seedlings by soil particles and permit grass establishment.

On the average, we have rain amounting to 0.5 inch or more on 6.7 days per year of which the rain amounts to 1 inch or more on 1.6 days and 2 inches or more on 0.1 day. Wind velocities exceed 5, 10, 15, and 20 mph for 234, 47, 8, and 1 days, respectively.

Size of Soil Aggregates

The fractions of soil aggregates larger than 0.833 mm in diameter in the surface inch of soil were 94, 73, 71, 51, and 41% by dry weight when packing was completed with soil moisture contents of 15.0, 9.6, 9.4, 6.8, and 1.0%, respectively. The soil plowed but not packed contained 58% of soil aggregates larger than 0.833 mm in diameter in the surface inch. Thus, packing the McGrew sandy loam while moist created a hard, non-erodible surface, and packing the soil while dry broke the clods turned up by plow-

Table 3. Minimum and maximum soil temperatures (°F), at depths of 1 and 6 inches below ridges and furrows, and air temperatures.

Date (1967)	Location on relief	Depth 1 inch Minimum	Depth 1 inch Maximum	Depth 6 inches Minimum	Depth 6 inches Maximum	Air temperature[a] Minimum	Air temperature[a] Maximum
July 20	Ridge	—	104	—	88	50	82
	Furrow	—	97	—	80		
August 25	Ridge	59	97	64	80	57	90
	Furrow	62	90	68	75		

[a] Air temperatures were taken in a standard instrument shelter.

Table 4. Soil movement (inches) from ridges to furrows, and precipitation (inches).

Erosive effect	Date or period of observation	Ridge orientation N–S	NE–SW	E–W	SE–NW	Mean	Total precipitation
Ridge cut	1	.3	.4	.4	.6	.4[a]	1.7
	2	.6	.8	.7	1.1	.8	3.5
	Sum	.9[b]	1.2	1.1	1.7	1.2	5.2
Furrow fill	1	.2	.2	.3	.3	.3[c]	id.
	2	.4	.7	.3	.3	.4	id.
	Sum	.6[d]	.9	.6	.6	.7	id.
Remaining ridge height	July 18, 1967	2.9	3.0	3.2	3.2	3.1	
	Sept. 13, 1967	2.3	2.4	2.5	2.3	2.4	
	April 8, 1968	1.4	.9	1.5	.9	1.2	

[a] The L.S.D. at 99% for these 2 means = .2.
[b] The L.S.D. at 95% for these 4 sums = .4.
[c] The L.S.D. at 99% for these 2 means = .1.
[d] The L.S.D. at 99% for these 4 sums = .2.

ing into a large proportion of small erodible particles. We conclude that the soil involved in these studies should be packed while at a moisture content of 9 to 12% to obtain a surface condition adequately resistant to wind erosion.

Discussion

Seedbed preparation by moldboard plowing and packing of small ridges appears to fulfill two essential requirements for successful seeding—control wind erosion and eliminate competing vegetation. In addition, the moderating effect of the ridged relief on soil temperature and moisture in the furrows is equivalent to that attained by furrow and wheel-track planting (McGinnies, 1959; Hyder, et al., 1961). On the other hand, the ridged relief imposes the problem of soil movement to the furrows and the possibility of burying the seed too deeply. The packing of ridges as well as furrows tends to reduce this problem, but the ridges are not firm enough to eliminate the hazard. Subsequent modifications in roller design might achieve an increase in ridge firmness and durability without sacrificing resistance to wind erosion.

In previous papers on the subject of packing small ridges to control wind erosion (op. cit.) we have emphasized the effect of surface roughness on reducing wind velocity and erosive force at the surface. However, the universal equation for measuring wind erosion (op. cit.) shows that the degree of roughness alone cannot provide adequate control. Our success in stopping wind erosion temporarily should be attributed largely to the hard surface formed by packing moist soil.

Seeded grasses provide little benefit in controlling wind erosion in the first year, but prairie sunflower (*Helianthus petiolaris* Nutt.) and Russian thistle (*Salsola kali tenuifolia* Tausch.) generally provide an effective cover in 2 or 3 months after plowing.

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