Effects of Moisture and Soil Packers on Consolidation and Cloddiness of Soil

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CLODDY soils generally are less erodible by wind than are non-cloddy soils, and the amount of erosion depends on the proportion, size, and bulk density of soil aggregates (2)*. Ideally, soil should contain about 50 percent clods ≧ 1 cm (0.4 in.) in diameter for maximum wind resistance (3). Under field conditions it is often difficult to obtain clods when they are most needed. Therefore, information on factors that influence clod formation is needed.

Tillage can produce clods but their quantity and quality depend largely on the physical forces of cohesion. Moisture, clay content, cementing agents, and bulk density all influence the cohesive forces within soil.

An earlier study at the Wind Erosion Laboratory (7) showed that cloddiness of disturbed soils can be increased by packing, under optimum moisture conditions for compaction, prior to tillage. Other investigators have noted that soil density influences the number of tillage clods. Bateman (1) noted the occurrence of large clods and slabs after plowing a Drummer silty clay loam that had been previously compacted. Flocker (6) found a 77.7-lb increase in weight of clods greater than 2.0 in. in diameter in a 1⅓ cu ft sample of Yolo fine sandy loam soil that had been compacted from 78 to 97 lb per cubic foot.

The studies cited have shown that soil cloddiness may be increased by compaction under optimum conditions. They have not provided information on two practical questions: the magnitude of bulk densities obtainable with the ordinary soil packers available to farmers and the proportion and size of clods obtainable by packing at conditions other than optimum. This paper present results of a study designed to answer these two questions for a sandy loam soil.

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* Numbers in parentheses refer to the appended references.

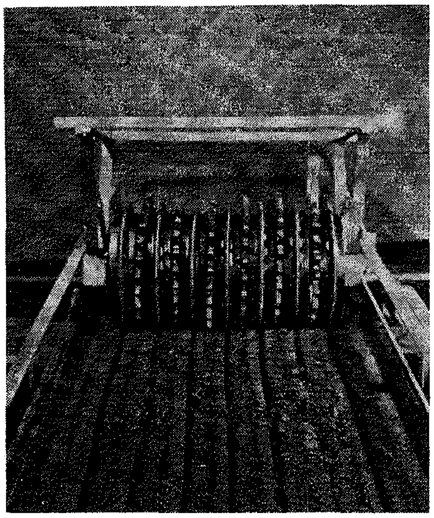

FIG. 1 Sprocket packer.

Experimental Equipment and Procedure

Two different experiments were conducted using the same soil. The laboratory tillage and soil handling procedures used were described earlier (7). Physical characteristics of the sandy loam are presented in Table 1.

TABLE 1. SOME PHYSICAL CHARACTERISTICS OF SANDY LOAM SOIL USED IN TWO TILLAGE EXPERIMENTS

Characteristic	Value
Sand, percent	62.40
Silt, percent	21.30
Clay, percent	16.30
Liquid limit, percent moisture	19.67
Plastic limit, percent moisture	14.64
Optimum moisture for compaction, percent	14.70
Maximum density, Standard Proctor (pounds per cubic foot)	110.50

The first experiment was designed to determine bulk densities obtainable using three selected commercial agricultural soil packers: a sprocket packer, a diamond packer, and a narrow, V-wheel packer (Figs. 1, 2 and 3). Physical data on each packer are shown in Table 2. Packer treatments were (a) 225 lb total weight with single pass over soil, (b) 500 lb total weight with single pass over soil, and (c) 225 lb total weight with six passes over soil surface. Treatments were replicated three times at optimum moisture content for compaction. A 200-lb smooth lawn roller was passed over the soil once ahead of the packers to provide a uniform surface and to consolidate the soil.

Bulk densities were determined by profiling the test section with a Cornell penetrometer and averaging the densities obtained. The penetrometer was calibrated by using known bulk densities and determining the force in pounds required to penetrate the sandy loam soil over a range of moisture contents.

To determine the influence of moisture on soil density and cloddiness, three different packing forces and three moisture contents were replicated three times in a second experiment. Moisture levels were (a) optimum moisture content (OMC), 14.7 percent, (b) 0.8 OMC, 11.8 percent, and (c) 0.6 OMC, 8.8 percent (10). Packing forces were (a) two passes with 200-lb roller, (b) six passes with 305-lb roller, and (c) six passes with 305-lb roller plus one coverage with a 20-lb tamper dropped 6 in. In the second experiment bulk densities were determined from 3-in. core samples and by profiling with the penetrometer.

Loose soil was placed in the test section, packed and tilled 6 in. deep with a full-size, 2-in. chisel point immediately after packing. The force required to pull the chisel through the soil was measured by means of a strain link and appropriate amplifying and recording equipment.

Soil thrown up on the surface by tillage was placed in soil pans, air-dried, and passed through a rotary sieve to determine clod-size distribution (4). Mechanical stability was computed from the ratio of the weight of clods greater than 2.0 mm remaining after a second sieving (5).

TABLE 2. PHYSICAL DATA ON AGRICULTURAL SOIL PACKERS

Characteristic	Packer		
	Sprocket	Diamond	V-wheel
Wheel diameter, in.	15	22	22
Wheel spacing, in.	3¾	10	5½
Width of each wheel, in.	2⅞	6	1
Weight of each wheel, lb	20	50	35
Surface area covered, percent	77*	17	18
Packing pressure for 500 lb total weight, PSI†	5	7	10

* Does not include area covered by 10-lb sprocket wheel.
† Based on 8-in. projected soil contact length for diamond and V-wheel and 5½ inch contact length for sprocket.

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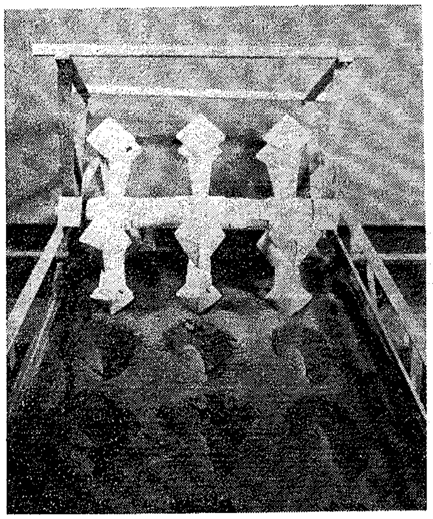

FIG. 2 Diamond packer.

RESULTS

Soil Packers

None of the packers used increased the soil density appreciably. Increasing the packer weight from 225 to 500 lb increased the average density only 1.0, 1.7, and 1.2 lb per cubic foot for the sprocket, diamond, and V wheel, respectively. Six passes over the surface increased soil density by 3.7, 3.6, and 2.3 lb per cubic foot for the sprocket, diamond, and V-wheel packers, respectively. Fig. 4 shows the percentage of clods greater than 6.4 mm in diameter for the packer treatments. The V-wheel packer produced less than 10 percent clods greater than 6.4 mm under all treatments. Diamond and sprocket packers showed some response to multiple passes over the surface; the sprocket produced somewhat more clods than the diamond.

Influence of Soil Moisture and Bulk Density

Fig. 5 shows the influence of moisture and bulk density on the percentage of clods greater than 6.4 mm. Yield of clods decreased with decreasing moisture. Using the same packing pressure and lowering the moisture content would logically yield a lower bulk density. That moisture content at the same density should be so predominant in influencing the quantity of clods produced is less apparent. For example, soil packed to 80 lb per cubic foot and then chiseled at optimum moisture content yielded 19 and 52 percent more clods greater than 6.4 mm than soil chiseled at 0.8 and 0.6 OMC, respectively.

Likewise, the high influence of moisture near the optimum for compaction is indicated by comparing the densities obtained with the maximum packing force at the three moisture levels. Lowering the moisture 3 percent from optimum reduced the density about 6 lb per cubic foot while decreasing the moisture an additional 3 percent reduced the density only about 1 lb per cubic foot.

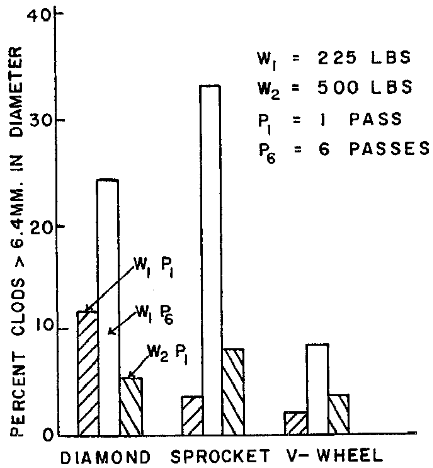

FIG. 4 Soil cloddiness after chiseling as influenced by type of packer, packer weight, and number of passes over the soil surface.

Clods produced by chiseling after packing to three different bulk densities at 0.6 OMC is shown in Fig. 6. Good clod yield at the highest density is evident (pan on right). However, these clods were so fragile that most of them were destroyed by the mechanical action of the rotary sieve. Therefore, the 0.6 OMC curve of Fig. 5 does not reflect effective cloddiness produced at this moisture level. The clods formed at the same packing force but different moisture levels are shown in Fig. 7.

Mechanical stability as influenced by soil density and moisture is shown in Fig. 8. Clods formed at densities below 75 lb per cubic foot at 0.8 OMC and below 83 lb per cubic foot at 0.6 OMC were so unstable that none greater than 6.4 mm remained after the first rotary sieving to be resieved. Therefore, no 0.6 OMC curve is shown. Likewise, only points above 75 lb per cubic foot are shown on the 0.8 OMC curve. At the highest densities, clods

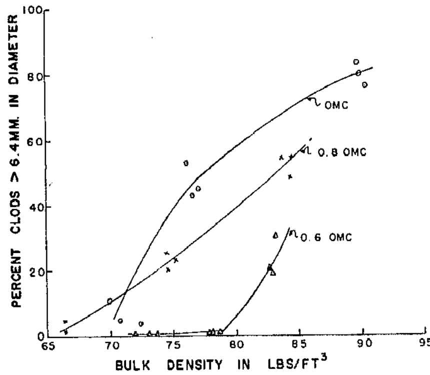

FIG. 5 Soil cloddiness after chiseling in relation to soil density and moisture.

formed at lower moisture content were less stable than clods formed at OMC. At 0.6 OMC, approximately 30 percent of the clods greater than 2.0 mm passed through this sieve size during the second sieving.

Effect on Drawbar Draft

Drawbar draft requirements increase as both density and moisture content are increased simultaneously. At 0.8 OMC and 0.6 OMC there is less draft at a given density than at OMC because soil cohesive forces are less. At a bulk density of 80 lb per cubic foot, raising the moisture content from 0.6 OMC to OMC approximately doubled the draft (Fig. 9).

Comparison of Core Sampler and Cornell Penetrometer

The relation between soil bulk density by core sampling and by Cornell penetrometer measurements is shown in Fig. 10. The linear regression equation obtained was $P_D = 13.18 + 0.80\ C_D$, where P_D is penetrometer density and C_D is the core density. This equation shows equal density at about 65 lb per cubic foot but the core densities become increasingly larger than the penetrometer densities until a maximum difference of 7 lb per cubic foot is reached at a density of 100 lb per cubic foot. The penetrometer is particularly sensitive to moisture content. For example, on the sandy loam soil an average penetrometer force of 50 lb indicated a bulk density of 84.4, 87.7, 91.3 and 100.5 lb per cubic foot

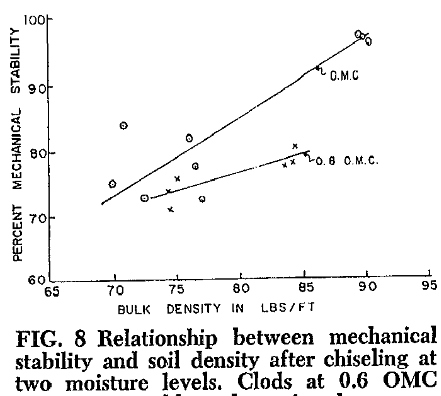

FIG. 8 Relationship between mechanical stability and soil density after chiseling at two moisture levels. Clods at 0.6 OMC were too unstable to be resieved.

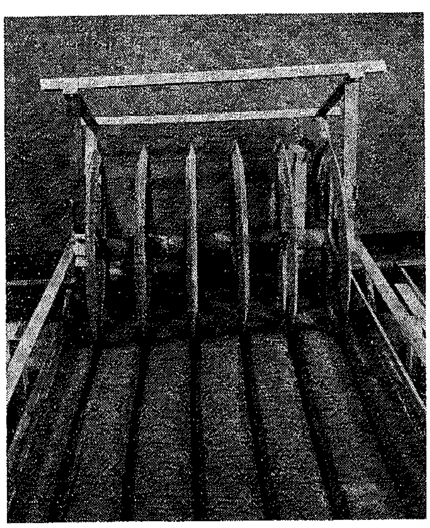

FIG. 3 V-wheel packer.

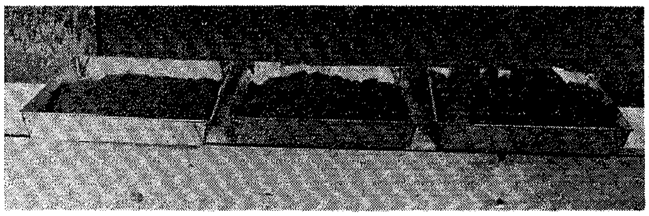

FIG. 6 Influence of bulk density on clod sizes produced by a narrow-point chisel at 0.6 optimum moisture content for compaction. Left to right, bulk density of 73.0, 78.2, and 83.0 lb per cu ft.

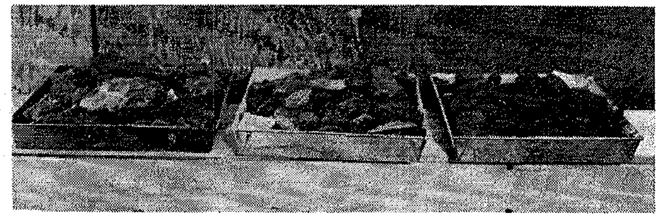

FIG. 7 Influence of soil moisture on clod formation. Left to right, optimum moisture content for compaction, 0.8 and 0.6 OMC.

at respective moisture contents of 8.8, 11.8, 14.7 and 16.5 percent. Terry and Wilson (10) stated that the most nearly accurate results are obtained with the penetrometer when the moisture content of the soil is about 20 percent. Evidently this applies to a particular soil texture and not to soils in general. Twenty percent moisture was above the liquid limit for the sandy loam soil used in the study reported in this paper. At this limit the soil acts as a viscous liquid and no force would be recorded on the penetrometer.

Interpretation of Results

Commercial agricultural soil packers did not compact the soil to an appreciable degree even at optimum moisture conditions for compaction in this study. Most are designed to firm seedbeds, crush clods, mulch soil, roughen surfaces, and other uses. It is highly unlikely that one would pass a packer over the soil six times to obtain clods to control wind erosion. However, if such extreme measures were used, multiple passes with the sprocket packer would produce a condition more conducive to clod production after tillage than would the other packers tested. This can be explained in terms of surface area covered. Omitting the area covered by the sprocket wheel, the sprocket packer covers about 77 percent of the ground surface with each pass compared with about 18 percent by the diamond and V-wheel packers. Soil immediately beneath the diamond head breaks out as a fairly large clod which accounts for its better response than the V-wheel. Packing pressures applied by each wheel at 500 pounds total weight were about 5, 7, and 10 psi for the sprocket, diamond, V wheel, respectively.

Stout, *et al* (9) obtained a bulk density of 85.5 lb per cubic foot with 15 psi packing pressure on a sandy loam soil of mechanical composition very close to the soil used in this study. They compacted a 2-in. soil layer at field capacity. Morton and Buchele (8) packed a 3 to 4-in. layer of the same soil that Stout used. They obtained 81.1 lb per cubic foot with 16 psi at 20 percent moisture content. At a density of 81.1 lb per cubic foot the soil in the study reported here yielded 60 percent clods greater than 6.4 mm at OMC.

Cloddiness produced by chisel tillage depends on both bulk density of the soil and moisture content at time of tillage. Increasing the density from 75 to 80 lb per cubic foot at optimum moisture content increased the greater than 6.4 mm clods 20 percent. Increasing the moisture content from 0.8 OMC to OMC at a density of 80 lb per cubic foot increased the percentage of greater than 6.4 mm clods 19 percent.

The results obtained would directly apply to field conditions where a loose soil is packed and immediately chiseled, and they clearly indicate that unless the soil is near OMC, it would be useless to try to pack and then chisel to produce clods. However, the results would be quite different if the soil were packed to a certain density, allowed to dry and then chiseled. Accordingly another approach would be to pack soil when moist, prior to the time chiseling is needed.

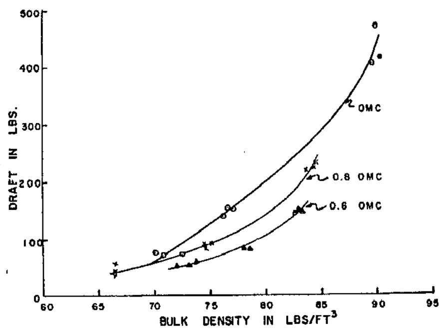

FIG. 9 Draft requirements of a single narrow-point chisel in relation to soil density and moisture content.

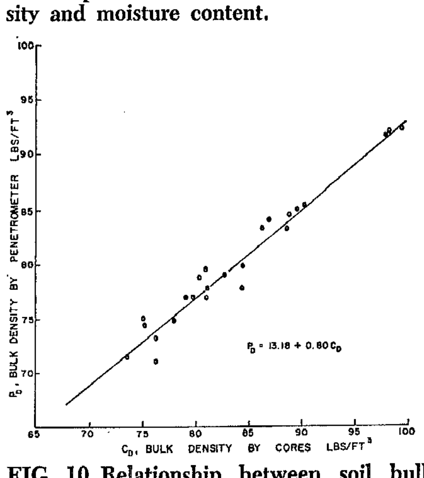

FIG. 10 Relationship between soil bulk density by core sampling and by Cornell penetrometer measurements.

Summary

The extent and magnitude of soil bulk densities obtainable with three commercial agricultural soil packers were investigated by varying the packer weight and number of passes over the soil surface (Figs. 1, 2, 3). Chiseling, after packing, was performed at optimum moisture content for compaction on a sandy loam soil in the laboratory. Measurements of treatments were in terms of soil bulk density and clod yield. Also studied were the effects of packing at moisture contents other than optimum.

None of the packers appreciably increased the soil bulk density. Multiple passes of a sprocket and a diamond packer increased clod yield some, but a V-wheel packer increased clods very little. Apparently heavier type packers like those used in highway construction are necessary to obtain fairly high densities with a single pass over the surface.

Both soil bulk density and moisture content greatly affect the quantity of clods produced. It is especially important that the soil be packed near optimum moisture content. Packing below 0.8 OMC produced fragile, unstable clods.

Bulk densities obtained with a 3-in. core sampler and those obtained with the Cornell soil penetrometer were compared.

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