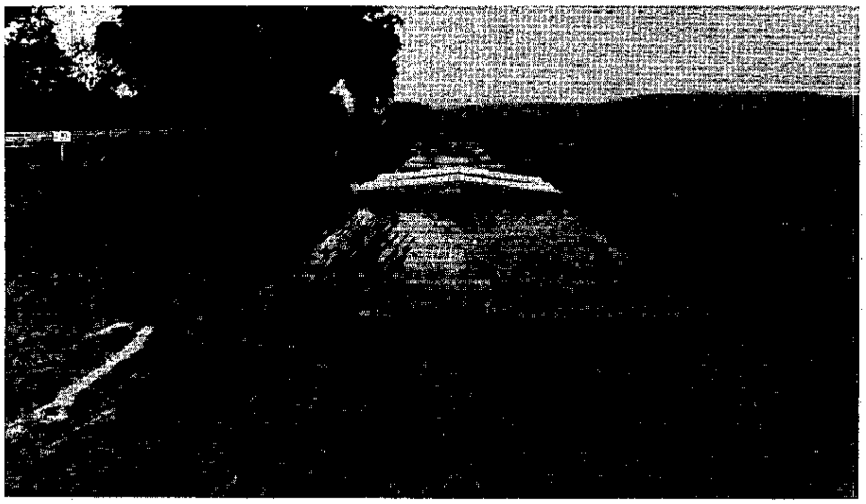

Fig. 1 Appearance of all plots covered during a period of actual rainfall. Aluminum roofing over a wooden frame, shown in the middle ground, was used to cover one of the plots

How Moisture and Tillage Affect Soil Cloddiness for Wind Erosion Control

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Size and stability of clods (including rate of breakdown and resistance to crushing) are studied in terms of soil moisture and type of tillage implement

SOIL conditions for wind erosion control are quite different from those usually considered to be most desirable for a good seedbed. On bare, unprotected soil a rough, cloddy surface has proved best for controlling erosion by wind. Studies have shown that the percentage of soil particles greater than 0.84 mm in diameter is a simple index to wind erodibility (1)*. The greater the percent larger than this size, the less soil will be lost by wind action. Thus a major aim in tillage operations for wind erosion control is to form clods of sufficient size to resist movement by wind.

Probably the two most important factors influencing the structural and surface conditions produced at time of tillage for a particular soil are moisture content and type of tillage action. This is especially true for medium and fine-textured soils.

This paper presents the results of a study designed to yield information on these two factors in relation to wind erosion control and to evaluate the effects of natural weathering and subsequent tillage on the original clods formed.

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*Numbers in parentheses refer to the appended references.

Experimental Procedure

The experiment was statistically designed as a split-plot, randomized complete block, the main plots of which were five moisture levels ranging from 8 to 25 percent replicated four times on a silty clay loam. Each plot was 15 by 30 ft. Subplots, 10 by 15 ft, included three tillage treatments using a standard 5-ft one-way disk, a 5-ft V-type subsurface sweep, and a 14-in. two-bottom moldboard plow.

The soil was pretreated with a soil packer to give approximately the same bulk density and to level the surface.

Moisture control was obtained principally by plot covering (Fig. 1), by water application, and by extracting excess moisture with vegetation. Detailed descriptions of these and other control procedures will be described in a thesis (4).

Prior to initial tillage, the plots with vegetation were shaved with a flat spade. Tillage operational variables of depth and speed were kept constant at about 4 in. and 3.2 mph, respectively. Subsequent tillage was accomplished at approximately 1 and 3-month intervals with a tandem disk and rotary hoe.

Surface soil samples were taken for dry and/or wet sieving on three occasions, *(a)* immediately following the initial tillage operations, *(b)* after a period of weathering, and *(c)* following the last tillage operations (Fig. 2). Individual samples were taken from a one square meter area with a flat spade.

By wet sieving Chepil (2) found that the percentage of aggregates greater than 0.84 mm and less than 0.02 mm in diameter are closely related to the erodibility of a particular soil by wind, and separates of these sizes only were made. Since relative information was all that was desired, the sieving time was decreased to one-tenth of that used by Yoder (5) and the samples were prewetted in a vacuum.

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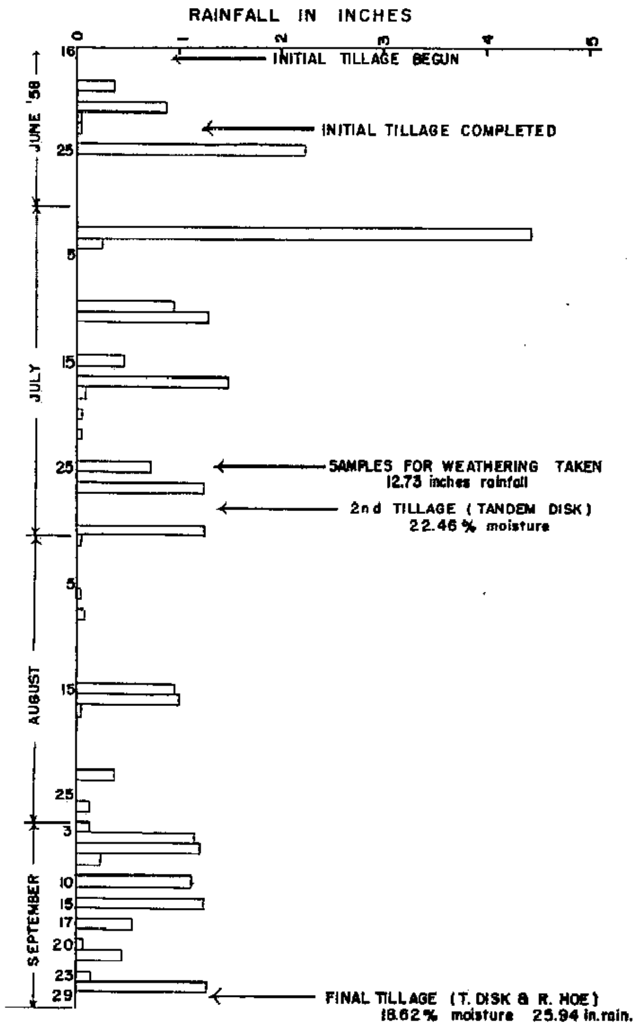

Fig. 2 A summary of rainfall and tillage

Four representative clods per plot were selected at random following the initial tillage and crushed with a one-half-inch cantilever beam. Half of the clods were crushed at the moisture content at time of tillage and half after air drying. The force necessary to cause fracture was measured with a Brush Electronics strain amplifier and oscillograph.

Results and Discussion

Before numerical or quantitative results are presented, some general observations should be made. The soil at the lowest moisture content (8 percent), which is below the permanent wilting point for this soil, was extremely hard. Penetration of the tillage tools was difficult, especially with the one-way disk. The moldboard plow turned out very large clods with very little pulverization (Fig. 3). The

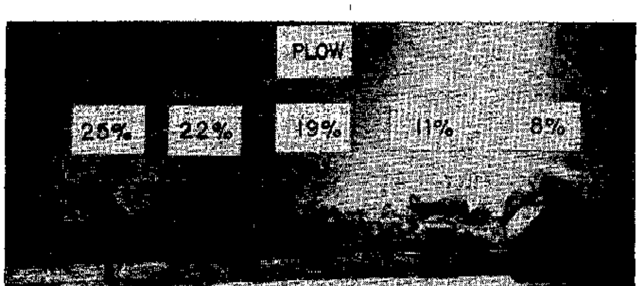

Fig. 3 Examples of clod sizes produced by the moldboard plow at the moisture contents indicated

TABLE 1. SUMMARY OF AN ANALYSIS OF VARIANCE FOR MOISTURE AND TILLAGE IMPLEMENT FOLLOWING THE VARIOUS OPERATIONS

Variable	Operation	Variance ratio	
		Moisture	Tillage
% > 38 mm	Initial tillage	26.53**	18.12**
% > 38 mm	Weathering	2.80	36.05**
% > 38 mm	Final tillage	1.48	0.64
% > 0.84 mm	Initial tillage	12.67**	57.56**
% > 0.84 mm	Weathering	2.00	48.79**
% > 0.84 mm	Final tillage	1.48	0.34
% > 0.42 mm	Initial tillage	8.78*	61.19**
% > 0.42 mm	Weathering	1.81	49.68**
% > 0.42 mm	Final tillage	1.66	0.47
% mech. stability	Initial tillage	9.32*	33.83**
% mech. stability	Weathering	1.08	35.89**
% mech. stability	Final tillage	0.19	0.08
% > 0.84 mm (wet sieving)	Initial tillage	2.64	33.08**
% > 0.84 mm (wet sieving)	Final tillage	–	2.36

*Significant at 1 percent level.
**Significant at 0.1 percent level.
All others are nonsignificant (less than 5 percent level).

subsurface sweep left the surface relatively undisplaced, but the soil fractured into large clods, probably along lines of cleavage induced by drying. In relative size the clods formed at the intermediate moisture contents appeared much smaller.

Initial Tillage

Actual average moisture levels for the four replications were 8.1, 11.2, 19.8, 22.0, and 25.2 percent with individual plot minimum and maximum of 7.3 and 27.5 percent, respectively.

Results of an analysis of variance for moisture and tillage implement are summarized in Table 1. After the initial tillage, the variance ratio was significant at the 1 or 0.1 percent level for moisture and for tillage on all the dry clod variables and on mechanical stability. This furnishes strong evidence that both moisture content at time of tillage and the tillage implement have a decided effect on the percent of soil in clods and on the size of clods formed.

Contingent upon the significance of the variance ratio (5 percent or higher), linear or curvilinear regression procedures were used to derive relationships to express the clod variables of percent greater than 38 mm, percent greater than 0.84 mm, percent less than 0.42 mm, and the mechanical stability as a function of moisture content for the three tillage implements. Fig. 4 reveals that the moldboard plow formed a higher percentage of large clods

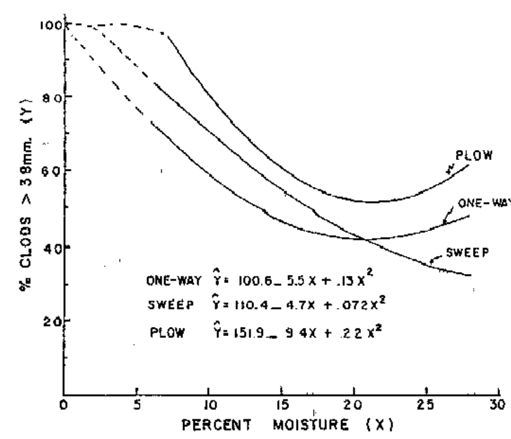

Fig. 4 Variation of percent of clods greater than 38 mm with moisture content after initial tillage

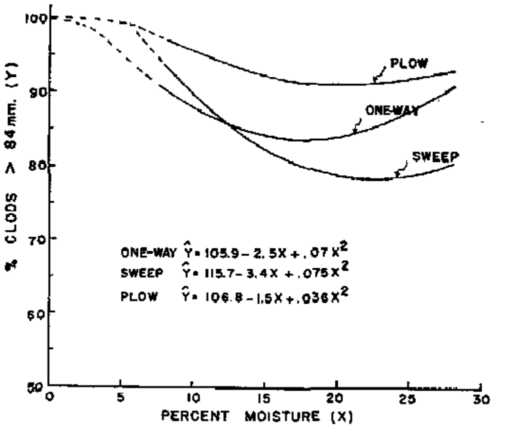

Fig. 5 Relationship between soil moisture and percent of clods greater than 0.84 mm following the initial tillage operations

throughout the range of moisture than did the one-way disk or sweep. At moisture contents less than approximately 20 percent, the sweep produced a higher percentage of large clods than the one-way, but above this moisture level the one-way was superior. The plow and one-way produced a higher percentage of large clods with both a decrease and an increase in moisture content from about 21 percent, while the percentage of large clods produced by the sweep continually decreased with increasing moisture content. None of the curves allow extrapolation outside the range of moisture used in the study.

Fig. 5 shows the percent of material as clods greater than 0.84 mm in diameter as a function of moisture content for the three tillage implements. Again the moldboard plow yielded more cloddiness over the entire range of moisture content than did the one-way or sweep. At moisture contents above 12 percent, the one-way was superior to the sweep, but below 12 percent the sweep produced more cloddiness. All three implements yielded greater percentages at high and low moisture content than at intermediate values.

Percentages of materials less than 0.42 mm are given in Fig. 6. The plow caused less pulverization than the other two implements. The sweep and one-way interchanged again at about 12 percent moisture. All three implements showed greater pulverization at intermediate moisture contents. The differences for moisture content may not appear too great, but an actual comparison of the quantity of soil of this size per acre based on a one-half inch depth of soil is quite large. For example, the sweep produced about 5 percent fine material at 8 percent moisture and about 13.5 percent at 20 percent moisture. On a weight basis the soil

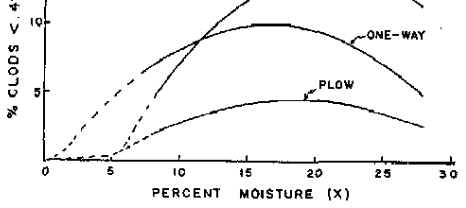

Fig. 6 Soil moisture vs. percent clods less than 0.42 mm after initial tillage

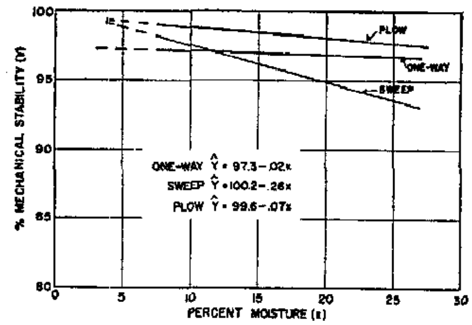

Fig. 7 Soil moisture vs. mechanical stability for the three tillage implements after initial tillage

tilled at 20 percent contains about 5 tons per acre more soil in this erodible fraction in a one-half-inch depth than the same soil tilled at 8 percent moisture.

Mechanical stability as determined by the amount of fine material abraded by a second rotary-sieving operation was rather high for all implements and moisture contents. This would be expected with a cohesive silty clay loam. Although the differences were slight, the variance ratio was significant at the 1 percent level for moisture and 0.1 percent level for tillage. Fig. 7 shows that soil tilled with the moldboard plow had the highest mechanical stability with the one-way superior to the sweep above 12 percent moisture. The sweep shows a more decided decrease in mechanical stability with an increase in moisture content.

Results of the wet sieve aggregate analysis show no significant difference for moisture (Table 1), but highly significant differences for tillage implement. Averages of the data for the percent aggregates greater than 0.84 mm were 10.4, 7.5, and 18.6 for the one-way, sweep, and plow, respectively. There was not more than one percent difference among the tillage implements for the percent of soil particles less than 0.02 mm in diameter.

Crushing strength-moisture relationships for the clods were derived using semigraphical methods of Lipka (3). These equations with the corresponding curves computed from them for the field moist samples are shown in Fig. 8. As would be expected, the crushing strength decreased rapidly with increases in soil moisture. Clods formed at 8 percent were approximately three to four times stronger than those formed at 25 percent. This is, of course, a nebulous strength and not an intrinsic property of the soil, and varies with density, moisture content, and degree of consolidation. It does help explain why tillage breaks out large clods at low moisture contents in cohesive soils. Since the mechanical strength is increased with drying, once over, "plow-plant" operations may cause pulverization of the soil, especially if performed at moisture contents that form weak, fragile clods.

The crushing strength of air-dry clods was not consistent. For example, soil tilled at the three higher levels showed a decisive increase in clod strength upon drying, while the soil tilled at the two lower moisture contents showed a general decrease in crushing strength when air-dried. This could be explained in terms of compressibility, shear, cohesion, and coherence. At the higher moisture contents the tillage tools caused some soil compression. Drying decreased the clod volume and formed a hard coherent mass that was very resistant to fracture by the resultant forces of compression and shear when the cantilever beam was ap-

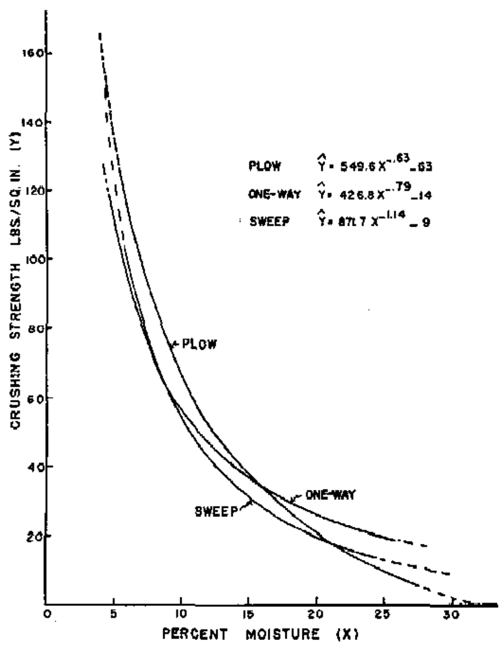

Fig. 8 Relationship between crushing strength and soil moisture at time of initial tillage for 100 clods trimmed to a 1 sq in. cross-sectional area before crushing with a ½-in. cantilever beam

plied. The implements at the lower moisture content did not compress the soil to any appreciable degree and therefore did not result in a change in true cohesion (coherence). This would mean that the primary factor affecting a change in the resistance of the clods to crushing would be the forces of apparent cohesion, i.e., those forces due to number and thickness of water films in the soil. As the soil dried, the apparent cohesion would decrease and thereby decrease the force necessary to cause fracture.

After Weathering

The effect of natural forces of weathering was evaluated approximately one month after the initial tillage (Fig. 2). The short period was considered sufficient due to the excessive precipitation therein (Fig. 2) which equaled the normal three months rainfall.

Analysis of variance of the data after weathering revealed that the variance ratios were not significant for moisture (Table 1). This means that influence of moisture on the original clods formed had largely disappeared during the period of weathering. The variance ratios were still highly significant for tillage implement (Table 1). Since moisture was not significant, bar graphs shown in Fig. 9 were made by averaging all the moisture data. The moldboard plow maintained the position it held after the initial tillage, i.e., more clods greater than 38 mm and greater than 0.84 mm and fewer clods smaller than 0.42 mm than the one-way or sweep. Except below or above certain moisture contents, the one-way had formed more large clods, fewer fine, and more greater than 0.84 mm than did the sweep. Following the period of weathering the position of the one-way and sweep were exactly reversed. However, the numerical differences were smaller.

Perhaps of equal importance is the rate of breakdown. For example, the plow on the average had three times more fine soil particles (less than 0.42 mm) after the period of weathering when compared to the amount after initial tillage, while the one-way and sweep had 1.8 and 1.1 times more, respectively. This could readily be explained on the basis of tillage action. The moldboard plow causes an inversion of the soil surface layer, the one-way some inversion and mixing, while the sweep leaves the surface relatively undisturbed. Apparently the soil exposed by the plow breaks down faster than that exposed by the other two implements.

Final Tillage

At the time of the last sampling, the plots had been tandem-disked three times, rotary-hoed twice, and had received 25.94 in. of rainfall (Fig. 2). Normally it would have taken approximately 10½ months to receive this amount, and in drier areas it could have taken as long as two years. The variance ratio showed no significant difference for moisture or tillage implement (Table 1). Therefore, the measurable effect of the initial tillage disappeared after further tillage operations and weathering.

The wet sieving analysis showed that the differences due to tillage implement had disappeared after the subsequent tillage operations.

CONCLUSIONS

On the basis of one soil texture, a silty clay loam, and without considering residue coverage, the following conclusions may be enumerated:

Soil Moisture

1 Soil moisture at time of tillage has a definite effect on the size distribution of clods produced. More erodible particles and fewer large clods were found at intermediate soil moisture levels (15 to 23 percent) for the soil used in the study. This is the range of moisture at which tillage is usually performed.

2 Soil moisture apparently has no measurable effect on the percentage of soil particles greater than 0.84 mm in diameter as determined by wet sieving.

3 The differences in clod size distribution due to moisture tend to be lost rather rapidly, especially under excessive rainfall conditions.

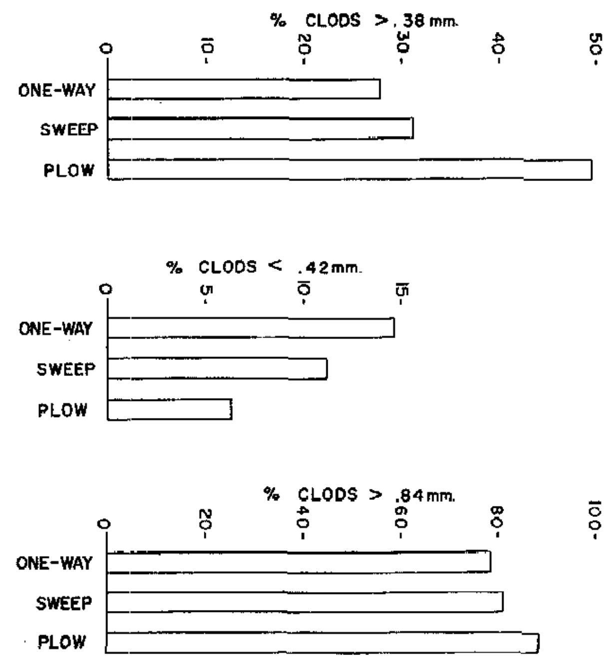

Fig. 9 Bar graph showing the clod variables for each tillage implement after a period of natural weathering

Tillage Implement

1 Type of tillage implement has a decided influence on the size and stability of the clods formed, and the differences persist longer than those due to moisture content.

2 The moldboard plow produces more large clods, fewer fine particles, and more clods greater than 0.84 mm with higher mechanical stability than the one-way disk or subsurface sweep.

3 Above certain moisture contents (12 to 20 percent for the soil used) the one-way disk yields more clods greater than 38 mm, greater than 0.84 mm, and fewer clods less than 0.42 mm with higher mechanical stability than the sweep; however, below these moisture levels the positions of the two implements are reversed.

4 The rate of breakdown after initial tillage was more rapid for the plow.

5 The order of tillage implements in relation to the percent of soil particles greater than 0.84 mm as determined by wet sieving is plow, one-way, and sweep.

6 Other tillage operations and weathering obliterates differences occuring after initial tillage.

Clod Strength

1 Clods formed at low moisture content have three to four times more resistance to crushing than those formed at higher moisture levels (greater than 16 percent).

2 Resistance to crushing may decrease with drying if the soil is tilled at low moisture; otherwise it increases rather strongly.

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