THE EFFECT OF SOIL MOISTURE AND TILLAGE ACTION ON SOIL CLODDINESS FOR WIND EROSION CONTROL

by

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INTRODUCTION

Soil conditions for wind erosion control are quite different from those usually considered to be most desirable for a good seed bed. On bare, unprotected soil a rough, cloddy surface has proved most satisfactory for controlling erosion by wind. Investigations have shown that the percentage of soil particles greater than 0.84 mm. in diameter is a simple index of 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 clod size distribution 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 study was initiated 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.

Objectives

The specific objectives of this study were: (1) to determine the effect of soil moisture at time of tillage on the percentage of soil in clods and the size distribution, (2) to evaluate the structural conditions produced by various tillage equipment operating at the same speed, depth, and moisture content, (3) to determine the influence of natural weathering and subsequent tillage on the clods formed by the initial tillage operation, and (4) to measure the crushing resistance of field moist and air dry clods.

Review of Literature

Numerous investigations have been made on the factors that influence wind erosion and its control. However, most are indirectly related to this study of controlled moisture under field conditions.

Russell (6) stated that the influence of moisture content at which a soil is worked on the aggregate structure developed by that working seems to have been first studied by Vassilenko and Setzinsky (1933), and Vilensky and Germanova (1934) in the Ukraine. Russell also included 20 references of Russian investigators dealing with the effects of cultivation on the structure of soils. The author did not have access to these publications.

The most directly related study of soil moisture at time of tillage was conducted by the Soil Research Laboratory at Swift Current, Sask., Canada (7). Results indicated that above certain moisture contents (6 to 9 percent for loam, 14 to 18 percent for clay) the degree of aggregation increased with moisture content. Larger and denser clods were formed as the moisture content increased. No information was given as to tillage implements, but did state that both laboratory and field studies were made.

Clod size distribution produced by various tillage implements have been reported by Woodruff and Chepil (8), Siddoway[1], and Woodruff[2] et.al. No effort was made to control moisture in these studies.

Cole and Morgan (3) stated that there is less pulverization of the soil by the moldboard plow than with many other cultivating implements, and that the

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[1] F. H. Siddoway, Annual Research Report. Western Section, Soil and Water Cons. Res. Br., Agr. Res. Ser., U. S. Dept. Agr., Cooperative with Tetonia Branch Agr. Exp. Sta., Univ. Idaho, 1956. (Unpublished)

[2] Woodruff et.al., "Residue Reduction by Various Types of Tillage Machinery," Wind Erosion Laboratory, Manhattan, Kansas, 1959. (Unpublished)

degree of roughness depends on the character of the soil and its moisture content when plowed. These statements are not substantiated by experimental data.

Surprisingly enough for such a fundamental problem, there is very little quantitative information available.

EXPERIMENTAL MATERIALS

The material and equipment used in this study may be divided into three classifications: (1) material necessary for effective field moisture control, (2) equipment used in the tillage operation, and (3) soil processing equipment.

Moisture control material included black polyethylene of 4 or 6 mil thickness, embossed aluminum roofing, 15-pound weight asphalt felt, and pressure spraying equipment consisting of a small gasoline engine, a pressure pump, and a $7\frac{1}{2}$-foot spraying boom.

The initial tillage tools were a standard 5-foot one-way disk with 18-inch disk diameter on 9-inch centers, a 5-foot V-type subsurface sweep, and a 14-inch two bottom moldboard plow. The angle between the barrel of the disk and a line perpendicular to the direction of travel was approximately 40 degrees. Subsequent tillage implements were a tandem disk and rotary hoe. The one-way disk and subsurface sweep are shown in Plate I.

Two rotary sieves, a clod-crusher shown in Plate II, and standard wet sieving apparatus were used as soil processing equipment.

Some of the more important soil physical properties are as follows:

1. Mechanical composition; sand 19.5%, silt 49.1%, clay 31.4%.
2. Moisture holding capacity as determined by the pressure membrane method; field capacity 30%, permanent wilting point 14.5%.
3. Consistency constants; liquid limit 33%, plastic limit 21.6%.

EXPLANATION OF PLATE I

Fig. 1. Five-foot one-way disk
Fig. 2. Five-foot V-type subsurface sweep

PLATE I

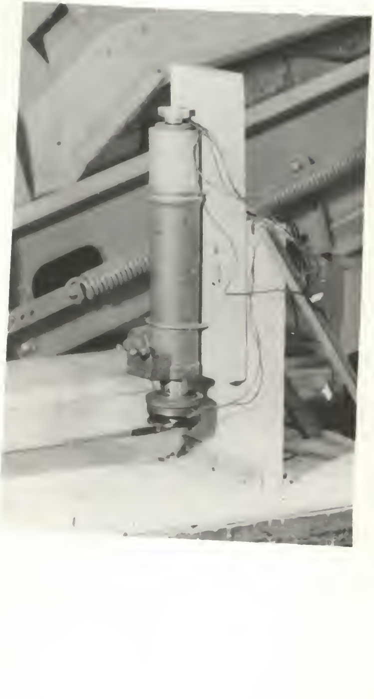
Fig. 1

Fig. 2

EXPLANATION OF PLATE II

Cantilever beam which is connected to strain indicating equipment to measure crushing resistance of the clods formed.

PLATE II



PROCEDURE

The experiment involved field plots statistically designed as a split-plot randomized complete block. Main plots were 5 moisture levels varying from 8 to 25 percent replicated four times on a silty clay loam. Each plot was 15' x 30'. Subplots, 10' x 15', included three tillage treatments using three different implements described under experimental materials.

The soil was pretreated by cultipacking to give approximately the same bulk density and to level the surface.

To intercept direct rainfall, all but one of the plots were covered with black polyethylene plastic of 4 or 6 mils thickness as shown in Plate III. Each 15' x 30' plot was covered with a 20' x 33' sheet of plastic. The sheets were rolled on 2" x 2" x 20' lengths of pine to facilitate covering and uncovering the areas. Loose soil and sand bags were used to anchor the covers around the sides and at the ends. Sheet aluminum attached to wooden frames mounted on wheels was used to cover the remaining plot (Plate III, Fig. 1). Two frames, each covering an area 16' x 20' were constructed and placed end to end to cover one plot. Each frame was rolled back over the adjoining plot when it was necessary to uncover the area.

Surface runoff was diverted by constructing small berms with a tractor and grader blade on the upslope sides and around the ends of the plots. Since a berm on the downhill side will cause ponding of water during precipitation, it was not constructed.

Fifteen-pound weight asphalt felt was placed vertically in a commercially dug trench to a depth of one foot to prevent lateral movement of moisture from the surrounding area (Plate III, Fig. 2).

EXPLANATION OF PLATE III

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

Fig. 2. Asphalt felt placed to a depth of one-foot around each 15' x 30' area to prevent lateral movement of moisture in the soil layer.

PLATE III

Fig. 1

Fig. 2

Since low soil moisture content cannot be obtained by covering alone it was necessary to devise a means of extracting moisture. Vegetation is about the only economical and practical means to use. Wheat and oats were planted on the plots where low moisture contents were desired and allowed to grow until the desired moisture level was reached and then shaved with a flat spade at the ground surface and removed (Plate IV).

Water was added to the plots requiring high moisture content with pressure spraying equipment. The equipment was driven along each side of the plot with a spray boom of sufficient length to cover one-half of the 15-foot width with each pass.

Samples for determining moisture content and bulk density were taken just prior to tillage. Operational variables of depth and speed were kept constant at about 4 inches and 3.2 m.p.h., respectively.

Surface soil samples were taken for dry and/or wet sieving on three occasions, (1) immediately following the initial tillage operations, (2) after a period of weathering, and (3) following the last tillage operations used in the study (Fig. 3). Individual samples were taken from a one square meter area with a flat spade.

The author is cognizant of the various opinions concerning the interpretation of results obtained by the wet sieving method of aggregate analysis. Many factors such as soil sample preparation techniques, wetting of soil with or without a vacuum, and sieving time appear to influence the results. For wind erosion purposes, Chepil (2) has found that the percent of aggregates greater than 0.84 mm. and less than .02 mm. in diameter are closely related to the erodibility of a particular soil by wind. Using this information, separates of this size only were made. Since only relative information was desired, the sieving time was decreased to 1/10 of that used by Yoder (9), and the samples were prewetted under a vacuum.

EXPLANATION OF PLATE IV

Oats planted to extract moisture. Polyethylene is rolled back except during periods of actual or impending rainfall.

PLATE IV

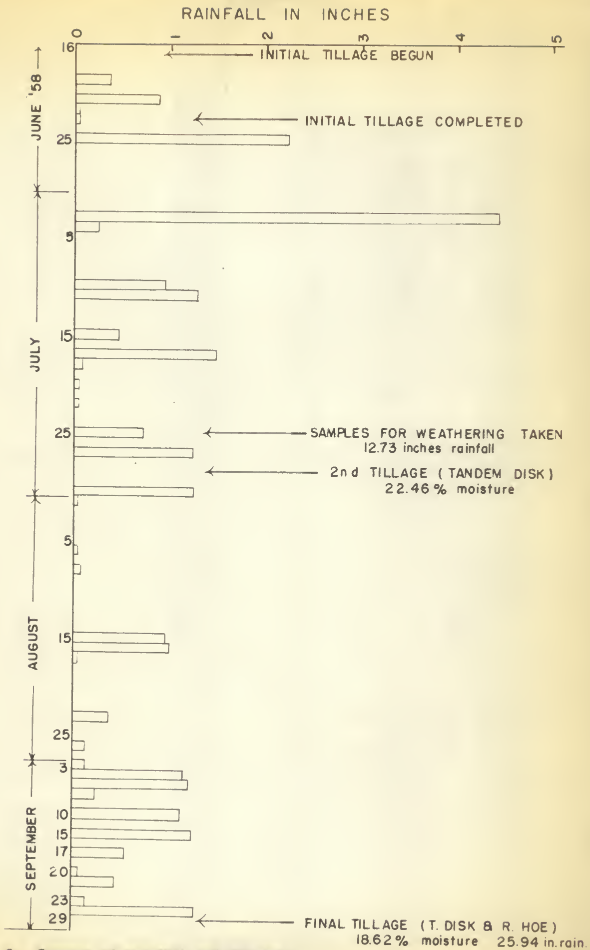


Fig. 3. Summary of rainfall and tillage.

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

RESULTS

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 (Plate V). The 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 average dry densities of 87.9, 86.5, 88.7, 86.1, and 86.6 pounds per cubic foot for each level, respectively. Individual plot minimum and maximum moisture content was 7.3 and 27.5.

Results of dry sieving are presented in Table 1. Table 2 and 3 summarize the results of an analysis of variance for moisture, tillage implement, and the interaction of these two factors. 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

EXPLANATION OF PLATE V

Example of clod sizes produced by the moldboard plow at the moisture contents indicated.

PLATE V

Table 1. Dry sieving after initial tillage.

Plot #	% Moisture	One-Way % > 38mm.	% > .84mm.	% < .42mm.	% Stability
1	8.38	71.2	93.4	4.6	97.9
9	8.44	59.4	88.2	8.4	96.4
11	8.15	61.8	88.5	7.8	97.6
17	7.33	61.2	90.0	6.6	96.6
Ave	8.08				
4	11.66	48.6	86.8	8.3	97.0
6	11.10	57.8	88.4	8.0	97.8
13	11.67	59.2	87.8	8.6	97.4
20	10.35	64.4	87.6	8.8	96.8
Ave	11.20				
8	19.33	33.7	85.2	8.9	96.3
12	20.06	46.4	83.4	10.9	96.2
14	20.22	49.9	88.2	7.4	97.0
18	19.51	43.8	80.6	12.6	95.8
Ave	19.78				
5	21.46	45.4	85.4	9.0	96.7
10	21.61	41.8	87.3	7.3	96.5
16	22.64	37.8	86.4	9.4	96.5
19	22.23	41.5	84.6	9.6	96.6
Ave	21.98				
2	24.99	43.2	85.1	9.0	96.2
3	23.90	52.1	91.8	4.6	97.7
7	24.41	34.2	88.2	6.2	96.6
15	27.48	53.9	90.6	5.4	98.0
Ave	25.20				

Plot #	% Moisture	Sweep % > 38mm.	% > .84mm.	% < .42mm.	% Stability
1	8.38	67.4	91.8	5.4	98.0
9	8.44	82.2	95.0	3.8	98.4
11	8.15	82.0	93.3	4.8	99.0
17	7.33	74.2	93.5	4.2	98.0
Ave	8.08				
4	11.66	70.0	93.4	4.2	97.6
6	11.10	59.9	85.6	9.9	96.5
13	11.67	74.3	91.3	5.8	97.4
20	10.35	61.0	83.5	11.7	97.4
Ave	11.20				

(Table 1 continues on next page)

Table 1. (Continued)

Plot #	% Moisture	Sweep % > 38mm.	Sweep % > .84mm.	Sweep % < .42mm.	Sweep % Stability
8	19.33	62.1	85.6	9.6	97.2
12	20.06	35.1	66.8	23.0	91.4
14	20.22	44.7	78.0	14.2	94.4
18	19.51	34.2	70.8	20.0	93.1
Ave	19.78				
5	21.46	44.1	80.2	13.4	95.7
10	21.61	43.4	87.0	7.8	97.1
16	22.64	30.4	78.6	14.2	94.4
19	22.23	31.3	73.1	17.5	91.8
Ave	21.98				
2	24.99	38.8	83.4	10.2	94.1
3	23.90	36.2	78.0	14.0	93.3
7	24.41	38.6	80.9	11.9	96.2
15	27.48	35.5	76.9	14.6	92.9
Ave	25.20				

Plot #	% Moisture	Plow % > 38mm.	Plow % > .84mm.	Plow % < .42mm.	Plow % Stability
1	8.38	83.6	96.4	2.4	98.8
9	8.44	88.0	97.1	2.0	99.0
11	8.15	85.6	96.6	2.4	98.9
17	7.33	89.8	97.2	1.8	98.9
Ave	8.08				
4	11.66	77.6	95.2	3.2	98.8
6	11.10	75.0	95.2	3.2	99.3
13	11.67	79.8	96.0	2.6	99.0
20	10.35	85.3	96.5	2.4	99.0
Ave	11.20				
8	19.33	57.4	94.0	3.5	98.5
12	20.06	34.4	88.6	5.9	97.8
14	20.22	54.4	93.4	4.0	98.6
18	19.51	43.6	91.3	5.0	97.6
Ave	19.78				
5	21.46	75.6	96.2	2.2	99.2
10	21.61	46.8	91.4	4.9	97.6
16	22.64	43.8	90.0	5.3	97.1
19	22.23	42.2	91.2	4.6	97.8
Ave	21.98				
2	24.99	61.0	94.0	3.1	98.0
3	23.90	51.4	90.8	4.8	97.4
7	24.41	38.2	92.4	3.8	97.8
15	27.48	66.0	95.6	2.2	98.6
Ave	25.20				

Table 2. Summary of an analysis of variance for moisture and tillage implement following the various operations.

Variable	Operation	Variance ratio		
		Moisture	Tillage	Tillage x Moisture
% > 38 mm.	Initial tillage	26.53***	18.12***	2.02
% > 38 mm.	Weathering	2.80	36.05***	1.05
% > 38 mm.	Final tillage	1.48	0.64	1.38
% > .84 mm.	Initial tillage	12.67***	57.56***	4.20**
% > .84 mm.	Weathering	2.00	48.79***	0.95
% > .84 mm.	Final tillage	1.48	0.34	0.49
% < .42 mm.	Initial tillage	8.78**	61.19***	4.61**
% < .42 mm.	Weathering	1.81	49.68***	0.89
% < .42 mm.	Final tillage	1.66	0.47	0.53
% Mech. stability	Initial tillage	9.32**	33.83***	3.37**
% Mech. stability	Weathering	1.08	35.89***	0.89
% Mech. stability	Final tillage	0.19	0.08	0.79
% > .84 mm. (Wet sieving)	Initial tillage	2.64	33.08***	0.95
% < .02 mm. (Wet sieving)	Initial tillage	3.68*	3.55*	0.49
% > .84 mm. (Wet sieving)	Final tillage	-	2.36	-

* - Significant at 5% level.
** - Significant at 1% level.
*** - Significant at 0.1% level.
All others are nonsignificant.

evidence that both moisture content at time of tillage and 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 .84 mm., percent less than .42 mm., and the mechanical stability as a function of moisture content for the three tillage implements (4). Fig. 4 reveals that the moldboard plow formed a higher percentage of large clods throughout the range of moisture than did either the one-way disk or sweep. At moisture contents

Table 3. Summary of means and LSD* for variables that were statistically significant.

Dry Sieving	LSD* = 3.7		LSD* = 3.3		LSD* = 2.34		LSD* = 0.09	
Operation	% Moisture	Means % > 38 mm.	% Moisture	Means % > .84 mm.	% Moisture	Means % < .42 mm.	% Moisture	Means Mech. stability
Initial	8.1	75.5	8.1	93.4	19.8	10.4	8.1	98.1
Initial	11.2	67.7	11.2	90.6	22.0	8.8	11.2	97.8
Initial	25.2	45.8	25.2	87.3	25.2	7.5	22.0	96.4
Initial	19.8	45.0	22.0	86.0	11.2	6.4	25.2	96.4
Initial	22.0	43.7	19.8	83.8	8.1	4.5	19.8	96.2

Dry Sieving	LSD* = 1.6		LSD* = 2.04		LSD* = 1.4		LSD* = 0.07	
Operation	Implement	Means % > 38 mm.	Implement	Means % > .84 mm.	Implement	Means % < .42 mm.	Implement	Means Mech. stability
Initial	Plow	64.0	Plow	94.0	Sweep	11.0	Plow	98.4
Initial	Sweep	52.3	One-way	87.4	One-way	8.1	One-way	96.9
Initial	One-way	50.4	Sweep	83.3	Plow	2.5	Sweep	95.7

Dry Sieving	LSD* = 5.6		LSD* = 2.2		LSD* = 1.4		LSD* = 0.96	
Operation	Implement	Means % > 38 mm.	Implement	Means % > .84 mm.	Implement	Means % < .42 mm.	Implement	Means Mech. stability
Weathering	Plow	49.6	Plow	88.2	One-way	14.2	Plow	95.2
Weathering	Sweep	31.2	Sweep	81.2	Sweep	12.4	Sweep	92.3
Weathering	One-way	27.9	One-way	78.6	Plow	7.6	One-way	91.3

Wet Sieving	LSD* = 0.42		LSD* = 2.9		LSD* = 0.53	
Operation	Implement	Means % < .02 mm.	Implement	Means % > .84 mm.	Moisture	Means % < .02 mm.
Initial	One-way	8.9	Plow	18.6	25.2	9.6
Initial	Sweep	8.7	One-way	10.4	8.1	8.6
Initial	Plow	7.8	Sweep	7.5	22.0	8.3
Initial					19.8	7.9
Initial					11.2	7.9

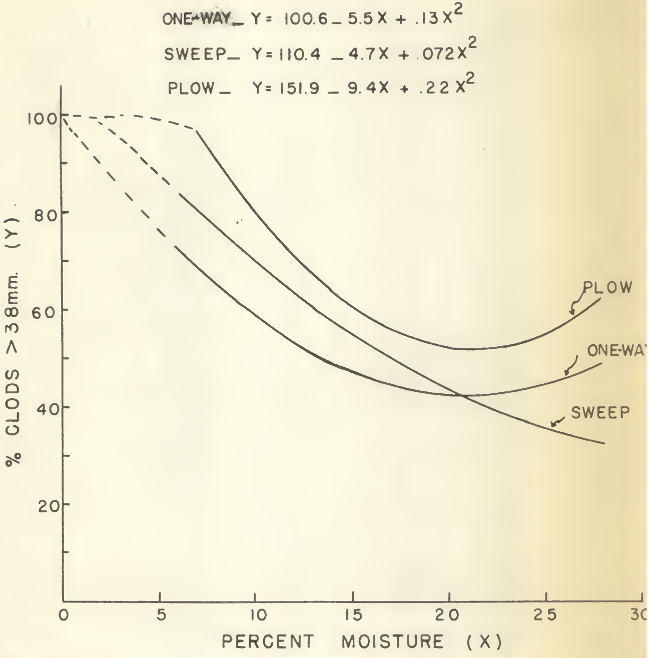


Fig. 4. Variation of percent clods > 38 mm. with moisture content after initial tillage. The curves were derived from the relationships established by the equations.

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. Table 3 shows that there were no significant differences among the three highest moisture levels for the percent clods greater than 38 mm. in diameter; however, all three implements were significantly different. 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 .84 mm. in diameter as a function of moisture content for the three tillage implements. Again it should be noted that 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. Some moisture levels showed no statistical differences in the percentage of clods greater than this size (Table 3). Again all tillage implements were significantly different.

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

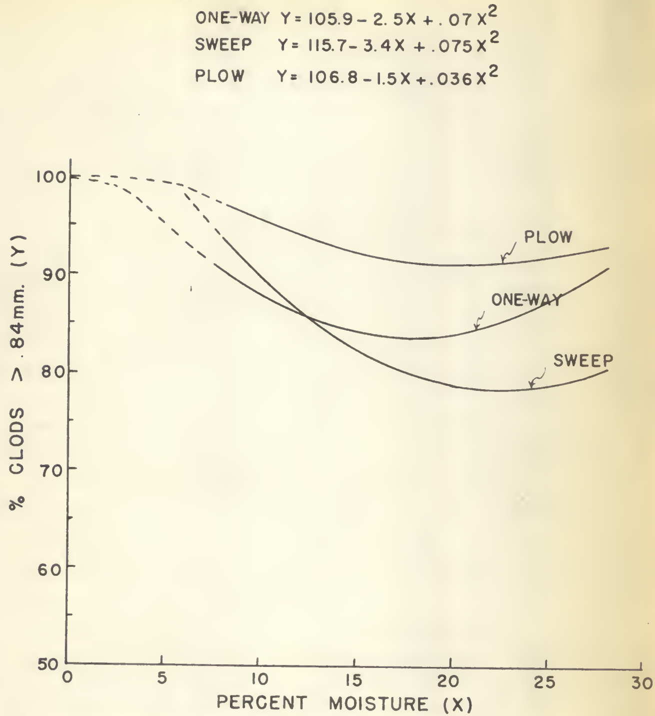


Fig. 5. Relationship between soil moisture and percent clods > .84 mm. following the initial tillage operations.

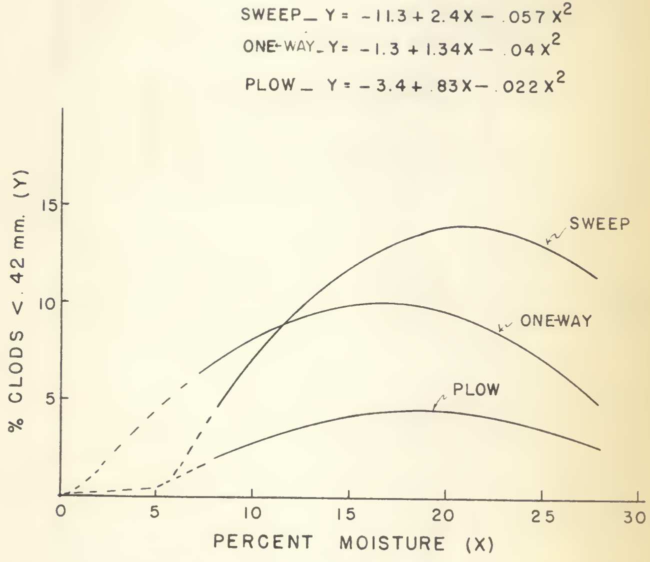


Fig. 6. Soil moisture versus percent clods < .42 mm. after initial tillage.

at 8 percent moisture and about 13.5 percent at 20 percent moisture. On a weight basis the soil tilled at 20 percent contains about 13 tons per acre more soil in this erodible fraction 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.

Wet sieving data is shown in Table 4. Analysis of variance show no significant differences for moisture on the percent of aggregates greater than .84 mm. in diameter, but highly significant differences were obtained for tillage implements. Averages of the data were 10.4, 7.5 and 18.6 percent for the one-way, sweep, and plow, respectively. The percentage of soil particles less than .02 mm. in diameter was significant at the 5 percent level for both tillage implement and moisture. However, LSD values in Table 3 furnishes evidence that there are no differences between the one-way and sweep, and also that several moisture levels were about the same.

Crushing strength-moisture relationships for the clods were derived using semi-graphical methods of Lipka (5). These equations with the corresponding curves computed from them for the field moist samples are shown in Fig. 8. The actual data is found in Table 5. As would be expected, the crushing strength decreased rapidly with increases in soil moisture. Clods formed at 8 percent moisture content were approximately 3 to 4 times stronger than those formed at

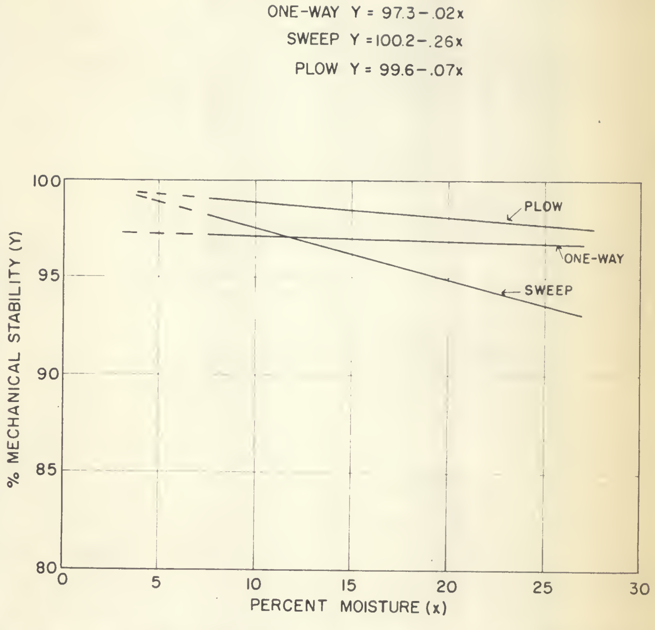


Fig. 7. Soil moisture versus mechanical stability for the three tillage implements after initial tillage.

Table 4. Wet sieving after initial tillage.

Plot #	Initial % Moisture	One-Way		Sweep		Plow	
		% > .84mm.	% < .02mm.	% > .84mm.	% < .02mm.	% > .84mm.	% < .02mm.
1	8.38	12.9	9.8	8.1	7.8	10.5	9.9
9	8.44	7.5	8.6	8.9	9.7	13.4	9.2
11	8.15	5.7	8.4	5.2	9.0	13.3	7.8
17	7.33	8.7	9.0	12.5	7.3	13.4	7.0
Ave.	8.08	8.7	9.0	8.7	8.4	12.6	8.5
4	11.66	12.1	7.6	14.1	8.5	12.0	7.8
6	11.10	12.6	8.5	5.8	8.2	21.4	7.8
13	11.67	8.7	8.2	10.2	6.8	16.4	7.6
20	10.35	6.6	8.6	5.8	8.1	27.5	7.0
Ave.	11.20	10.0	8.2	9.0	7.9	19.3	7.6
8	19.33	10.8	8.9	6.5	8.0	21.1	7.2
12	20.06	8.8	7.8	2.7	7.0	12.4	7.9
14	20.22	9.8	7.9	5.9	8.4	23.0	6.2
18	19.51	4.5	9.5	3.6	8.2	16.6	8.2
Ave.	19.78	8.4	8.5	4.7	7.9	19.1	7.4
5	21.46	10.1	9.1	6.0	10.0	25.0	7.3
10	21.61	12.1	7.5	13.7	8.2	21.0	6.9
16	22.64	14.4	9.8	11.0	9.6	19.3	8.4
19	22.23	16.2	7.0	3.5	8.6	23.3	7.0
Ave.	21.98	13.2	8.4	8.6	9.1	22.1	7.4
2	24.99	8.0	11.2	4.1	12.8	17.6	10.3
3	23.90	9.3	10.6	5.8	9.6	15.3	7.8
7	24.41	14.6	11.3	12.4	8.1	26.2	7.9
15	27.48	13.8	8.9	4.8	9.3	24.2	7.8
Ave.	25.20	11.4	10.5	6.8	10.0	20.8	8.4

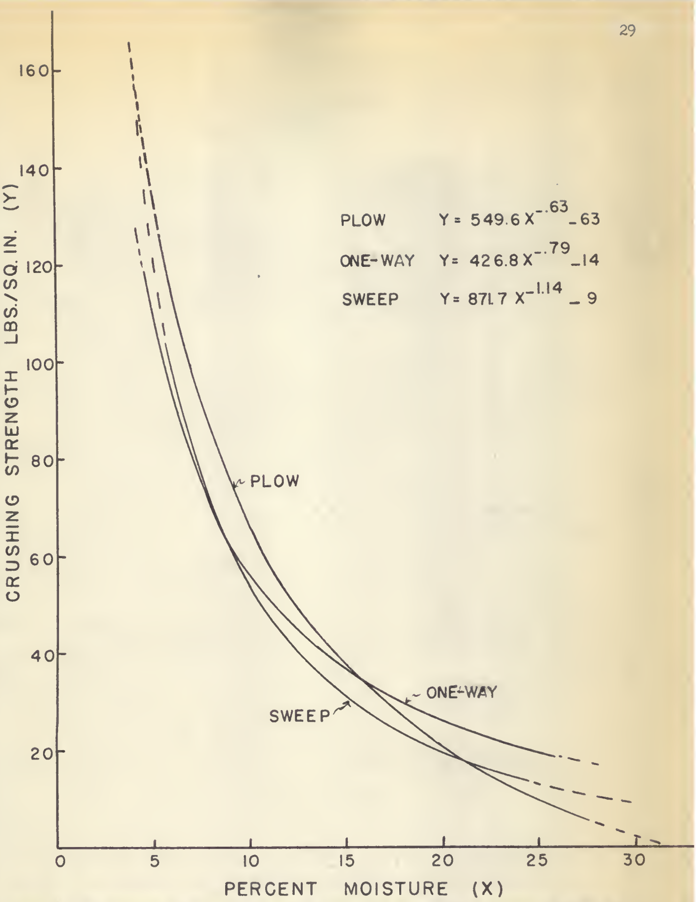


Fig. 8. Relationship between crushing strength and soil moisture at time of initial tillage for 120 clods trimmed to a 1 square inch cross sectional area before crushing with a one-half inch cantilever beam.

Table 5. Crushing strength of field moist clods after initial tillage.

One-Way		Sweep		Plow	
% Moisture	Crushing stress #/in^2	% Moisture	Crushing stress #/in^2	% Moisture	Crushing stress #/in^2
4.17	117.0	4.59	87.0	7.79	105.5
7.32	59.7	3.46	105.5	5.51	124.0
6.32	124.0	6.95	105.5	7.76	144.5
6.20	124.0	7.05	101.0	6.34	78.0
6.97	78.0	6.27	101.0	7.13	105.5
7.27	103.0	5.86	91.7	6.75	105.5
6.09	101.0	9.93	41.0	7.23	59.7
10.97	39.0	10.46	50.0	7.59	101.0
7.93	57.0	7.31	82.5	11.44	64.0
7.46	124.0	7.94	78.0	10.95	62.0
8.43	151.2	8.48	112.3	8.20	82.5
7.32	55.0	8.75	105.5	7.93	85.0
9.53	73.5	7.48	80.0	10.70	82.5
7.39	78.0	8.44	96.0	10.77	62.0
8.13	117.0	18.85	14.5	10.62	53.0
21.87	26.2	19.97	41.5	9.45	71.0
20.61	36.1	17.17	12.8	17.26	23.5
19.42	28.9	20.08	26.7	10.46	46.9
20.06	23.5	18.18	17.3	19.24	20.0
18.31	15.8	16.06	21.8	11.71	55.0
19.67	34.4	17.48	7.4	18.70	21.0
16.47	18.2	17.91	21.8	17.47	34.4
16.63	26.2	21.47	28.9	17.58	41.5
22.54	18.2	20.47	33.4	16.06	26.2
21.54	39.8	12.08	25.3	19.93	30.8
18.99	32.5	17.81	28.9	20.16	26.2
18.01	22.7	20.27	18.2	19.12	20.0
13.02	69.0	20.06	18.2	20.55	27.1
20.06	25.3	19.96	26.2	20.54	14.5
18.41	16.4	19.33	14.5	19.25	15.5
21.90	23.5	22.21	21.8	21.38	8.3
21.36	32.5	24.37	20.9	20.13	14.5
17.03	28.0	18.40	18.2	18.87	20.9
17.91	32.5	20.68	30.8	17.58	24.5
21.79	38.9	21.25	12.8	24.20	13.7
21.07	23.5	21.56	7.4	22.42	23.5
20.80	37.9	18.64	32.5	21.94	15.5
18.59	28.9	19.61	34.4	18.61	23.5

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 increases with drying, "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 found not to be 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 (Fig. 9). This could be explained in terms of compressibility, shear, cohesion, and coherence. The tillage tools at the higher moisture contents caused some compression of the soil and upon drying decreased in volume, forming a hard coherent mass that was very resistant to fracture by the resultant forces of compression and shear when the cantilever beam was applied. Because of the type of tillage action this should be especially true for the plow and one-way. Fig. 9 tends to substantiate this hypothesis. 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. 3). The short period was considered

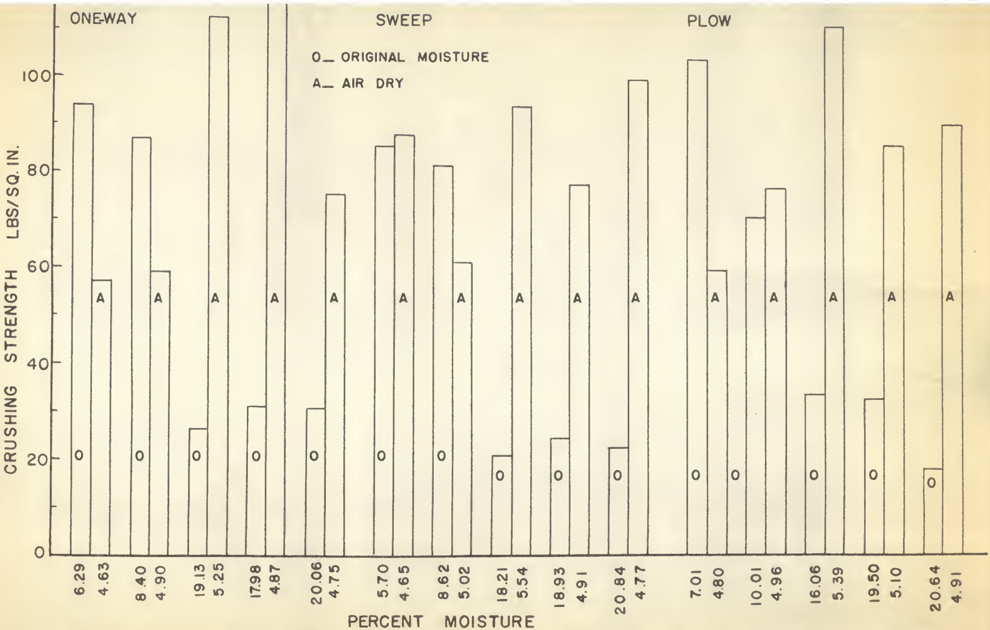


Fig. 9. Bar graph showing the relationship between the crushing strength of clods immediately after tillage and upon air drying.

sufficient due to the excessive precipitation occurring during the period (Fig. 3). Normally it would have taken about three months to yield the amount of moisture received.

Dry sieving results after weathering are shown in Table 6. Analysis of variance of the data revealed that the variance ratio was not significant for moisture (Table 2). This means that influence of moisture on the original clods formed had largely disappeared during the period of weathering. The variance ratio was still highly significant for tillage implement (Table 2). Since moisture was not significant, bar graphs shown in Fig. 10 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 .84 mm. and fewer clods less 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 .84 mm. than did the sweep. Following the period of weathering the sweep on the average was superior to the one-way. 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 .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 broke down faster than that exposed by the other two implements.

Table 6. Dry sieving after natural weathering.

Plot #	Original % moisture	One-Way % > 38mm.	% > .84mm.	% < .42mm.	% Stability
1	8.38	26.3	79.8	12.6	90.0
9	8.44	23.4	76.5	15.4	88.2
11	8.15	43.6	80.6	13.4	92.8
17	7.33	31.5	78.6	14.2	90.2
Ave.	8.08	31.2	78.9	13.9	90.3
4	11.66	18.6	83.3	10.8	92.0
6	11.10	26.0	80.5	12.6	92.1
13	11.67	43.0	79.7	13.7	91.9
20	10.35	25.8	79.9	20.3	89.5
Ave.	11.20	28.4	78.6	14.4	91.4
8	19.33	45.4	83.4	11.2	93.5
12	20.06	9.2	66.9	22.2	86.7
14	20.22	25.1	74.5	16.8	89.4
18	19.51	17.2	76.9	15.5	92.1
Ave.	19.78	24.2	75.4	16.4	90.4
5	21.46	28.3	79.7	13.1	93.0
10	21.61	29.3	84.0	10.2	92.9
16	22.64	23.5	80.3	13.2	91.1
19	22.23	21.6	73.3	17.8	90.4
Ave.	21.98	25.7	79.3	13.6	91.8
2	24.99	27.7	78.6	14.1	91.8
3	23.90	28.7	84.2	9.6	94.5
7	24.41	28.9	80.6	12.7	92.5
15	27.48	34.6	80.0	13.7	91.8
Ave.	25.20	30.0	80.8	12.5	92.6

Plot #	Original % moisture	Sweep % > 38mm.	% > .84mm.	% < .42mm.	% Stability
1	8.38	30.0	81.2	12.1	92.2
9	8.44	43.8	84.9	10.3	94.2
11	8.15	50.2	84.6	10.8	92.8
17	7.33	44.8	85.8	9.6	93.5
Ave.	8.08	42.2	84.1	10.7	93.2
4	11.66	44.4	89.1	6.8	94.8
6	11.10	22.3	83.8	10.3	92.5
13	11.67	29.1	81.7	11.8	93.2
20	10.35	22.8	75.7	16.7	89.4
Ave.	11.20	29.6	82.6	11.4	92.5
8	19.33	28.2	75.8	16.3	90.7
12	20.06	38.1	77.7	14.8	91.0
14	20.22	27.1	81.7	12.4	92.7
18	19.51	30.1	77.5	14.8	91.1
Ave.	19.78	30.9	78.2	14.6	91.4

(Table 6 continued on next page)

Table 6 (Concluded)

Plot #	Original % moisture	Sweep			
		% > 38mm.	% > .84mm.	% < .42mm.	% Stability
5	21.46	33.9	80.5	12.4	93.9
10	21.61	20.0	79.8	12.5	91.7
16	22.64	17.5	78.3	14.4	92.1
19	22.23	11.9	74.4	17.1	89.3
Ave.	21.98	20.8	78.3	14.1	91.8
2	24.99	29.7	82.3	11.5	92.2
3	23.90	33.0	82.5	11.1	93.0
7	24.41	34.3	83.5	10.6	94.0
15	27.48	32.0	82.8	11.5	91.5
Ave.	25.20	32.2	82.8	11.2	92.7

Plot #	Original % moisture	Plow			
		% > 38mm.	% > .84mm.	% < .42mm.	% Stability
1	8.38	51.8	87.7	7.7	94.3
9	8.44	62.8	95.8	4.8	96.3
11	8.15	61.9	89.6	6.6	95.8
17	7.33	57.1	89.8	6.5	94.8
Ave.	8.08	58.4	90.7	6.4	95.3
4	11.66	68.4	92.3	4.8	96.9
6	11.10	67.8	93.2	4.4	97.9
13	11.67	49.3	87.4	7.8	95.1
20	10.35	41.2	84.8	9.6	94.3
Ave.	11.20	56.7	89.4	6.6	96.0
8	19.33	48.8	89.6	6.6	96.5
12	20.06	58.5	89.6	6.8	95.9
14	20.22	38.3	80.1	13.3	91.7
18	19.51	40.0	88.5	7.1	93.7
Ave.	19.78	46.4	87.0	8.4	94.4
5	21.46	57.2	87.2	8.6	96.7
10	21.61	38.0	85.7	9.0	93.9
16	22.64	45.3	87.1	8.3	95.2
19	22.23	35.8	86.7	8.0	94.0
Ave.	21.98	44.1	86.7	8.5	95.0
2	24.99	45.4	88.4	7.2	95.5
3	23.90	28.8	85.5	9.1	93.3
7	24.41	37.7	86.6	8.8	95.3
15	27.48	58.8	89.1	6.9	96.1
Ave.	25.20	42.7	87.4	8.0	95.0

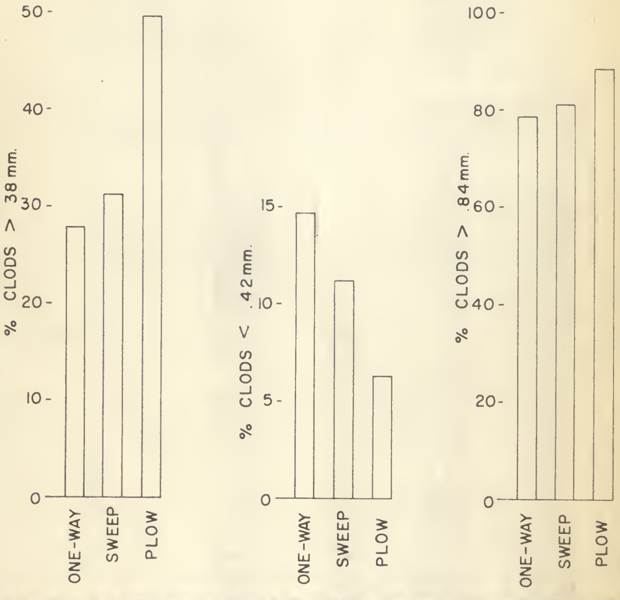


Fig. 10. Bar graph showing the clod variables for each tillage implement after a period of natural weathering.

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 inches of rainfall (Fig. 3). Normally it would have taken approximately 10½ months to receive this amount, and in drier areas it could have taken almost 2 years. Dry sieving results are shown in Table 7. The variance ratio computed from an analysis of the data showed no significant difference for moisture or tillage implement (Table 2). 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.

DISCUSSION

The study presents the differences in clod size distribution produced by three common type tillage tools and differences due to soil moisture at time of tillage. Also the effect of natural weathering and subsequent tillage operations are evaluated. No effort was made to study the effects of speed and depth of operation.

Without reference to moisture the results obtained for tillage implements agree quite well with those obtained by other workers.

Woodruff and Chepil (8) reported that the one-way disk on a silt loam produced about 5 percent more clods greater than 19.2 mm. and greater than .84 mm. than the subsurface sweep. Also that the mechanical stability was about 10-12 percent higher on one-way tillage.

Table 7. Dry sieving after final tillage.

Plot #	Original % moisture	One-Way % > 38mm.	One-Way % > .84mm.	One-Way % < .42mm.	One-Way % Stability
1	8.38	8.2	76.0	15.0	96.0
9	8.44	2.8	71.4	17.5	95.2
11	8.15	6.0	76.0	13.4	96.1
17	7.33	5.2	79.0	11.2	96.2
Ave.	8.08	5.6	75.6	14.3	95.9
4	11.66	5.6	79.6	12.5	96.4
6	11.10	4.6	79.6	11.2	96.4
13	11.67	13.2	82.1	9.1	97.2
20	10.35	12.1	77.7	12.6	96.2
Ave.	11.20	8.9	79.8	11.4	96.6
8	19.33	8.2	73.6	16.4	95.0
12	20.06	7.0	74.0	15.9	95.4
14	20.22	2.0	70.2	17.4	94.2
18	19.51	3.0	76.0	14.0	95.4
Ave.	19.78	5.1	73.4	16.0	95.0
5	21.46	3.7	76.5	13.0	96.0
10	21.61	8.8	76.2	14.5	95.1
16	22.64	2.8	77.8	13.1	96.1
19	22.23	4.3	79.6	11.9	97.0
Ave.	21.98	4.9	77.6	13.1	96.1
2	24.99	5.6	76.2	16.0	95.8
3	23.90	8.0	77.4	13.8	95.8
7	24.41	6.4	80.0	12.4	96.4
15	27.48	1.5	76.3	14.6	95.7
Ave.	25.20	5.4	77.5	14.2	95.9

Plot #	Original % moisture	Sweep % > 38mm.	Sweep % > .84mm.	Sweep % < .42mm.	Sweep % Stability
1	8.38	1.7	69.4	18.9	96.0
9	8.44	5.1	85.9	6.9	96.9
11	8.15	1.2	75.4	13.4	95.0
17	7.33	3.0	79.4	11.3	96.2
Ave.	8.08	2.8	77.6	12.6	96.0
4	11.66	8.0	81.8	9.9	97.0
6	11.10	9.2	80.9	11.4	96.2
13	11.67	2.5	75.4	13.7	96.2
20	10.35	2.0	76.6	14.4	94.2
Ave.	11.20	5.4	78.7	12.4	95.9

(Table 7 continued on next page)

Table 7 (Concluded)

Plot #	Original % moisture	Sweep % > 38mm.	% > .84mm.	% < .42mm.	% Stability
8	11.20	6.2	73.6	16.0	96.0
12	19.33	3.8	74.4	15.6	96.0
14	20.06	12.4	76.8	14.8	95.8
18	20.22	12.0	79.4	11.8	96.8
Ave.	19.51	8.6	76.1	14.6	96.2
5	21.46	8.2	78.0	13.3	96.5
10	21.61	6.7	82.1	9.8	96.7
16	22.64	9.0	76.8	13.6	96.6
19	22.23	4.8	66.4	22.0	89.0
Ave.	21.98	7.2	75.8	14.7	94.7
2	24.99	6.3	74.4	17.0	95.8
3	23.90	11.2	80.8	12.3	96.0
7	24.41	9.1	82.0	10.2	95.8
15	27.48	11.0	77.2	14.6	96.6
Ave.	25.20	9.4	78.6	13.5	96.1

Plot #	Original % moisture	Plow % > 38mm.	% > .84mm.	% < .42mm.	% Stability
1	8.38	13.2	79.0	13.2	96.4
9	8.44	15.4	86.7	7.2	97.8
11	8.15	2.6	68.4	19.2	94.2
17	7.33	5.2	72.4	16.1	94.4
Ave.	8.08	9.1	76.6	13.9	95.7
4	11.66	7.7	78.0	13.4	95.5
6	11.10	10.6	77.7	13.5	96.0
13	11.67	6.2	75.8	14.3	96.0
20	10.35	4.2	75.2	14.6	95.7
Ave.	11.20	7.2	76.7	14.0	95.8
8	19.33	5.6	66.8	21.3	95.2
12	20.06	9.6	76.4	14.4	97.4
14	20.22	7.7	75.2	15.2	94.8
18	19.51	5.2	76.0	14.6	97.4
Ave.	19.78	7.0	73.6	16.3	96.2
5	21.46	6.0	78.0	13.7	95.4
10	21.61	3.4	81.9	10.2	96.9
16	22.64	7.1	76.8	13.6	96.6
19	22.23	3.6	77.6	12.8	95.6
Ave.	21.98	5.0	78.6	12.6	96.1
2	24.99	8.8	76.8	15.0	95.6
3	23.90	4.0	72.8	17.2	94.6
7	24.41	16.3	81.0	11.5	96.9
15	27.48	3.8	73.6	16.6	96.0
Ave.	25.20	8.2	76.1	15.1	95.8

In Idaho, Siddoway[1] found that the sweep pulverized the soil about 17 percent more than the plow and 7 percent more than the one-way, but contrary to the results of this study more large clods (greater than 19.2 mm.) were formed by the sweep than the one-way or plow.

Woodruff[2] et.al. found on a silt loam that one-way tilled soil contained about 16 percent more clods greater than .34 mm. and about 17 percent less fine particles than soil tilled with the 8-foot V-type sweep.

It appears from this study and other investigations that the subsurface sweep definitely pulverizes the soil more than the one-way disk and moldboard plow. However, this relationship may not hold if the soil is extremely dry at time of tillage.

CONCLUSIONS

Before arriving at any conclusion it might be appropriate to mention some of the limitations of the study. The results are based on one soil texture, a silty clay loam. Differences exhibited should be less distinct for coarser textured soils and more distinct for finer textured ones. No tillage implement can be designated as superior in relation to wind erosion control based on this study alone. Other important factors such as residue reduction, weed control, etc. would have to be considered. With these limitations in mind the following conclusions may be enumerated.

Soil Moisture

1. Soil moisture at time of tillage has a definite effect on the size

[1]F. H. Siddoway, Annual Research Report. Western Section, Soil and Water Cons. Res. Br., Agr. Res. Ser., U. S. Dept. Agr. Cooperative with Tetonia Branch Agr. Exp. Sta., Univ. Idaho, 1956. (Unpublished)

[2]Woodruff et.al., "Residue Reduction by Various Types of Tillage Machinery," Wind Erosion Laboratory, Manhattan, Kansas, 1959. (Unpublished)

distribution of clods produced. More erodible particles, fewer large clods, and lower mechanical stability 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 .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.

Tillage Implement

1. Type of tillage implement has a decided influence on the size and stability of the clods formed, and the differences are harder to overcome than those due to moisture content.
2. The moldboard plow produced more large clods, less fine particles, and more clods greater than .84 mm. with higher mechanical stability than the one-way disk or subsurface sweep.
3. Above certain moisture contents (12 or 20 percent for the soil used) the one-way disk yielded more clods greater than 38 mm., greater than .84 mm., and fewer clods less than .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 .84 mm. as determined by wet sieving was plow, one-way, and sweep.
6. Other tillage operations and weathering obliterates differences occurring after initial tillage.

Clod Strength

1. Clods formed at low moisture content have three to four time 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.

General

The clods at anytime on a particular soil are associated with the moisture content at time of tillage and tillage implement used in the last tillage operation.

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THE EFFECT OF SOIL MOISTURE AND TILLAGE ACTION ON SOIL CLODDINESS FOR WIND EROSION CONTROL

by

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The objectives of this study were: (1) to determine the effect of soil moisture at time of tillage on the percentage of soil in clods and the size distribution, (2) to evaluate the structural conditions produced by various tillage equipment operating at the same speed, depth, and moisture content, (3) to determine the influence of natural weathering and subsequent tillage on the clods formed by the initial tillage operations, and (4) to measure the crushing resistance of field moist and air dry clods.

The experiment involved field plots statistically designed as a split-plot randomized complete block. Main plots were five moisture levels ranging from 8 to 25 percent and replicated four times on a silty clay loam. Subplots included three tillage treatments using three different implements. They were a standard 5-foot one-way disk, a 5-foot V-type subsurface sweep, and a 14-inch two-bottom moldboard plow.

Moisture control was obtained principally by plot covering, by water application, and by extracting excess moisture with vegetation.

Surface soil samples from a one square meter area were taken for dry and/or wet sieving on three occasions, (1) immediately following the initial tillage operations, (2) after a period of weathering, and (3) following the last tillage operations with a tandem disk and rotary hoe used in the study. A total of 240 clods were selected at random after the initial tillage and fractured with a one-half inch cantilever beam while field moist and air dry.

Contingent on the significance of the variance ratio F, linear or curvilinear regression procedures were used to derive relationships to express the clod variables of percent greater than 38 mm., percent greater than .84 mm., percent less than .42 mm., and mechanical stability as a function of moisture content for the three tillage implements. The variance ratio was highly significant for both moisture and tillage implement on all the clod separates and mechanical stability following the initial tillage. After a period of weathering in which 12.73 inches of rainfall occurred, there was no significant difference for moisture on any of the clod variables or mechanical stability. However, the variance ratio was still highly significant for tillage implement. After further tillage operations there was no significant difference for moisture or tillage.

The plow formed a larger percentage of big clods and less fine material than either the one-way or sweep. Not only was this true after the initial tillage, but also remained true following the period of weathering. The same was true for mechanical stability. The one-way and sweep reversed relative positions after the period of weathering. The one-way had been adjacent to the plow following the initial tillage, but was replaced by the sweep after weathering.

A wet sieve analysis showed that the percent of soil particles less than .02 mm. in diameter was significantly lower for the plow than the other two implements. Moisture was significant at the 5 percent level. The soil tilled at the highest level (25.2 percent) contained more water stable particles less than .02 mm. Percentage of aggregates greater than .84 mm. was not significant for moisture but was highly significant for tillage implement. Average percentages were 18.7, 10.4, and 7.5 for the plow, one-way, and sweep, respectively.

Crushing strength was approximately three to four times greater for clods formed at low moisture content than those formed at higher levels. The crushing strength of air-dry clods was not consistant. For example, the soil tilled at the three higher levels showed a decisive increase in clod strength with drying, while the soil tilled at the two lower moisture contents showed a general decrease in resistance to crushing.

From this study it appears that the clods at any time on a particular soil are associated with the moisture content at time of tillage and tillage implement used in the last tillage operation.