Influence of One-Way-Disk and Subsurface-Sweep Tillage on Factors Affecting Wind Erosion

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MAJOR factors influencing wind erodibility of field surfaces have been previously delineated as soil cloddiness, surface roughness, and amount of crop residue (3).* Studies showed that tillage machinery exerts an exceedingly important influence on all these factors (4, 6, 7).

The one-way disk is widely used in preparing land for wheat. Many fields, particularly in areas where summer fallowing is practiced, receive both initial and subsequent weed-control tillage with the one-way disk. While this tillage implement has been and is universally used in dry-land areas, little information is available on the effects of different adjustments and methods of operation of the machine. It is generally believed that improper methods of operation tend to pulverize clods, bury residues, and reduce surface roughness, thus leaving the soil susceptible to wind erosion. Information is needed on the effects of different speeds, depths, and angle adjustments of the one-way disk to either substantiate or invalidate these opinions.

The subsurface sweep has been used for many years as a tillage tool in some dry-land farming areas but has only recently received widespread acceptance. This implement is generally believed to be an excellent tool for leaving residues on the surface, thereby reducing erosion and perhaps loss of soil moisture through evaporation. However, it has been considered a tool which leaves the surface in an erodible condition if crop residues are lacking. There is need for more definite information on these points and for a comparison of the sweep and the one-way-disk methods when operated under comparable conditions.

This paper presents the results of a study designed to obtain information on the effects of operational variables on one-way disk tillage and on the comparative performance of subsurface sweep and one-way tillage.

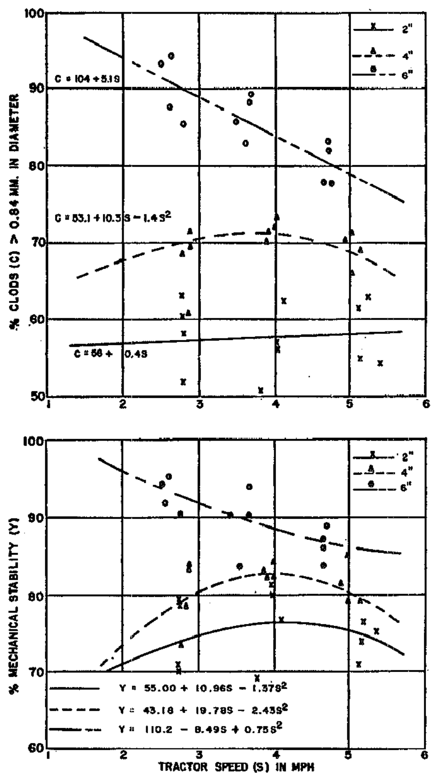

FIG. 1 Clod-speed and stability-speed relationships for 2, 4, and 6-in. depths of tillage after the first one-way operation.

Procedures and Equipment

Summer fallow procedure in which the one-way disk or subsurface sweep was used for both an initial and two subsequent cultivation operations was followed in this study.

The land had not been tilled since harvesting the previous year's wheat crop and was covered with about a ton of standing wheat stubble. Fifteen one-way tillage plots, each 40 by 150 ft, were laid out in the corner of a 320-acre field. The remainder of the field was tilled with a subsurface sweep. Measurements of the effect of this tillage were made at a location about 300 ft from the one-way plots. Table 1 shows the type of tillage, dates when operations were performed, and soil moisture at time of tillage.

A standard 5-ft one-way disk pulled by a large tractor was used in the one-way experiments to obtain sufficient power for tillage at fast speeds and deep depths. Two 7-ft V-type sweeps pulled in a gang arrangement were used in the subsurface sweep operation.

One-way tillage on single plots was accomplished at depths of 2, 4, and 6 in. and average speeds of 2.5, 3.6, and 4.6 mph at a one-way angle of 50 deg, and at one-way angles of 43, 50, and 53 deg at speeds of 2.5, 3.6 and 4.6 mph at a depth of 4 in. Subsurface sweep tillage was accomplished at an approximate speed of 3.5 mph and a depth of 4 in.

Effects of the tillage operations and of freezing and thawing during winter were measured in terms of clod structure and mechanical stability, amounts of residue and weed growth, surface roughness, and erodibility. Clod structure and mechanical stability were measured with a rotary sieve used regularly in this work. Residue amounts were determined by weighing oven-dried samples obtained from three 1-square meter areas from each plot. Surface roughness and erodibility were estimated from residue-cloddiness-roughness-erodibility equations derived from previous studies (3). Clod, residue, and moisture samples were taken before tillage began, after each one-way or sweep-tillage operation, after seeding, and finally after the winter season. Estimates of roughness and computation of erodibility were made only at the time of the final sampling.

One-Way Tillage Effects on Clod Structure and Stability

Single tillage operations.—The percentage of cloddy material greater than 0.84 mm in diameter and clod stability as measured after the first one-way operation is shown in Figs. 1 and 2. Data from plots tilled with a constant one-way angle of 50 deg, depths of 2, 4, and 6 in., and at varying speeds are plotted in Fig. 1. Data from plots tilled at a constant depth of 4 in., one-way angles of 43, 50, and 53 deg, and at varying speeds are plotted in Fig. 2. Curves were fitted to the data with non-linear correlation procedures (5). Since the data are averages of four clod samples from single plots and have considerable scatter, no particular significance is attached to the relationships indicated on the

TABLE 1.—DESCRIPTION OF TILLAGE OPERATIONS, DATE OF TILLAGE, AND SOIL MOISTURE CONDITIONS

Type of tillage operation performed	Date	Percent water in soil at depth of		
		0-4 in	4-12 in	12-24 in
First one-way or sweep	5-8-56	12.1	23.2	22.9
Second one-way or sweep	6-25-56	18.6	22.7	21.8
Third one-way or sweep	8-6-56	15.4	21.4	21.1
Tandem disk and drill	10-1-56	4.3	18.3	20.9

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*Numbers in parentheses refer to the appended references.

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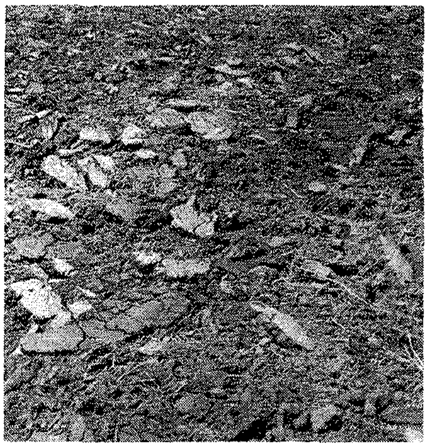
2-in. depth



6-in. depth

FIG. 2 View of surface cloddiness after the first one-way operation at 2 and 6-in. depths of tillage.

figures. The procedure was used merely to establish the best fit to the data at hand.

Fig. 1 shows that increasing speed when tillage was accomplished at the 6-in. depth resulted in reduced clod stability and amounts of material greater than 0.84 mm in diameter. At the 2 and 4-in. depths speed had little effect. Deep tillage also is shown to leave more cloddy material of greater stability on the surface than does shallow tillage. Fig. 2 shows this contrasting effect on plots tilled 2 and 6 in. deep.

Fig. 3 shows that after the first one-way operation clod stability and the percentage of cloddy material greater than 0.84 mm in diameter were generally greater on plots tilled with either a 50 or 53-deg angle than on those tilled with a 43-deg angle. Speed had only a slight and variable effect on cloddy material and clod stability. Some indication of more cloddiness of higher stability was noted with tillage at slow or fast speed than with intermediate speeds when using a 43 or 53-deg angle. The reverse was true for tillage with a 50-deg angle.

Effects of different depths, speeds, and angles of one-way tillage on cloddiness and stability were not easily distinguished after the second and third operations. There was some slight indication of greater soil cloddiness and stability with tillage at deep depths, small angles, and slow speeds, but no consistent relationship could be established for these individual operations.

Repeated tillage operations. — Speed-depth and speed-angle effects of repeated one-way operations, elapsed time, and the weathering action of the winter months on clod stability and clod sizes greater than 0.84 and greater than 19.2 mm in diameter are shown in Figs. 4 and 5.

Fig. 4 shows results obtained from plots tilled at three depths and speeds but with a constant one-way angle of 50 deg. Speed of tillage had a variable effect on surface cloddiness. There was some indication, however, of more clods remaining on the field at the end of winter when tillage had been accomplished at the slowest speed. Effects of depth of tillage as reflected at the time of the fifth sampling indicated a slightly higher precentage of material greater than 0.84 mm in diameter remaining on those plots tilled at the 6-in. depth. Percentage of greater than 19.2 mm material was about the same for all depths at the end of the winter months.

Previous studies of seasonal fluctuations in soil structure (1) have shown a natural buildup of soil cloddiness during the summer. This buildup is of course superimposed on tillage effects presented in this study. However, since it would have an essentially equal effect on all of the tillage plots, its presence does not preclude making relative comparisons of the effect of one treatment to another. In this respect the overall trend of soil cloddiness in relation to time and number of tillage operations was interesting. Peaks in cloddiness were reached at different dates or after different numbers of operations. Maximum cloddiness occurred after three operations with 2-in. tillage, after two operations with 4-in. tillage, and after the first operation with 6-in. tillage. Clod stability generally followed this trend; however, it did not

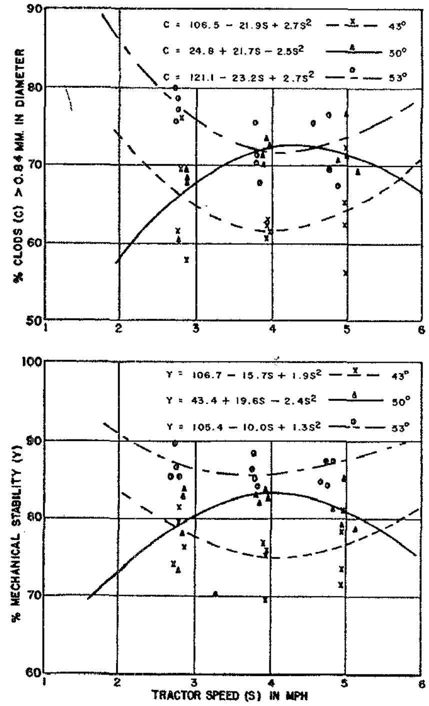


FIG. 3 Clod-speed and stability-speed relationships for 43, 50, and 53-deg angle tillage after the first one-way operation.

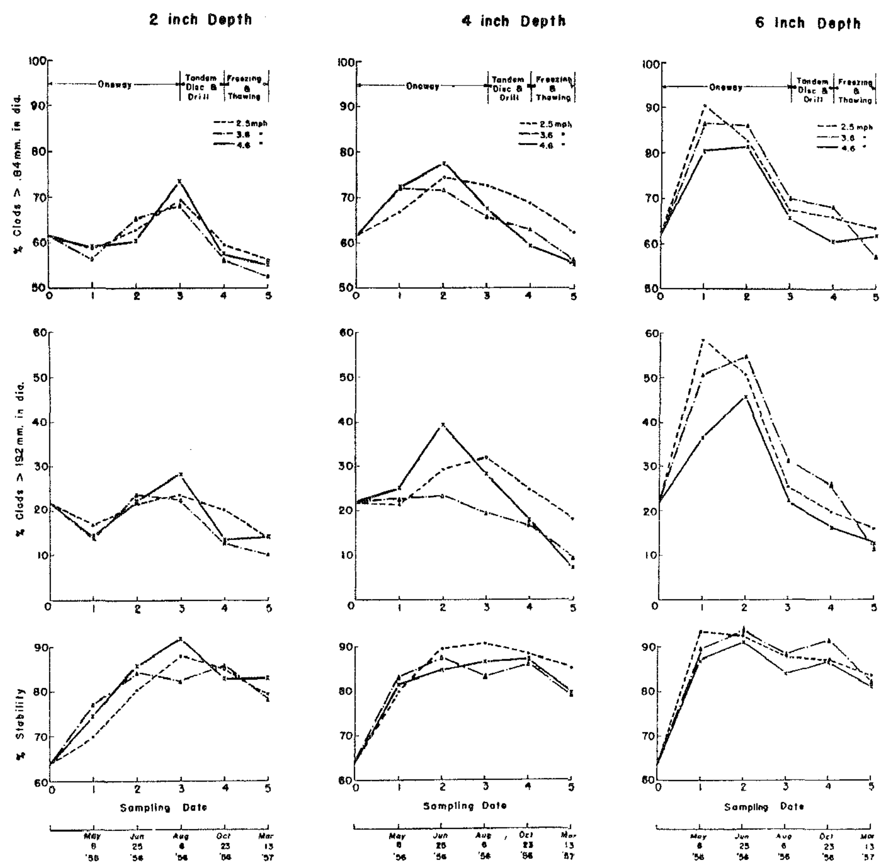


FIG. 4 Effects of one-way operations, elapsed time, and weathering action during winter on cloddy material greater than 0.84 mm and greater than 19.2 mm in diameter, and on clod stability for one-way tillage at 2, 4, and 6-in. depths with a constant 50-deg angle.

decrease much until after the field had passed through the winter period.

Fig. 5 shows results obtained with tillage at three different angles and speeds but at a constant depth of 4 in. Here again speed of tillage was variable in effect with some slight indication of more claddiness with tillage at the slowest speed throughout most of the period. Average results after five samplings showed the amount of cloddiness on 43 and 50-deg angle tillage to be about equal and slightly higher than the cloddiness on the 53-deg angle tillage. Peaks in soil cloddiness were reached after the second operation for 43 and 50-deg angle tillage and after the first operation for 53-deg angle tillage. Clod stability reached its maximum value after either the second or third operation on all angles, was slightly higher on 53-deg angle tillage after the first operation, and did not show a sharp reduction until after the field passed through the winter months.

One-Way Tillage Effects on Plant Residue

Single tillage operations.—Average percentages of wheat straw and stubble remaining on the surface after the first one-way operation were as follows:

TABLE 2.—EFFECTS OF DEPTH OF TILLAGE (50-DEG ANGLE) ON AMOUNT OF RESIDUE LEFT ON SURFACE

Depth, inches	Average speed, mph	Straw and stubble on surface, percent of total
2	2.5	37
2	3.6 or 4.6	26
4	2.5	29
4	3.6 or 4.6	14
6	2.5	12
6	3.6 or 4.6	12

TABLE 3.—EFFECTS OF ANGLE OF ONE-WAY (4-IN. DEPTH) ON AMOUNT OF RESIDUE LEFT ON SURFACE

Angle degrees	Average speed, mph	Straw and stubble on surface, percent of total
43	2.5 or 3.6	51
43	4.6	37
50	2.5	29
50	3.6 or 4.6	14
53	2.5	15
53	3.6 or 4.6	25

Speed of tillage had an extremely variable effect on residue placement. In general, however, there was little difference between the effect of intermediate and fast speeds when considering speed-depth effects (Table 2). Slow speeds generally maintained slightly more straw on the surface after the first operation than faster speeds. In speed-angle considerations, (Table 3) slow and intermediate speeds had nearly equal effects for 43-deg angle tillage, while intermediate and fast speeds are comparable for 50- and 53-deg angle tillage. Percentage of stubble was generally reduced with increased depths and angles of tillage. Maximum straw residue maintained on the surface was 51 per cent with 43-deg angle slow or intermediate speed tillage. Minimum amounts of about 12 percent were left with 6-in. tillage.

Effects of different one-way operational variables on residue placement during the second and third cultivation operations were somewhat confounded due to weed growth and inconsistencies in speed effects. Analysis showed, however, that if speed were ignored, the first, second, and third tillage residue burial data could be grouped

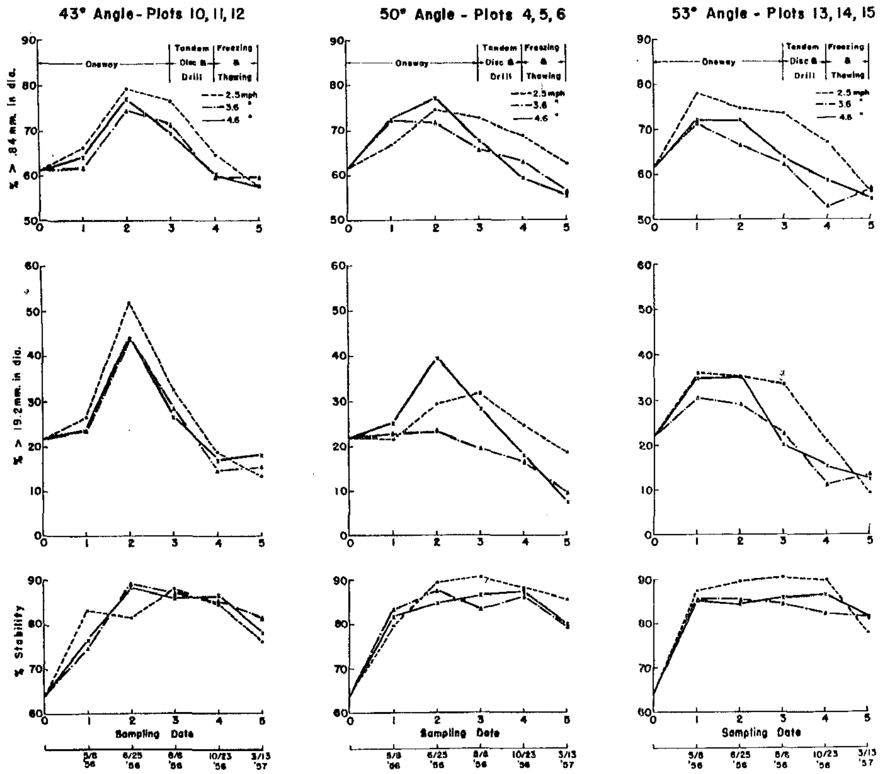


FIG. 5 Effects of one-way operations, elapsed time, and weathering action during winter on cloddy material greater than 0.84 mm and greater than 19.2 mm in diameter, and on clod stability for one-way tillage at 43, 50, and 53-deg angles with a constant depth of 4.0 in.

by depths and angles of tillage and could be used to derive relationships expressing residue burial as a function of total residue (weeds plus straw and stubble) on the surface at the initiation of tillage. Fig. 6 indicates the amount of residue burial increased with increased depth of tillage when large amounts of residue were initially present. However, with reduced residue, depth of tillage had less effect on the amount of burial. For example, with 2000 lb per acre of residue approximately 88, 80, and 69 percent was buried by tillage at 6, 4, and 2-in. depths, respectively, compared to 60, 74, and 68 percent for the same depths when 500 lb per acre were available initially.

Tillage at 50 and 53-deg angles was comparable in effect and buried about 79 percent of the residue when 2000 lb per acre was available initially. Forty-three-degree angle tillage under the same initial conditions buried about 57 percent. When initial amounts of residue were 500 lb per acre, 80, 80, and 60 percent was buried for 50, 53, and 43-deg angle tillage, respectively.

Repeated tillage operations.—Effects of repeated one-way operations on wheat straw and stubble residues are summarized in Table 4. Since speed had a variable effect on residue placement, amounts shown are averages for the three speeds used with each depth and angle of tillage. Stubble

TABLE 4.—EFFECTS OF REPEATED TILLAGE ON WHEAT RESIDUE

Number of one-way operations	Wheat residue on surface before or after tillage at: Depths (50-deg angle) 2 in	4 in	6 in	Angles (4.0-inch depth) 43 deg	50 deg	53 deg
	lb per acre	lb per acre	lb per acre	lb per acre	lb per acre	lb per acre
0	2000	2000	2000	2000	2000	2000
1	590	375	226	907	375	433
2	268	65	132	472	65	175
3	27	4	24	58	4	15

TABLE 5.—EFFECTS OF ONE-WAY TILLAGE ON WEED GROWTH

One-way tillage: Depth	Angle	Amount and species of weeds growing: Before second operation: Amount	Predominate species	Before third operation: Amount	Predominate species
Inches	Degrees	lb per acre		lb per acre	
2	50	610	Russian thistle*	407	Russian thistle
4	50	158	Russian thistle	372	Pigweed
6	50	57	Pigweed†	393	Pigweed
4	43	572	Russian thistle	638	Russian thistle
4	50	158	Russian thistle	372	Pigweed
4	53	87	Pigweed	527	Pigweed

*Salsola pestifer.
†Amaranthus graecizans L.

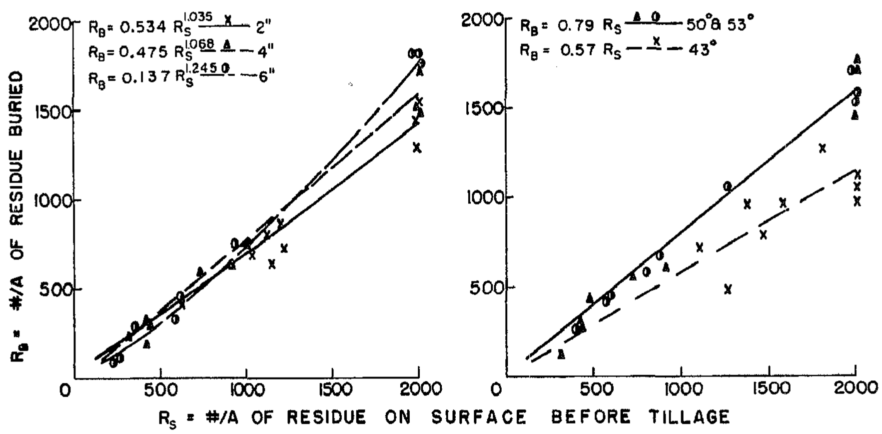


FIG. 6 Residue burial in relation to total amounts of residue available at the start of a tillage operation. Points are averages of three replications for each of three dates of one-way operations.

residues disappeared rapidly with repeated one-way operations. After three operations only negligible amounts of straw remained on the plots. On those plots tilled at a 4-in. depth and 50-deg angle, only traces of straw remained after two operations.

Table 5 shows the effect of different depths and angles of one-way tillage on the amount and species of weed growth occurring before the second and third cultivation operations. Amounts shown are averages for the three speeds used with each depth and angle.

Weed growth varied with different methods of operating the one-way disk. It was greater before the third operation than before the second operation with the exception of 2-in. depth tillage. Heaviest growth of Russian thistle was on 2-in. depth and 43-deg angle tillage before both the second and third operation. Heaviest pigweed growth was on 4 and 6-in. depth and 53-deg angle tillage after the third operation. The 57 and 87 lb per acre of weeds growing on 6-in. depth and 53-deg angle tillage plots, respectively, before the second operation indicates that weed growth was markedly delayed in starting on these plots. Third tillage data shows, however, that both species were growing in substantial quantities by the time this operation was carried out.

Shallow depth or small angle tillage promoted growth of Russian thistle (Salsola pestifer), while deep or wide angle tillage produced a more favorable condition for growth of pigweed (Amaranthus graecizans L.). These results agree with known behavior of seeds of these species of weeds (2). Those of Russian thistle have short periods of induced and natural dormancy and, if buried deeper than 3 in., fail to emerge and soon rot away. The lack of Russian thistle growth on deeper tillage and more effective angle for soil inversion indicates that the seeds were buried below 3 in. and little or no growth resulted. The seeds of pigweed, on the other hand, have a period of induced dormancy that lasts many years. If buried below 3 in., many of them remain dormant until they are brought on or near the surface, where they will germinate. These results show that deep one-way disking brought to the surface viable seeds buried by previous tillage. Peak germination for pigweed occurred in midsummer and for Russian thistle in the early spring, again agreeing with results of previous work (2).

This study further indicated that total amounts of residue, i.e., weeds and stubble, at the end of the winter after land has been summer-fallowed and planted to wheat were negligible and about equal, irrespective of the one-way treatment (Table 6). However, the rate at which the residues depreciate varied with the tillage treatment. For example, there was more total residue at the end of three operations on 2-in. depth or 43-deg angle tillage plots than on plots tilled at 6-in. depth or a 53-deg angle. These two treatments destroyed less wheat stubble and permitted more weeds to grow, thus leaving a larger accumulative total of residue. It is difficult to assess the real advantages and disadvantages of weed growth. However, since there was no evidence of less moisture on plots having the greatest amount of weed growth, it would seem that during a dry year it might be advantageous to delay cultivation until weeds are of sufficient size to provide substantial amounts of residue. The reduced wind erosion hazard resulting from the trash weeds might be of more importance than the loss of soil moisture resulting from their growth.

The data in Table 6 also stresses the importance of good vigorous stands of wheat in the early spring months. It is clear that very little protection from wind erosion can be expected from small remains of a previous wheat crop or weeds.

One-Way Tillage Effects on Surface Roughness and Erodibility

Equivalent surface roughness and erodibility index values for the 15 one-way plots based on conditions on March 13, 1957, are given in Table 7.

Lowest surface roughness values were obtained on plots tilled at fast speeds to a 2 or 4-in depth or with the one-way set at a 53-deg angle. Highest roughness values occurred on those plots tilled with a 43-deg one-way angle. This was due both to more weed residue on the surface and to the ridged undulating surface obtained because of the fact that a one-way disk set at a small angle did not "throw" enough soil to completely fill the open furrow left by the previous round of tillage.

The general trend of the erodibility index arranged in order of highest to lowest value was 4-in. tillage at intermediate and fast speeds; 53-deg angle tillage at all speeds; 2-in. tillage at intermediate and fast speeds; 6-in. tillage at intermediate and fast speeds; and 43-deg angle tillage at all speeds. Erodibility was highest on the 4-in. depth tillage because of little residue and lower amounts of cloddy material on the surface. Erodibility was lowest on 43-deg angle tilled plots because of greater roughness and larger amounts of residue present on the surface.

TABLE 6.—EFFECTS OF REPEATED TILLAGE AND NATURAL WEATHERING ON TOTAL PLANT RESIDUES

Type of tillage or natural disturbance	Date of sampling	Total plant residues on surface before or after tillage at:					
		Depths (50-deg angle)			Angles (4.0-inch depth)		
		2 in	4 in	6 in	43 deg	50 deg	53 deg
		lb per acre	lb per acre	lb per acre	lb per acre	lb per acre	lb per acre
Before first tillage	5-8-56	2000	2000	2000	2000	2000	2000
First one-way	5-8-56	590	375	226	907	375	433
Second one-way	6-25-56	531	176	139	775	176	213
Third one-way	8-6-56	300	154	203	359	154	195
Tandem disk and drill	10-23-56	117	59	82	139	59	76
Natural weathering	3-13-57	69	35	47	82	35	45

TABLE 7.—ROUGHNESS AND ERODIBILITY OF ONE-WAY PLOTS AT TIME OF FIFTH SAMPLING ON MARCH 13, 1957

Plot number	Average tillage speed	Tillage depth	Tillage angle	Roughness equivalent	Erodibility
	Mph	Inches	Degrees	Inches	Tons per acre
1	2.5	2.0	50	2.3	0.75
2	3.6	2.0	50	2.3	1.10
3	4.6	2.0	50	2.1	1.40
4	2.5	4.0	50	2.4	0.55
5	3.6	4.0	50	2.0	2.60
6	4.6	4.0	50	1.9	3.10
7	2.5	6.0	50	2.8	0.50
8	3.6	6.0	50	3.0	1.00
9	4.6	6.0	50	2.8	0.78
10	2.5	4.0	43	3.3	0.75
11	3.6	4.0	43	3.0	0.50
12	4.6	4.0	43	3.4	0.38
13	2.5	4.0	53	2.0	1.20
14	3.6	4.0	53	1.8	1.90
15	4.6	4.0	53	1.6	1.60

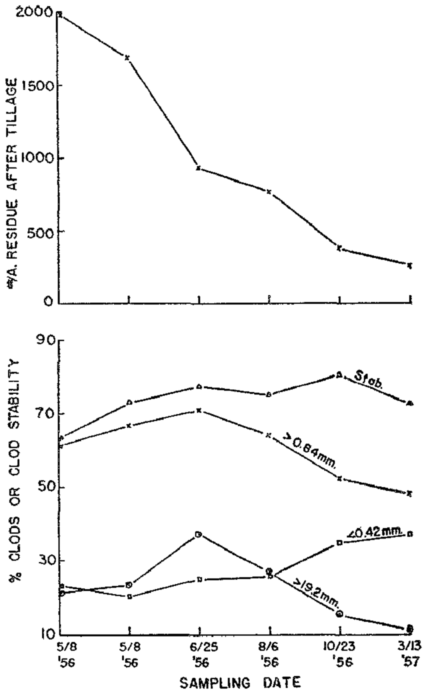


FIG. 7 Effects of subsurface-sweep operations, elapsed time, and weathering action on clod structure and residues—first 5/8 entry before tillage.

Subsurface Sweep Tillage

Effects of repeated subsurface sweep operations and elapsed time on clod structure and residues are shown in Fig. 7.

Clod Structure.—Since the seasonal factor mentioned under the section on repeated one-way tillage also applies to these results they are discussed only in terms of comparisons between one-way and sweep tillage. Maximum percentages of clods greater than 19.2 mm in diameter were obtained with the subsurface sweep after the second operation. In this respect the curve is similar to the one obtained with the one-way disk set at a 50-deg angle and a 4-in. depth. The 11 percent of clods this size remaining on the surface at the end of the sampling period was about the same as obtained with the 50 and 53-deg angle tillage but about 5 percent less than that obtained with the 43-deg angle one-way tillage.

Maximum percentages of material greater than 0.84 mm in diameter were also obtained after the second tillage. This maximum approximated the results obtained with 4-in. depth 50-deg angle tillage, which had the least of the one-way operations. End results show about 48 percent of clods greater than 0.84 mm in diameter or about 5 percent less than the lowest value obtained with the one-way tillage.

Maximum clod stability, about 80 percent, was obtained after the fourth operation. This value was approximately 10 percent less than those for the one-way operation. Clod stability was also generally lower on the subsurface plots throughout the entire tillage and sampling period. The end value of 72 percent stable clods was 8 to 10 percent less than any of the one-way plots.

Fig. 7 shows a steady increase in the highly erodible soil fractions less than 0.42 mm in diameter with each successive sweep operation. Maximum percentage of material this size was obtained at end of sampling period. This is 3 to 15 percent higher than results of the one-way plots.

Residues.—Sweep tillage left far more residue on the surface than did the one-way method. Eighty-five percent of the residue remained on the surface after the first operation compared to about 50 percent for the best one-way operation. End results at time of fifth sampling show 260 lb per acre on the subsurface-sweep tillage. This was 178 lb per acre more than on the best one-way operation (43-deg angle —Table 6) and 225 lb per acre more than on the poorest one-way tillage (50-deg angle—Table 6). Fig. 8 shows residue conditions after the first and third operations.

Surface Roughness and Erodibility.—Surface roughness on the sweep tillage was 3.1 in. and was exceeded only by the 43-deg angle slow and fast speed one-way tillage, which was 3.3 and 3.4 in., respectively. Computed erodibility was 0.40 tons per acre or the second lowest value obtained (Table 7). Low erodibility and higher surface roughness resulted from the greater amounts of residue even though approximately 5 percent more erodible fractions were obtained with the sweep than with the one-way disk.

Conclusions

This study demonstrates that tillage tools and the adjustment and methods of operating them affect soil cloddiness, surface roughness, and residue placement, thereby influencing wind erodibility of field soils.

Keeping in mind that this study presents the results of rather detailed measurements of only one summer-fallow procedure carried out during drought conditions, the following general conclusions may be drawn:

1. A greater percentage of non-erodible clods of higher stability will be produced and maintained through the winter by deep (6-in.) one-way tillage than by shallow (2 or 4-in.) one-way or by subsurface-sweep tillage. There will be slightly more of these clods for a given depth if the one-way tillage is accomplished at a slow speed (2.5 mph) and a small angle (43 deg) than if fast speeds (3.5 to 4.5 mph) and large angles (50 and 53 deg) are used. Sweep tillage will leave less non-erodible clods of lower stability at the end of the winter than will the poorest one-way operation.

2. Far more total residue, in fact from three to seven times more, will remain on the soil surface at the end of winter after a summer fallow operation with the subsurface sweep than after a one-way operation. A maximum of about 50 percent of the total residue will remain on the surface with shallow depth (2-in.) or small angle (43 deg) one-way tillage after the first operation as compared to about 85 percent after the first sweep operation. Shallow depth and small angle one-way tillage accomplished at slow speeds will generally leave more residue than deep depths and wide angles. Best weed control will be accomplished with wide angle (50 deg or 53 deg) or deep (6-in.) one-way tillage. Shallow or small angle one-way tillage will promote growth of Russian thistle while deep and wide angles will promote pigweed growth.

3. Greatest surface roughness and lowest erodibility will be obtained with small angle (43 deg) or deep depth (6-in.) one-way tillage and with the subsurface sweep.

After first sweep operation

After third sweep operation

FIG.8 Views of subsurface sweep tilled area after first and third operations.

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