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Dry Soil Aggregation as Influenced by Crop and Tillage[1]

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ABSTRACT

Soil loss by wind erosion is greater in the spring due to higher wind velocities, loss of protective crop residues by tillage and decomposition, and overwinter changes in nonerodible soil aggregates. This study was conducted to determine the effect of crop species and tillage on soil aggregation. Plots of continuous winter wheat (*Triticum aestivum* L.), grain sorghum (*Sorghum bicolor* L. Moench), and soybean (*Glycine max* L. Merr.) with tillage treatments of mechanical, chemical, and combination of mechanical and chemical weed control were sampled for aggregate distribution, stability, and overwinter breakdown.

Winter wheat plots contained more nonerodible aggregates (> 0.84 mm), and the aggregates were more stable and more resistant to overwinter breakdown than were aggregates from sorghum or soybean plots. Soybean plots were lowest in all three variables measured. Tillage-treatment effects varied, with the chemical-treated plots containing the most nonerodible aggregates and the mechanical-treated plots having the most stable aggregates.

***Additional Index Words:* nonerodible aggregates, aggregate stability, overwinter breakdown, winter wheat, grain sorghum, soybeans.**

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Large soil aggregates, commonly called clods, have been established as a major factor for controlling wind erosion of cultivated soils; in fact, Chepil found dry aggregates > 0.84 mm in diameter to be generally nonerodible by wind (4, 5), and the percent of those particles in the soil is inversely related to the amount of wind erosion (4). Over winter, clods tend to break down to a size erodible by wind, and that breakdown is accompanied by reaggregation of the fine soil particles to make the surface more erodible in the spring than in the fall (6). Percentage of water-stable aggregates will decrease over winter due to alternate freezing and thawing (17, 20). Breakdown of soil aggregates due to freezing will increase with increasing water content (9, 11, 18).

Alternate freezing and thawing can increase aggregation if soil texture and moisture conditions are right (2, 3). In one study, snow cover decreased the percentage of aggregates < 1.0 mm in a medium-textured soil (1). Bare soil became highly erosive because of the destructive effect of freeze drying.

Differences in the amount of soil clods > 0.84 mm in diameter produced by various tillage implements are measurable in the fall (16, 19) but disappear over winter (2).

The type of crop grown influences aggregate size and soil erodibility. Percentage of aggregates > 0.84 mm in diameter was higher for a wheat–fallow rotation than for one that included grass–alfalfa, alfalfa alone, or sweet clover (16). In a corn–soybean rotation, soil losses by water erosion were greater after soybeans than after corn (10, 14, 15).

The objective of the study reported here was to determine the effect of crop type and tillage on the number, size distribution, and stability of soil aggregates.

MATERIALS AND METHODS

Plots of continuous grain sorghum [*Sorghum bicolor* L. Moench var. Pioneer 826], soybean [*Glycine max* L. Merr. var. Williams], and winter wheat (*Triticum aestivum* L. var. Newton) were established in 1975 on Muir silt loam (fine-silty, mixed, mesic, Cumulic Haplustolls). Plots were 6 by 18.3 m with a randomized block design replicated four times.

Tillage treatments were: (i) mechanical—tillage for weed control until planting, with chemical weed control after planting; (ii) chemical—weed control totally with chemicals; and (iii) combination—mechanical and chemical weed control before planting, with chemical weed control after planting. Details of tillage sequences and chemicals used are given in Table 1. Nitrogen and phosphorus were applied to all crops at the rate of 67 and 56 kg/ha, respectively.

Surface soil samples were taken in the fall after the last tillage and in the spring prior to first tillage. A single composite sample weighing approximately 6.5 kg was obtained by combining six partially filled flat-bottomed shovels of surface soil from the 0- to 3-cm depth taken at random over the area of each plot at each sampling date. Size distributions and mechanical stability of soil aggregates were determined by dry rotary sieving procedures developed by Chepil (8) using the modified rotary sieve (12). Aggregate stability was determined by resieving aggregates > 0.84 mm four times. Large pieces of crop residue were removed before sieving where possible without disturbing the sample. Fall 1977 samples were not obtained because of high soil water content and an early freeze.

RESULTS AND DISCUSSION

Continuous winter wheat plots contained more soil aggregates > 0.84 mm in diameter in both fall and spring than did grain sorghum and soybean plots (Table 2), and the aggregates were more stable (Table 3). Soybean plots had significantly fewer soil aggregates > 0.84 mm in diameter than did winter wheat plots at each sampling date, and they were significantly less stable. Grain sorghum plots had intermediate aggregate stability and amounts of nonerodible aggregates.

Tillage methods from harvest to the fall aggregate sampling were different (Table 1), but crop effects overshadowed those differences. Grain sorghum plots and soybean plots were listed, but grain sorghum plots contained significantly more soil aggregates > 0.84 mm in diameter than the soybean plots and as many soil aggregates of this size as the chiseled, tandem-disked, and planted winter wheat plots.

Soil loss by wind erosion varies inversely with the percentage of soil aggregates > 0.84 mm in diameter (4). Based on the surface soil aggregates found in this

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Table 1—Sequence and timing of tillage operations and chemicals used for each crop and tillage treatment.

Tillage treatment	Date			Crop: Grain sorghum	Soybean	Winter wheat
Mechanical	11/18/75	11/19/76	10/30/78	Fall aggregate sample	Fall aggregate sample	Fall aggregate sample
		4/15–4/30†		Tandem disk	Tandem disk	
	5/ 2/76	5/10/77	4/26/78	Spring aggregate sample	Spring aggregate sample	Spring aggregate sample
		5/1 –5/31		Field cultivator (twice)	Field cultivator (twice)	
		5/7 –5/21				2,4-D‡
		5/16–5/31		Plant	Plant	
				Propachlor + Atrazine‡	Alachlor + Metribuzin‡	
		6/28–7/4				Harvest
		7/4 –7/18				Chisel
		8/1 –8/31				Tandem disk (twice)
		9/1 –9/30				Field cultivator (twice)
		10/1 –10/17		Harvest	Harvest	Plant
				Shred stalks		
		10/15–10/31		Blank listing	Blank listing	
Chemical	11/18/75	11/19/76	10/30/78	Fall aggregate sample	Fall aggregate sample	Fall aggregate sample
		4/25–5/10		Glyphosate‡	Glyphosate	
	5/ 2/76	5/10/77	4/26/78	Spring aggregate sample	Spring aggregate sample	Spring aggregate sample
		5/ 7–5/21				2,4-D
		5/16–5/31		Plant	Plant	
				Propachlor + Atrazine	Alachlor + Metribuzin	
		9/10–9/27				Glyphosate
		10/1 –10/17		Harvest	Harvest	Plant
Combination	11/18/75	11/19/76	10/30/78	Fall aggregate sample	Fall aggregate sample	Fall aggregate sample
		4/15–4/30		Tandem disk	Tandem disk	
	5/ 2/76	5/10/77	4/26/78	Spring aggregate sample	Spring aggregate sample	Spring aggregate sample
		4/25–5/10		Glyphosate	Glyphosate	
		5/ 7–5/21				2,4-D
		5/16–5/31		Plant	Plant	
				Propachlor + Atrazine	Alachlor + Metribuzin	
		6/28–7/4				Harvest
		7/ 4–7/18				Chisel
		9/10–9/27				Glyphosate
		10/ 1–10/17		Harvest	Harvest	Plant
				Shred stalks		
		10/15–10/31		Blank listing	Blank listing	

† Range of dates of tillage operations.
‡ Propachlor—3.4 kg/ha of 2-chlor-*N*-isopropylacetanilide.
Atrazine—1.1 kg/ha of 2-chloro-4-(ethylamino)-6-(isopropylamino)-*s*-triazine.
Alachlor—2.2 kg/ha of 2-chloro-2′,6′-diethyl-*N*-(methoxymethyl) acetanilide.
Metribuzin—0.6 kg/ha of 4-amino-6-*tert*-butyl-3-(methylthio)-*as*-triazin-5(4*H*)-one.
2,4-D—0.6 kg A.I./ha of (2,4-dichlorophenoxy) acetic acid.
Glyphosate—1.1 kg/ha of *N*-(phosphonomethyl) glycine.
Chemical names are provided for information only and do not constitute an endorsement by the USDA.

Table 2—Effect of crop type on percentage of aggregates >0.84 mm in diameter.

Crop	Sample date: Fall 1975	Spring 1976	Fall 1976	Spring 1977	Fall 1978	Spring 1979	Average: Fall	Spring
				%				
Wheat	78.8 a*	84.2 a	71.1 a	65.8 a	84.5 a	82.9 a	78.1 a	77.6 a
Sorghum	74.4 b	67.7 b	72.2 a	61.2 b	83.5 a	72.4 b	76.7 a	70.8 b
Soybean	66.3 c	64.2 c	62.1 b	52.6 c	77.8 b	57.2 c	68.7 b	58.0 c

* Means in a column followed by the same letter are not significantly different at the 0.05 level by Duncan's New Multiple Range Test (DNMRT).

Table 3—Effect of crop type on the mechanical stability of aggregates >0.84 mm in diameter.

Crop	Sample date: Fall 1975	Spring 1976	Fall 1976	Spring 1977	Fall 1978	Spring 1979	Average: Fall	Spring
				%				
Wheat	92.4 a*	91.2 a	92.2 a	87.6 a	95.1 a	90.2 a	93.2 a	89.7 a
Sorghum	90.5 b	88.6 b	91.8 a	84.3 b	94.7 ab	90.2 a	92.3 b	87.7 b
Soybean	87.7 c	85.2 c	89.6 b	82.8 b	93.2 b	85.0 b	90.2 c	84.3 c

* Means in a column followed by the same letter are not significantly different at the 0.05 level by DNMRT.

study, soybean plots are potentially more erodible by wind than are wheat or sorghum plots. That agrees with observations of farmers and Soil Conservation Service personnel on the wind erodibility of corn and soybean fields.

The overwinter change in the amount of soil aggregates > 0.84 mm in diameter varied with the winter climate and crop (Table 4). In winter wheat plots, large soil aggregates increased over the winter of 1975–1976 and decreased over the next two winters

Table 4—Effect of crop type on the overwinter gain (+) or loss (−) in the percentage of soil aggregates >0.84 mm in diameter.

Crop	Winter of 1975–1976	1976–1977	1978–1979	Average
		%		
Wheat	+5.4 a*	−5.3 a	−1.6 a	−0.5
Sorghum	−6.7 b	−11.0 a	−11.1 b	−9.6
Soybean	−2.1 b	−9.5 a	−20.6 c	−10.7

* Means in a column followed by the same letter are not significantly different at the 0.05 level by DNMRT.

Table 5—Effect of crop type on the aggregate size distribution overwinter gain (+) or loss (−). Average of three winters.

Crop	Aggregate size range (mm) <0.42	0.42–0.84	0.84–2.0	2.0–6.4	6.4–19.0	19.0–44.5	>44.5
				%			
Wheat	−0.12	+0.65	−0.29	−3.65	−5.37	+1.74	+6.26
Sorghum	+4.71	+4.83	+1.78	−1.70	−3.02	−2.01	−4.59
Soybean	+6.47	+4.12	+0.93	−1.76	−3.28	−1.57	−4.25

sampled. The extremely harsh winter of 1978–1979 reduced soybean-plot nonerodible aggregates significantly more than those in sorghum or winter wheat plots.

The overwinter period of 1978–1979 was cold and snowy. Twenty-eight cm of snow fell the last week in December and 67.5 cm more fell in January. The ground was covered with snow for 57 days. Temperatures were 2 and 7.5°C below normal for January and February, respectively. March was wet with 10.9 cm of rainfall and averaged 1.4°C warmer than normal.

Aggregate-size distribution analysis indicated that in the wheat plots, aggregates 2 to 19 mm in diameter were consolidated into aggregates > 19 mm, whereas in sorghum and soybean plots, aggregates > 2 mm broke down into aggregates < 2 mm in diameter over winter (Table 5).

Crop differences could have been due to plant-growth characteristics and chemical composition. Legume residues, such as soybean, decompose more rapidly than do wide C/N ratio crops such as wheat and sorghum (13). Decomposing residues increase the number of nonerodible aggregates, whereas decomposed organic matter has the opposite effect (7). These effects are more pronounced with large loadings of residues. Soybeans do not produce as much aboveground residue as sorghum and wheat produce. The soybean taproot also supplies fewer roots for decomposition in the surface soil layers than wheat and sorghum fibrous root systems do.

The chemical-tillage treatment tended to produce the largest amount of soil aggregates > 0.84 mm in diameter in both the fall and spring (Table 6). However, they were less stable in the spring than the aggregates produced by mechanical tillage, except in the fall of 1975 (Table 7). The combination of mechanical and chemical tillage produced the lowest amount of aggregates > 0.84 mm in the fall, which is critical for soil protection overwinter.

Tillage effects on overwinter change in soil aggregates > 0.84 mm in diameter were varied (Table 8). The chemical-tillage treatment plots lost the most nonerodible aggregates the first two winters but the loss was significantly less than with either of the other treatments during the high snowfall winter of 1978–1979. The presence of standing crop residues probably maintained a snow cover on the soil, protecting the aggregates from breakdown due to freeze drying as reported by Anderson and Bisal (1).

CONCLUSIONS

Species of crop grown continuously influence the amount of soil aggregates > 0.84 mm in diameter, dry aggregate stability, and the resistance to overwinter breakdown. Averages over six sampling dates and three winters indicated that, for the three variables measured, the sequence was winter wheat > grain sorghum > soybeans.

Tillage results varied. The chemical treatment plots had most clods > 0.84 mm in diameter and the mechanical treatment plots had clods with the greatest mechanical stability. Clods of the chemical treatment plots were most resistant to overwinter breakdown when snowfall was high and temperatures low because

Table 6—Effect of tillage treatment on the percentage of aggregates >0.84 mm in diameter.

Tillage	Sample date: Fall 1975	Spring 1976	Fall 1976	Spring 1977	Fall 1978	Spring 1979	Average: Fall	Spring
				%				
Mechanical	71.7 b*	73.6 a	71.6 a	63.4 a	80.0 b	65.8 b	74.4 b	67.6 a
Chemical	76.8 a	69.6 a	73.7 a	60.3 a	82.4 a	79.4 a	77.6 a	69.8 a
Combination	71.2 b	72.9 a	60.1 b	55.8 a	83.4 a	67.3 b	71.6 c	65.3 b

* Means in a column followed by the same letter are not significantly different at the 0.05 level by DNMRT.

Table 7—Effect of tillage treatment on the mechanical stability of aggregates >0.84 mm in diameter.

Tillage	Sample date: Fall 1975	Spring 1976	Fall 1976	Spring 1977	Fall 1978	Spring 1979	Average: Fall	Spring
				%				
Mechanical	89.3 b*	90.6 a	93.2 a	89.2 a	94.7 a	88.8 a	92.4 a	89.5 a
Chemical	91.6 a	86.4 b	91.3 b	83.2 b	93.1 b	87.5 a	92.0 a	85.7 b
Combination	89.7 b	88.0 b	89.2 c	82.3 b	95.2 a	89.2 a	91.4 a	86.5 b

* Means in a column followed by the same letter are not significantly different at the 0.05 level by DNMRT.

Table 8—Effect of tillage treatment on the overwinter gain (+) or loss (−) in the percentage of soil aggregates >0.84 mm in diameter.

Tillage	Winter of 1975–1976	Winter of 1976–1977	Winter of 1978–1979	Average
	%			
Mechanical	+1.9 a*	−8.2 ab	−14.2 b	−6.8
Chemical	+7.2 b	−13.4 b	−3.0 a	−7.9
Combination	+1.7 a	−4.3 a	−16.1 b	−6.2

* Means in a column followed by the same letter are not significantly different at the 0.05 level by DNMRT.

the standing crop residues trapped snow, which protected the aggregates from freeze drying.

LITERATURE CITED

1. Anderson, C. H., and Frederick Bisal. 1969. Snow cover effect on the erodible soil fraction. Can. J. Soil Sci. 49:287–296.
2. Anderson, C. H., and A. Wenhardt. 1966. Soil erodibility, fall and spring. Can. J. Soil Sci. 46:255–259.
3. Bisal, Frederick, and K. F. Nielsen. 1967. Effect of frost action on the size of soil aggregates. Soil Sci. 104:268–272.
4. Chepil, W. S. 1942. Measurement of wind erosiveness by dry sieving procedure. Sci. Agric. 23:154–160.
5. Chepil, W. S. 1943. Relation of wind erosion to the water-stable and dry clod structure of soil. Soil Sci. 55:275–287.
6. Chepil, W. S. 1954. Seasonal fluctuations in soil structure and erodibility of soils by wind. Soil Sci. Soc. Am. Proc. 18:13–16.
7. Chepil, W. S. 1955. Factors that influence clod structure and erodibility of soil by wind: V. Organic matter at various stages of decomposition. Soil Sci. 80:413–421.
8. Chepil, W. S. 1962. A compact rotary sieve and the importance of dry sieving in physical soil analysis. Soil Sci. Soc. Am. Proc. 26:4–6.
9. Hinman, W. C., and Frederick Bisal. 1968. Alterations of soil structure upon freezing and thawing and subsequent drying. Can. J. Soil Sci. 48:193–197.
10. Laflen, J. M., and W. C. Moldenhauer. 1979. Soil and water losses from corn–soybean rotations. Soil Sci. Soc. Am. J. 43:1213–1215.
11. Logsdail, D. E., and L. R. Webber. 1959. Effect of frost action on structure of Haldimond clay. Can. J. Soil Sci. 39:103–106.
12. Lyles, Leon, J. D. Dickerson, and L. A. Disrud. 1970. Modified rotary sieve for improved accuracy. Soil Sci. 109:207–210.
13. McCalla, T. M., and F. L. Duley. 1943. Disintegration of crop residues as influenced by subtillage and plowing. J. Am. Soc. Agron. 35:306–315.
14. Moldenhauer, W. C., and W. H. Wischmeier. 1969. Soybeans in corn–soybean rotation permit erosion but put blame on corn. Crops Soils 21:20.
15. Oschwald, W. R., and J. C. Siemens. 1976. Soil erosion after soybeans. p. 74–81. *In* L. D. Hill (ed.) World soybean research. Interstate Printers and Publishers, Danville, Ill.
16. Siddoway, F. H. 1963. Effects of cropping and tillage methods on dry aggregate soil structure. Soil Sci. Soc. Am. Proc. 27:452–454.
17. Slater, C. S. 1951. Winter aspects of soil structure. J. Soil Water Conserv. 6:38–40, 42.
18. Slater, C. S., and Henry Hopp. 1949. The action of frost on the water-stability of soils. J. Agric. Res. 78:341–345.
19. Smika, D. E. 1979. Nonerodible soil aggregates in surface soil as related to tillage practice. p. 147–152. Proc. 8th Int. Conf. Soil Tillage Res. Organ., Bundesrepublik Deutschland.
20. Willis, W. O. 1955. Freezing and thawing, wetting and drying in soils treated with organic chemicals. Soil Sci. Soc. Am. Proc. 19:263–267.