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Nonerodible Aggregates and Concentration of Fats, Waxes, and Oils in Soils as Related to Wheat Straw Mulch[1]

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ABSTRACT

Nonerodible (>0.84 mm) soil aggregates and concentration of fats, waxes and oils in the surface 5-cm depth were determined as related to (i) rates of initial straw mulch, (ii) date of initial fallow tillage, (iii) removal of straw, and (iv) nitrogen fertilization. Nonerodible soil aggregates were also determined as affected by tillage implements commonly used in fallow with residue removed by burning and with residue present.

Increasing the amount of wheat (*Triticum aestivum* L.) straw mulch from 1,680 to 3,360 kg/ha on the soil surface at the start of fallow increased nonerodible aggregation by 5% and fats, waxes, and oils in the soil by 0.019 mg/g of soil. Delaying initial fallow tillage after harvest until spring increased nonerodible aggregates by 3% and fats, waxes, and oils in the soil by 0.052 mg/g of soil. Without N, mulched soil contained 7% more nonerodible aggregates and 0.010 mg more fats, waxes, and oils/g of soil than did bare soil.

All implements tested, except the oneway disk, increased initial nonerodible aggregation by 2 to 7% when wheat stubble had been removed prior to the tillage operation. The oneway disk decreased nonerodible aggregation 4%. During subsequent tillage, all implements decreased nonerodible aggregation except the chisel. Successive operation with the oneway disk decreased aggregation the most at 9%/operation.

Nonerodible soil aggregates at time of winter wheat seeding (Sept.) and the following spring were highest with a fallow tillage sequence of tandem disk, blade twice, and rodweed with flat chisel points twice. This sequence destroyed 67% of the initial residue. Nonerodible aggregation was lowest when the tandem disk was used three times, followed by rodweeder with flat chisel points twice. These operations destroyed 90% of the original residue. Overwinter decrease in nonerodible aggregation was smallest when only the blade and rodweeder with flat chisel points were used.

Additional Index Words: **tillage, crop residue, wheat-fallow rotation.**

WIND EROSION is a serious hazard to agriculture in the Great Plains each year. A wind erosion equation developed (11) to determine the soil erosion potential and conditions needed to reduce erosion in the field showed soil aggregation to be a very important factor. Wind erosion can be controlled satisfactorily when a surface soil contains a minimum of 67% soil aggregates >0.84 mm in diam (nonerodible) (12). However, the relations of tillage and cultural practices to soil aggregation are not completely understood (11).

Results have been reported showing a higher percentage of nonerodible soil aggregates in surface soil where mulch was present than where the soil surface was bare (8). Decomposing wheat (*Triticum aestivum* L.) straw in the soil has also been shown to increase nonerodible soil aggregates (3, 4). Soil aggregates are formed by the binding together of individual soil particles by substances in the soil (1). Therefore, the mulch was believed to provide binding substances not present when the soil surface was bare.

Because fats, waxes, and oils are present in the soil (9), serve as soil aggregate binders (6), and make up 1.5% of average wheat straw (7), we hypothesized that decomposition of wheat straw, on or near the soil surface would provide a source of these aggregate binders, thereby increasing soil aggregation. To test this hypothesis, the concentration of fats, waxes, and oils were determined and related to nonerodible aggregates in soils subjected to different cultural treatments during fallow at North Platte, Nebraska, and Akron, Colorado. Implement and fallow-residue manipulation effects on soil aggregation were also determined.

METHODS AND MATERIALS

At Akron, Colorado, wheat residue rates and initial fallow blading times were studied. Residue rates were 1,680, 3,360, and 6,720 kg/ha on the soil surface at the start of fallow and initial blading times were after harvest (August 1) early spring (April 1) and mid-spring (May 10). Straw was added or removed from the soil surface to obtain the desired residue rate. The experiment was conducted on a Weld silt loam using a randomized block design with 3 replications.

Wheat stubble management practices (main plots) studied at North Platte, Nebraska were removal of straw by mowing and raking after harvest, and stubble mulch tillage with 5,600 and 6,720 kg/ha of straw mulch on the soil surface at the start of fallow. Both practices had subplots with 0 and 168 kg/ha of N. The experiment was conducted on a Holdrege silt loam using a split-plot design with three replications of each treatment.

All treatments at both locations were tilled with 1.8-m-wide blades and a rodweeder with 5-cm-wide by 23-cm-long flat chisel points spaced 15 cm apart in front of the rotating rod at a 40° angle to the soil surface to lift straw and clods over the rod. Soil samples were collected at the end of four wheat-fallow cycles at both locations.

Nonerodible soil aggregates (> 0.84 mm) were determined with a rotary sieve (5) on air-dry soil samples, collected from the 0- to 5-cm depth of soil, in all fallow wheat rotation studies. For each treatment in each replication, five samples with a surface area of 300 cm² were randomly collected from each 335 m² plot. Determinations were made on each sample separately and only treatment averages are reported.

Concentration of fats, waxes, and oils in 400 g of nonerodible soil aggregates from each sample were determined by extraction with ethyl ether (9). Although concentrations were not determined at the start of the experiments, both experimental sites had been uniformly cropped for several years before these studies were begun, and were assumed to contain uniform fat, wax, and oil concentrations.

To determine the effect of certain implements on soil aggregation without straw mulch as a factor, we conducted a study at North Platte, Nebraska, where the wheat stubble was burned before any tillage. Therefore, any change in aggregation would be due to the tillage implement alone. The soil was Holdrege

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Table 1—Nonerodible soil aggregates (>0.84 mm) and concentration of fats, waxes, and oils in soil with different residue rates after four wheat-fallow cycles at Akron, Colo.

Residue rate	Aggregates	Fats, waxes, and oils
kg/ha	%	mg/g
1,680	67 a*	0.110 x
3,360	72 b	0.129 y
6,720	74 b	0.146 z

* Values followed by the same letter within a column are not significantly different at the 5% level.

silt loam. Implements studied were sweep (0.7 m), V-blade (1.8 m), rodweeder (with flat chisel points), chisel (5 cm) spaced 30 cm apart, and oneway disk (60-cm disks). All implements were operated at a 12-cm depth and a 4.5-km/hour ground speed. After initial tillage with all implements, each implement was used, as needed for weed control, on soil previously tilled by each implement. All subsequent operations of each implement were performed on the same day and 5 operations were used during each fallow period. Soil samples for aggregate determination and soil water content were taken immediately before and after each tillage operation during the 3 fallow periods of the study. Treatments were replicated 3 times in a randomized block design, and results from the 3 years were averaged.

The effects of residue manipulation by tillage during fallow on soil aggregation and overwinter soil aggregate stability during the growth of a winter wheat crop was determined from a study conducted near Peetz, Colorado, on a Rosebud slit loam. Fallow tillage treatments studied for three winter wheat-fallow cycles were: (i) moldboard plow, tandem disk twice, rodweed with flat chisel points twice; (ii) blade 3 times, rodweed with flat chisel points twice: (iii) tandem disk 3 times, rodweed with flat chisel points twice; and (iv) tandem disk, blade twice, rodweed with flat chisel points twice. Treatments were replicated 3 times in a randomized block design. Samples for soil aggregate analysis were collected 29 Sept. and 19 April.

RESULTS AND DISCUSSION

Increasing the amount of wheat straw mulch from 1,680 to 3,360 kg/ha on the soil surface at the start of fallow significantly increased the nonerodible aggregates 5% and the concentration of fats, waxes, and oils 0.019 mg/g of soil (Table 1). As straw mulch was further increased to 6,720 kg/ha, percent nonerodible aggregates increased slightly but nonsignificantly, but the concentration of fats, waxes, and oils in the soil did increase significantly. Apparently, 74% nonerodible soil aggregates is near the maximum obtainable in this soil. Therefore, higher straw mulch rates which increase the concentration of fats, waxes, and oils in the soil will have little effect on the percent nonerodible aggregates present in a Weld silt loam soil. Siddoway (8) and Black (2) also reported increases in nonerodible aggregation with increasing straw mulch rates.

Delaying the initial blading time from after harvest until early spring and mid-spring increased the nonerodible aggregates by 3 and 5% respectively (Table 2). However, only the increase with mid-spring tillage was significant. The concentration of fats, waxes, and oils increased significantly by 0.052 and 0.071 mg/g of soil with delays of initial tillage until early spring and mid-spring, respectively. The blading after harvest was an additional tillage operation compared with initial spring blading, which in itself would be expected to decrease nonerodible aggregation. Also, as compared with no tillage, tillage in the fall exposed different soil to overwinter atmospheric conditions, which may have

Table 2—Nonerodible soil aggregates (>0.84 mm) and concentration of fats, waxes, and oils in aggregates from soil having different initial blading times after four wheat fallow cycles at Akron, Colo.

Blading time	Aggregates	Fats, waxes, and oils
	%	mg/g
After harvest	68 a*	0.079 x
Early spring	71 ab	0.131 y
Mid-spring	73 b	0.150 z

* Values followed by the same letter within a column are not significantly different at the 5% level.

Table 3—Nonerodible soil aggregates (>0.84 mm) and concentration of fats, waxes, and oils in aggregates from bare and mulched soils with and without N fertilizer after four wheat-fallow cycles at North Platte, Neb.

Treatment		Aggregates	Fats, waxes, and oils
		%	mg/g
Bare	0-N	57 a*	0.097 x
	168-N	63 b	0.114 y
Mulched	0-N	64 b	0.107 xy
	168-N	75 c	0.222 z

* Values followed by the same letter within a column are not significantly different at the 5% level.

hastened decompostion of fats, waxes, and oils to produce the lower concentration (Table 2).

When wheat straw was mowed and raked from the plot, the percent nonerodible aggregates was significantly lower than when mulch was left on the soil for comparable N fertilizer rates (Table 3). The use of N fertilizer increased the percent nonerodible aggregates and the concentration of fats, waxes, and oils in the bare soil to levels comparable with those of the mulched soil without N fertilizer. The surface soil contained sufficient nonerodible aggregates for satisfactory wind erosion control only on the mulched-fertilized treatment.

The higher concentration of fats, waxes, and oils in the mulched soil compared with the bare soil is attributed to the fats, waxes, and oils originally present in the straw mulch on the mulched soil treatment but were removed with the straw when the bare soil treatment was established. With N fertilizer the quantity of straw mulch was increased from an average of 5,600 to 6,720 kg/ha. Increasing the straw mulch to 6,720 kg/ha was shown earlier to increase the concentration of fats, waxes, and oils in the soil. The increase of fats, waxes, and oils in the bare soil with N fertilizer is attributed to increased straw production and plant root mass. Even when straw was mowed and raked off the plot, 100% was not removed and more straw probably remained on the surface of the fertilized than on that of the nonfertilized soil. Also, although root mass was not determined, it was undoubtedly influenced by N fertilizer.

Previous reference has been made to the fact that the relations of tillage and cultural practices to soil aggregation are not completely understood (11). Relationships of nonerodible soil aggregates to certain factors have been shown by other researchers (2, 3, 4, 8). The relation of higher percent nonerodible soil aggregates with mulch than with bare soil has been shown (2, 3, 8) and was also found in this study. The increase in aggregation with mulch has been attributed to the increased soil water present with the mulch (3). However, tilling a wet soil has been shown to produce less nonerodible soil aggregates than tilling the same soil

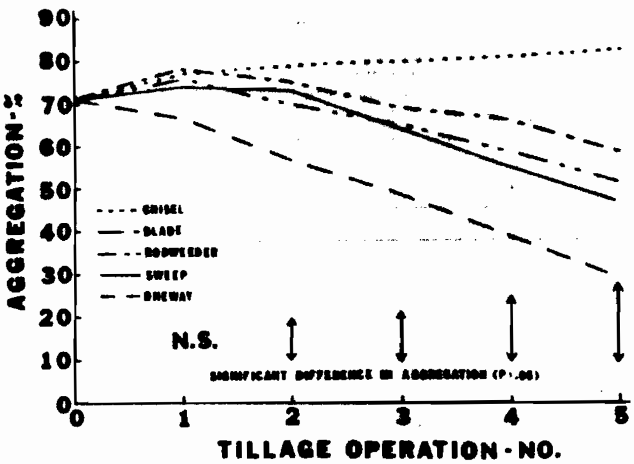

Fig. 1—Change in nonerodible aggregation with tillage implement and number of operations.

dry with the same implement (10). Therefore some factor(s) present as a result of the mulch other than increased soil water content must be responsible for the increased soil aggregation. The information reported herein show that nonerodible soil aggregates and the concentration of fats, waxes, and oils in the soil are highly related ($r = 0.86^{**}$). This relationship was not affected by soil management practice or location. We believe that mulch increases the fats, waxes, and oils in the soil which are important binding agents in the formation of nonerodible soil aggregates in these two Great Plains soils.

To ascertain the effects of tillage implements alone on soil aggregation, the wheat stubble was burned before any tillage was performed. Soil water content (data not shown) was not significantly different in the 0–12 cm depth for any of the tillage implements at any of the tillage times. This soil water situation would be expected because soils in the Great Plains rapidly dry to the depth of tillage when no mulch is present. Since all implements were used the same day for a designated tillage time, aggregation change with tillage was then the result of only the specific implement used. When used for the first fallow operation, sweeps, V-blades, rodweeder with flat chisel points, and chisel increased the percent nonerodible aggregates (Fig. 1). Nonerodible aggregation decreased with each subsequent operation of each implement, except the chisel. The oneway disk produced the greatest average decrease; only 30% nonerodible aggregates remained at the end of fallow. When used alone, the sweep, rodweeder with flat chisel points, and V-blades decreased aggregation 24, 19, and 12%, respectively, as compared with initial aggregation. These results do not agree completely with findings by others (2, 10), but cloddiness produced by tillage is highly variable. Many factors influence aggregate formation by tillage in the field; therefore, results from different research workers and locations seldom agree completely.

All implements were operated at the same depth and speed, therefore, changes in aggregation were due to the action of the implement alone. At this depth and speed, the mixing action of the oneway disk apparently was much more detrimental to nonerodible aggregation than the undercutting action of the blade or rodweeder with flat chisel points. The chisel effectively increased nonerodible aggregation each time it was used.

Table 4—Residue destroyed by tillage treatments and percent nonerodible soil aggregates at two samplings when different tillage implements were used on a Rosebud silt loam at Peetz, Colo.

Tillage implement* and operation sequence	Residue destroyed	Aggregates: End of fallow	Aggregates: End of winter
	%	%	%
Plow (1)[†] - disk (2) - rodweed (2)	100	66.3 a	58.7 a
Blade (3) - rodweed (2)	41	67.2 a	60.2 b
Disk (3) - rodweed (2)	90	65.3 a	56.6 a
Disk (1) - blade (2) - rodweed (2)	67	72.1 b	63.5 c

* Moldboard plow, tandem disk, rodweeder with flat chisel points and V-blade 1.8 m wide.

† Number in parentheses denotes number of operations of the implement preceding the number.

The original hypothesis was also tested by using different fallow tillage treatments that left different amounts of residue on the soil surface at the end of fallow. Percent nonerodible soil aggregates, at the end of fallow and at the end of winter, was highest when the initial fallow operation was a tandem disk, followed by two operations each with a blade and rodweeder with flat chisel points (Table 4). This is attributed to the fact that 33% of the original straw was left on the soil surface, yet some of the straw was mixed with surface soil by the single disk operation and a high straw-soil contact to the depth of tillage was created. The increased straw-soil contact increased straw decomposition to provide fats, waxes, and oils to more soil for aggregate binding which more than offset the detrimental affect of disking on aggregation. Nonerodible soil aggregate percentage was lowest when the tandem disk was used 3 times during fallow. Repeated operations of the tandem disk destroyed the aggregates themselves and produced results similar to that of a oneway disk (see Fig. 1). This treatment also destroyed 90% of the original straw mulch. When only blade and rodweeder were used, 59% of the original amount of straw was maintained on the soil surface. Since all treatments had identical amounts of straw on the soil surface at the start of fallow, the blade-rodweeder treatment resulted in less straw-soil contact near the soil surface than the disk-blade-rodweed treatment. Therefore, less straw was subjected to decomposition for the release of fats, waxes, and oils in the soil for aggregate binding. The plow treatment buried the straw too deep to influence aggregation in the surface soil; therefore, aggregation from these two treatments was between that of the single and triple disk treatments.

The decrease in percent nonerodible aggregates, from the end of fallow to the end of winter, was smallest when the blade followed by rodweeding was used which is similar to findings in Canada (10). Aggregates present when these tillage implements were used were evidently more resistant to winter climatic conditions than aggregates formed when other tillage implements are used during fallow.

CONCLUSIONS

Soil erosion by wind in the Central Great Plains can be reduced significantly by (i) using implements that have a minimal effect on the destruction of nonerodible aggregates,

(ii) maintaining as much as possible of the wheat straw mulch on the soil surface, (iii) combining (i) and (ii) to maintain as high as possible the concentration of fats, waxes, and oils in the soil to act as binders for soil aggregates. Increasing the concentration of fats, waxes, and oils in the soil to increase nonerodible aggregation is of greatest importance when they increase nonerodible soil aggregation to the level necessary for wind erosion control.

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