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Nonerodible Soil Aggregates in Surface Soil as Related to Tillage Practice 1/

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ABSTRACT

Percentages of nonerodible soil aggregates on the soil surface were determined after seeding of winter wheat in conventional stubble mulch, minimum and no-tillage fallow systems. The total percent of nonerodible aggregates was 64.2, 68.1, and 69.4% for conventional stubble mulch, minimum, and no-tillage systems, respectively. The increased aggregation is attributed to the larger amounts of straw mulch on the soil surface left as a result of fewer mechanical tillage operations during fallow. Residue increases were nearly twice as effective as the nonerodible aggregate increases in decreasing the wind erosion hazard.

Soil erosion by wind is active on most cultivated soils in the Central Great Plains of the United States today. Wind erosion is a potential threat in most years--it may occur whenever soil, vegetative, and climatic conditions are conducive. Conditions that promote wind erosion are (i) loose, dry, and finely divided soil, (ii) a smooth soil surface where vegetative cover is sparse or absent, (iii) a large enough field, and (iv) wind strong enough to initiate soil movement (5). Wind erosion is most serious in the Central Great Plains late in winter and early in spring (February through April) when atmospheric conditions are the least stable and create periods of high wind velocities. The period is one during which vegetative growth is dormant, and follows a period of weathering degradation of both vegetative materials and soil aggregates.

Soil erosion can be controlled by creating a soil surface that is resistant to erosion, decreasing windspeed (through shelterbelts or barriers), protecting the erodible-sized soil particles from the wind, or a combination of these practices. Increasing the surface roughness of the soil increases the resistance of a soil to erosion. Surface roughness can be increased by increasing the proportion of soil aggregates that are resistant to erosion on the surface. When about 67% of the aggregates on the soil surface are greater than 0.84 mm in diameter, the smaller, erodible-sized particles are protected and less likely to be picked up by the wind (6). Ridging the soil surface, or vegetative residue also protect the soil surface.

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Minimum and no-tillage fallow practices for winter wheat production have recently been introduced into the Central Great Plains (4). These practices have increased the quantity of residue that is maintained on the soil surface, which, in itself, helps to protect the soil from wind erosion. However, the formation and stability of nonerodible-sized soil aggregates is highly related to the quantity of wheat straw residue on the soil surface (3). Therefore, minimum or no-tillage fallow practices should increase the nonerodible soil aggregate fraction of the surface soil. This study was conducted to determine whether minimum tillage and no-tillage practices were influencing the percentage of nonerodible aggregates in the surface soil as compared with conventional stubble mulch tillage.

METHODS AND MATERIALS

Soil aggregate size distribution was determined on research plots that had been under conventional stubble mulch tillage, reduced tillage, or no-tillage fallow practices since 1973. Conventional stubble mulch tillage consisted of an average of six tillage operations during fallow. Common implements used were a series of 1.8 m wide blades or a rodweeder with semichisels used in various operational sequences. In all sequences, the first operation was a blade operation and the last was a rodweeder operation. Total width for each implement was about 4 m. Reduced tillage fallow consisted of weed control for the first 12 months with herbicides plus two tillage operations just before seeding for weed control with either the blades or the rodweeder. Under no-tillage, weeds were controlled with herbicides during the entire 14-month fallow period. The plots were on Weld silt loam (fine, montmorillonitic, mesic Aridic Paleustolls). They were 11 m by 30 m, and treatments were replicated 3 times. The plots were sampled for aggregate analysis after seeding of wheat in September 1975, 1976, 1977, and 1978. Six samples, each 15 by 25 by 5 cm, were randomly collected within each plot of each replication. Aggregate sizes of less than 0.84, 0.85 to 6.4, 6.5 to 12.6, 12.7 to 38, and more than 38 mm in diameter were determined on oven dry samples using dry rotary sieving procedures (1).

The amount of residue on the soil surface was determined from 3 sites within each plot using standardized procedures (5). Residue in the surface 7.6 cm of soil was determined using techniques described by Greb et al. (2).

RESULTS AND DISCUSSION

The amount of wheat straw residue left on the soil surface at seeding time was significantly increased by minimum and no-tillage practices as compared with conventional stubble mulch tillage (Table 1). The quantity of residue destroyed was directly related to the number of tillage operations. Each tillage operation destroyed about 200 kg of straw/ha from the soil surface.

The quantity of nondecomposed wheat straw found in the upper 7.6 cm of soil was also influenced by fallow tillage practice (Table 1). The least amount of residue was present in the plots under conventional stubble mulch tillage, and the most was in the plots under the no-tillage practice. The tillage treatments had been used for one wheat-fallow cycle before sampling was initiated, which had permitted incorporation of residue into the soil by two drilling operations. Also, the experimental area had been stubble mulch farmed for several years before the minimum and no-tillage practices were initiated, and, therefore, some straw had accumulated from this practice and was probably at about the level found in the conventional stubble mulch tillage plots during this study. The number of tillage operations did not affect residue in the soil as directly as it did residue on the soil surface. The residue in the soil ranged from an average of a 160 kg/ha decrease per operation for conventional as compared with minimum tillage to a 385 kg/ha decrease per operation for minimum as compared with no-tillage.

The total percent of nonerodible aggregates was significantly higher for both the minimum and no-tillage systems as compared with conventional stubble mulch tillage (Fig. 1). This trend was consistent each year of the study and the percent nonerodible aggregates for no-tillage ranged from a high of 75% to a low of 66%. There was no significant difference in total percent nonerodible aggregates between the minimum and no-tillage systems.

The total percent nonerodible aggregates was favorable on all treatments, but the minimum and no-tillage systems provided greater protection to the soil from wind erosion than did the conventional stubble mulch treatment. With conventional stubble mulch tillage, the total percent nonerodible aggregates could be inadequate for protecting the soil.

In the 0.85- to 6.4-mm nonerodible aggregate size, the percent of aggregates was highest with conventional stubble mulch tillage, but the difference was not statistically significant. I think that the higher percentage of aggregates in this size classification is important, however, because when these aggregates break down into the next smaller size, either naturally or by tillage, they will form a larger percentage of erodible sized aggregates than would be formed under minimum or no-tillage.

In the 12.7 to 38 and >38 mm aggregate size classes, the percent of nonerodible aggregates was largest with the minimum and no-tillage systems as compared with conventional stubble mulch tillage. The high percentage of these large aggregates is important, because the larger aggregates require more breakdown to reach the erodible size.

The total percent of nonerodible soil aggregates was highly related to the quantity of wheat residue on the soil surface ($r^2 = 0.990^{**}$). The correlation between nonerodible soil aggregates and residue in the surface 7.6 cm of soil was high ($r^2 = 0.891^{*}$), but not as good as the correlation with residue on the surface. This lower correlation with residue in the soil is not surprizing, because this residue probably lost the original bonding agents, so that its presence was not so influential in aggregate formation as residue on the soil surface.

The relative effectiveness of nonerodible aggregates or residue on the soil surface for wind erosion protection was determined with the use of the wind erosion equation (7). The increases in the soil aggregate and crop residue factors obtained with minimum and no-tillage over those obtained with the conventional stubble mulch tillage were used in the comparison, keeping all other terms in the equation constant. Increasing the nonerodible aggregate percentage by 3.9% with minimum tillage decreased potential erosion by 22.2% as compared with conventional stubble mulch tillage. With no-tillage, the additional 1.3% nonerodible aggregates decreased erosion potential an additional 5.6%. The 880 kg/ha increase in residue with minimum tillage decreased the erosion potential 36% as compared with conventional stubble mulch tillage. The 1050 kg/ha increase in residue with no-tillage decreased erosion potential by 45.6% as compared with conventional tillage. The residue increases were about twice as effective as the increases in non-erodible aggregates in decreasing the wind erosion hazard.

SUMMARY AND CONCLUSIONS

The minimum and no-tillage systems of fallow for winter wheat production in the Central Great Plains are superior to the conventional stubble mulch tillage system for developing nonerodible soil aggregates. The presence of greater quantities of wheat residue on the soil surface as a result of fewer mechanical tillage operations is probably the major factor responsible for the increased aggregation. The residue increases were nearly twice as effective as the nonerodible aggregate increases in decreasing the wind erosion hazard.

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Table 1. Wheat straw residue as related to fallow tillage practice.

Treatment	Residue Amount		
	Left on soil surface	Left in upper 7.5 cm of soil	Total
	kg/ha		
Conventional tillage	1000 a*	3160 a	4160
Minimum tillage	1800 b	3800 b	5680
No-tillage	2050 b	4570 c	6620

* Column values followed by the same letter are not significantly different at the 5% level.

Figure 1. Percentages of fine soil aggregate size classifications left by conventional, minimum, and no-tillage systems.