Influence of Soybean and Corn Cropping on Soil Aggregate Size and Stability[1]

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ABSTRACT

Higher rates of soil loss have been observed for soybean [*Glycine max* (L.) Merr.] cropping than for corn (*Zea mays* L.) cropping. The objective of this study was to determine whether 4 yr of continuous soybean and continuous corn cropping had altered the size and stability of soil aggregates within the tillage zone, which could affect soil seal formation and erodibility. Samples for analyses were obtained in June and October of 1980 from the Monona (fine-silty, mixed, mesic, Typic Hapludolls) and Clarion (fine-loamy, mixed, mesic, Typic Hapludolls) soils in Iowa. The mean-weight diameter of dry-sieved aggregates was significantly (p <0.05) lower for soybeans than corn in October, but the values were similar in June. The mean-weight diameter of wet-sieved aggregates was lower for soybeans than corn in both June and October, but the differences were not statistically significant. The mass of clay released from the bulk soil and two macroaggregate size fractions with laboratory shaking was slightly, but significantly (p <0.10), higher for corn than soybeans.

Additional Index Words: **soil structure, soil erodibility, *Glycine max* (L.) Merr., *Zea mays* L., soil tilth.**

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SOYBEAN [*Glycine max* (L.) Merr.] cropping has been found to increase soil loss relative to corn (*Zea mays* L.) cropping (Laflen and Moldenhauer, 1979; and Alberts et al., 1985). One of the factors that could be important in explaining observed differences in soil loss between these crops is the effect of cropping on aggregate size and stability. It is well known that raindrop impact, particularly on a wetted soil, can cause the surface soil aggregates to break down and form an infiltration limiting surface seal.

Soybean and corn cropping effects on aggregate stability have been studied, but the results are inconclusive and divided between those that have (Stauffer, 1946; Bathke and Blake, 1984) and those that have not (Browning et al., 1943; Strickling, 1950) found a detrimental influence of soybean cropping on aggregate stability. Fahad et al. (1982) found that continuous soybean cropping did not reduce the stability of aggregates in the 0- to 30-mm depth; however, some reduction in aggregate stability was noted within the 30- to 300-mm depth.

Aggregate size and stability are dynamic soil properties which change in response to aggregating and disaggregating forces in the field environment (Gish and Browning, 1948; and Strickling, 1950). Because of the nearly infinite variety of climatic, soil, cropping, and tillage factors present in the field, it is not too surprising that there is some lack of agreement in the literature on the relative effects of soybean and corn cropping on aggregate stability. Of the various researchers cited above, only Strickling (1950) obtained soil samples during the seedbed period when the soil was relatively loose and lacking ground cover. It is for this soil condition that maximum stability of the soil aggregates within the tillage zone is needed.

Our intent was to evaluate soybean and corn cropping effects on aggregate size and stability for periods when maximum soil losses usually occur. We tested the hypothesis that 4 yr of continuous soybean and continuous corn cropping had no differential effect on the size and stability of soil aggregates within the tillage zone.

MATERIALS AND METHODS

Soil samples were collected during 1980 from two fertile agricultural soils in Iowa. One soil was located within the deep loess hills region of western Iowa and northwestern Missouri. The soil series sampled was the Monona (fine-silty, mixed, mesic, Typic Hapludolls); located at the Western Iowa Experimental Farm near Castana on an 11% slope. The soil among the sample sites was texturally uniform with a sand, silt, and clay content of 10, 740, and 250 g kg^{-1}, respectively. The other soil was located within the glacial till region of central Iowa and southern Minnesota. The soil series sampled was the Clarion (fine-loamy, mixed, mesic, Typic Hapludolls); located near Ames on a 5% slope. The variation in sand, silt, and clay contents among the sample sites was within 10 g kg^{-1} of the mean values of 520, 280, and 200 g kg, respectively.

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Cropping treatments evaluated were continuous soybeans (BB) and continuous corn (CC) tilled by conventional methods. These treatments, which were part of a larger study, were established in 1976 using a randomized complete block design, with two blocks. Each 9.1- by 24-m plot was farmed with field equipment parallel to the slope. All plots were spring moldboard plowed and disked prior to planting.

Five soil samples were collected from each treatment in early June of 1980 from the 0- to 25-mm depth within nontrafficked interrows. Samples were collected about 14-d after disking and planting. Larger aggregates or clods were pulled apart until they passed a sieve with 9-mm screen openings. The soil was then spread evenly on a flat surface in the laboratory to allow the moisture of the soil to equilibrate with the humidity present at ordinary laboratory temperatures. After 3 d, the soil was stored in cardboard containers in the laboratory until analyses could be completed. Samples were obtained the following October using the same sampling procedure, except that additional samples were obtained from the 100- to 125-mm depth.

The size distribution of the air-dried aggregates was determined with a rototap machine containing a nest of six, 200-mm diam sieves having screen openings of 6.2, 3.4, 2.0, 1.0, 0.5, and 0.25 mm. The weight of soil retained on each sieve was measured after dry sieving 0.5 kg of soil for 15 s. The stability of macroaggregates (aggregates >0.25-mm diam) was determined by standard wet-sieving methods (Kemper and Chepil, 1965), except that the sieves used had screen openings of 2, 1, 0.5, and 0.25 mm. Mean-weight diameters (MWD) of the dry- and wet-sieved aggregate fractions were then calculated as described by Kemper and Chepil (1965). The stability of microaggregates (aggregates <0.25-mm diam) within the large macroaggregate fraction (6.2–3.4 mm), small macroaggregate fraction (0.5–0.25 mm), and the bulk soil was determined by shaking 10 g of sample in 100 mL of solvent (water or ethanol) in an orbital shaker for 24 h at 160 rpm and pipetting the clay (<0.002 mm) fraction by standard procedures.

Analysis of variance (ANOVA) procedures were performed on the data using the general linear model in the Statistical Analysis System (SAS) (Goodnight et al., 1982). Data from each sampling time were analyzed separately. The magnitude of the experimental error (variation between blocks within treatments) relative to the sampling error (variation among subsamples within treatments) was compared with an F test. If the F value was not significant, the two error terms were combined to obtain a pooled error term for testing main effects and interactions. If the F value was significant, the test of hypothesis was made using the experimental error. A pooled error term was used in the ANOVA of the dry-sieving data. Degrees of freedom associated with the pooled error for dry sieving were 15 and 31 for the June and October samplings, respectively. Degrees of freedom associated with the experimental error for wet sieving were 3 and 7 for the June and October samplings, respectively. A pooled error term with 94 degrees of freedom was used in the ANOVA of the microaggregate stability data. If the interaction term among the factors being investigated was significant, the least significant difference (LSD) was calculated and used to compare the simple treatment means. If the interaction term was not significant, only main effect means were compared by the LSD.

RESULTS

Soil Aggregate Size

Simple treatment means for dry sieving are presented in Table 1. Results from the ANOVA of data from samples collected in June showed that soil did (p <0.01) and crop did not affect the MWD of dry-sieved aggregates. The soil by crop interaction was significant (p <0.10). The significant soil effect and the soil by crop interaction may be related to differences in the physical condition of the soils when sampled. Both soils were sampled about 14 d after secondary tillage and planting. However, the two locations had received different amounts of rainfall prior to sampling. The surface of the Monona soil was lightly crusted and contained discrete aggregates and clods. In contrast, the surface of the Clarion soil was puddled and heavily crusted. The reorientation of soil particles due to aggregate slaking and dispersion would have increased the density and strength of the surface of the Clarion soil. As a result, the crust broke into large soil particles as it was passed through the 9-mm sieve, which increased the MWD of the dry soil. Conceptually, the interaction between soil and crop could be related to a negative influence of soybean cropping on aggregate stability. As previously mentioned, the surface of the Clarion soil had been puddled by rainfall prior to sampling. If the stability of soil aggregates had been reduced by 4 yr of continuous soybean cropping, the strength and/or thickness of the soil crust would probably have been higher for soybeans than corn. The <9-mm fraction for soybeans would be composed of larger soil particles (and a larger MWD) relative to corn because the stronger and/or thicker crust would have broken into larger pieces as it was passed through the 9-mm sieve.

Results from the ANOVA of data from samples collected in October showed that soil did not, crop did (p <0.05), and depth did (p <0.01) affect the MWD of dry-sieved aggregates. None of the two-way interactions were significant. The crop by depth interaction with soil was significant (p <0.05). The MWD of dry-sieved aggregates for continuous soybeans was significantly lower than that for continuous corn for the 100- to 125-mm depth of the Monona soil and the 0- to 25-mm depth of the Clarion soil. For both these situations, the MWD of dry-sieved aggregates for continuous soybeans was about 24% lower than that for continuous corn. The MWD of dry-sieved aggregates within the 0- to 25-mm depth was lower than that 100-mm deeper in the soil because of greater aggregate dispersion by weathering forces. The upper 25 mm of

Table 1. Effect of continuous soybean and corn cropping on the mean-weight diameter of dry-sieved and wet-sieved soil aggregates.

Sampling date	Sampling depth	Monona		Clarion	
		BB†	CC†	BB	CC
1980	mm	MWD, mm			
		Dry-sieved‡			
June	0–25	2.37	2.48	2.95	2.65
Oct.	0–25	1.91	2.06	1.90	2.48
	100–125	2.35	3.09	2.91	2.56
		Wet-sieved			
June	0–25	1.02	1.20	0.99	1.58
Oct.	0–25	1.85	1.76	2.35	3.03
	100–125	1.21	1.39	1.38	2.34

† BB = continuous soybeans and CC = continuous corn cropping treatments.

‡ Least significant difference ($p \leq 0.05$) among the dry-sieved means for the June and October samplings were 0.36 and 0.49 mm, respectively.

Table 2. Effect of continuous soybean and corn cropping on the stability of microaggregates within three soil fractions.†

		Soil fractions		
Solvent	Crop	Bulk	6.2–3.4 mm	0.5–0.25 mm
		clay, g kg⁻¹		
		Monona		
Water	BB	55	56	64
	CC	52	57	64
Ethanol	BB	59	52	55
	CC	56	56	57
		Clarion		
Water	BB	138	142	137
	CC	140	147	136
Ethanol	BB	59	59	16
	CC	78	65	27

† Soil samples were collected in June, 1980 from the 0- to 25-mm depth.

both soils was unconsolidated at the October sampling.

Soil Aggregate Stability

Table 1 shows the simple treatment means for wet sieving. Results from the ANOVA of data from samples collected in June showed that neither soil nor cropping affected the MWD of wet-sieved aggregates. However, a trend was certainly apparent with the main effect means for continuous soybeans and continuous corn being 1.01 and 1.39 mm, respectively.

Results from the ANOVA of data from samples collected in October showed that soil did ($p < 0.01$), crop did not, and depth did ($p < 0.05$) affect the MWD of wet-sieved aggregates. The interaction terms were not significant. Main effect means for continuous soybeans and continuous corn were 1.71 and 2.13 mm, respectively. The MWD of wet-sieved aggregates within the 0- to 25-mm depth was probably higher than that of the 100- to 125-mm depth because of greater air-drying at the soil surface (Gish and Browning, 1948; Reid and Goss, 1981). Differences in climatic conditions between the two locations during the 1980 growing season may have been responsible for the significant soil effect found for the October sampling (Gish and Browning, 1948).

The mass of clay released from microaggregates within the bulk soil and two macroaggregate size fractions after shaking for 24 h is shown in Table 2. Results from the ANOVA showed that the main effects of soil type, solvent, and soil fraction were all significant ($p < 0.01$). A significant cropping effect was found ($p < 0.10$), but the main effect mean for corn (78 g clay kg^{-1}) was higher than that for soybeans (74 g clay kg^{-1}). None of the two-way and three-way interactions with crop as a factor were significant. The Clarion soil released a much greater percentage of the total clay available, particularly with the water solvent, probably due to abrasion of the microaggregates by sand grains. It is unclear why there was such a large soil by solvent interaction.

DISCUSSION

Based upon the results of our F-test criterion, we must accept the hypothesis that soybean cropping has no detrimental effect on the size and stability of soil aggregates within the tillage zone. With the cropping effect ($p < 0.05$) found for dry sieving (October sampling) and the trends shown for wet sieving, our data suggest that 4 yr of continuous soybeans could have reduced aggregate size and stability and, thereby, increased the erodibility of these soils. For the dry sieving and microaggregate stability tests, experimental error was not higher than sampling error; thus, no additional source of variation between blocks within treatments was present. For wet sieving, a significant additional source of variation existed between blocks, which was a large soil by crop interaction with block. This variation reduced the power of the F-tests on main effects and interactions in the model. More blocks or a better experimental design would have been needed to improve the precision of the macroaggregate stability test.

The importance of aggregate size and stability relative to other factors such as soil microrelief, residue, and canopy cover, and the quantity of incorporated residue that could also explain differences in soil loss between soybeans and corn was not assessed in our study. We conclude from our results, however, that aggregate size and stability would be relatively unimportant in explaining the residual cropping effect of soybeans on soil loss (Van Doren et al., 1950, and Laflen and Moldenhauer, 1979). The residual effect has been evaluated generally by comparing soil losses for corn following soybeans to those for corn following corn. For most soils, macroaggregates are stabilized by roots and hyphae penetrating through the intra-aggregate pores (Tisdall and Oades, 1982). Corn roots are more fibrous and smaller in diameter than soybean roots and have a greater root length per unit volume of soil (Allmaras et al., 1975). Because root mass decreases rapidly from the row to interrow with row crops, however, only a relatively small proportion of the soil within the tillage zone is in intimate contact with row-crop roots in any one year. We tested our hypothesis after 4 yr of continuous soybean and continuous corn cropping. Because we could not reject it, it is highly unlikely that aggregate size and stability could be affected enough in one cropping year to contribute to a residual cropping effect of soybeans on soil loss.

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