The Effects of Organic Matter and Tillage on Maximum Compactability

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Introduction

Hugo Kruger of the INTA Experiment Station at Bordenave, Argentina presented data at a no-tillage symposium in Paraguay in August 1994, showing that "maximum compactability" as measured by the Proctor test was related to tillage history of the soil samples. Samples from conventionally tilled plots showed highest bulk densities, no-tillage samples showed the lowest, and minimum tillage samples gave intermediate values. As a result of his observations, in the fall of 1994, we began to determine maximum compactability on samples from plots and fields with variable land use history in Kentucky. This paper is a report of the preliminary results.

Materials and Methods

Samples were taken from 0- to 2-inch depths at the following locations:

(1) Maury silt loam was sampled in the old no-tillage plots at Lexington (Ismail et al., 1994). Four treatments were sampled: no-tillage, 0 and 300 Ib N/acre rates and conventional tillage, and 0 and 300 lb N/A rates on each of four replications for a total of 16 samples. In addition, one sod sample from alongside the plots was taken.

(2) Lonewood loam was sampled at eight farm locations in Russell County, Kentucky. Treatments included sod, no-tillage, and conventionally tilled fields of long duration.

(3) Pembroke silt loam was sampled in Logan County in four fields, all located close together. The treatments were fescue sod, no tillage soybeans, conventional corn, and alfalfa recently planted on a soil where conventional tillage had long been practiced.

All soils were crushed by hand while still slightly moist and passed through a 2-mm sieve. Soil organic carbon was determined on each sample using a Leco CR-12 Carbon Analyzer. This is a dry combustion analysis for organic carbon. Duplicate samples were used for all determinations.

Maximum compactability (the maximum bulk density obtainable) was determined using the standard method (ASTM, 1991) with the following details. The mold or compaction chamber was filled and compacted in four layers, each layer receiving 25 blows from a standard falling hammer, for a total of 100 blows. Water content was varied in each case from the dry side of maximum bulk density to the wet side. A minimum of four and occasionally five individual moisture contents were used to approximate the curve.

After the weight of wet soil in the compaction chamber was determined, three soil moisture samples were taken so that soil dry weight and moisture content could be determined. These samples were weighed, dried in the oven at 110 "C for 24 hours, and weighed again. We observed practically no variation in soil water content between the three subsamples.

Maximum bulk density for each sample was estimated by extrapolating the "dry" leg and the "wet" leg of the samples to a point of intersection. This point also gives the moisture content at which the maximum bulk density is attained.

Results and Discussion

Figure 1 shows typical bulk density results for two samples over moisture ranges. As can be seen, maximum bulk densities can be estimated with considerable precision. In addition, as Kruger had indicated, the no-tillage sample shows lower bulk densities than does the conventional sample.

Table 1 shows the land use and management of sites sampled, the soil series, the maximum bulk density, and the per-

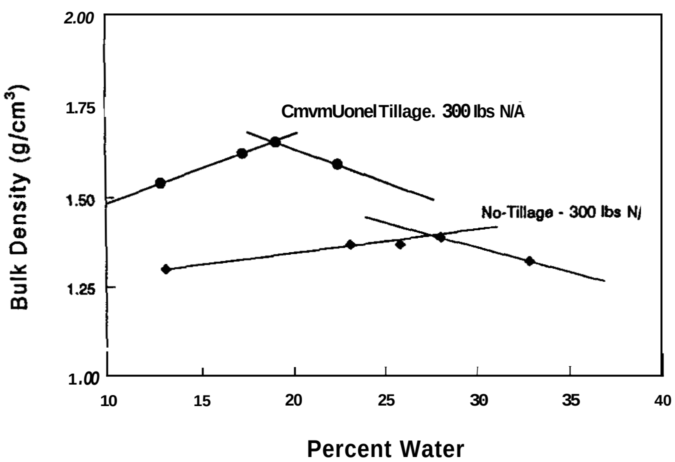

Figure 1. Bulk densities of a no-tillage and conventionally tilled Maury soil measured over a range of moisture.

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cent organic carbon. The range in both bulk density and organic carbon is relatively large, 1.4 to 1.8 g cm-3and 1.0 to 3.5% , respectively. These data were separated by soil series and plotted in Figures 2, 3, and 4.

Figure 2 shows the bulk densities of samples of Maury silt loam plotted against percent organic carbon. The data gave an r^2 of 0.922 and a slope of -0.15qt/A. The latter indicates a change of 0.15 g cm-3 in bulk density for each one percent change in organic carbon. The samples do not appear to separate according to tillage itself but instead are closely related to organic carbon, which, in these experimental plots, is a result of 25 years of continuous treatment.

Figure 3 shows the relationship between maximum bulk density and organic carbon percentage for Lonewood soils. Again, regardless of treatment, the relationship is dominated by organic carbon content of the samples. The slope of the curve is –0.23 g cm^{-3} per percent organic carbon, somewhat steeper than that found in the Maury silt loam. The r^2 value is 0.92, about the same fit as in the case of the Maury samples.

Figure 4 shows the same relationship for the four Pembroke silt loam samples. The slope and intercept of the Pembroke and Maury soils were exactly equal, 1.88 and –0.15, respectively, indicating that texture and perhaps other soil characteristics are very similar in the two soils.

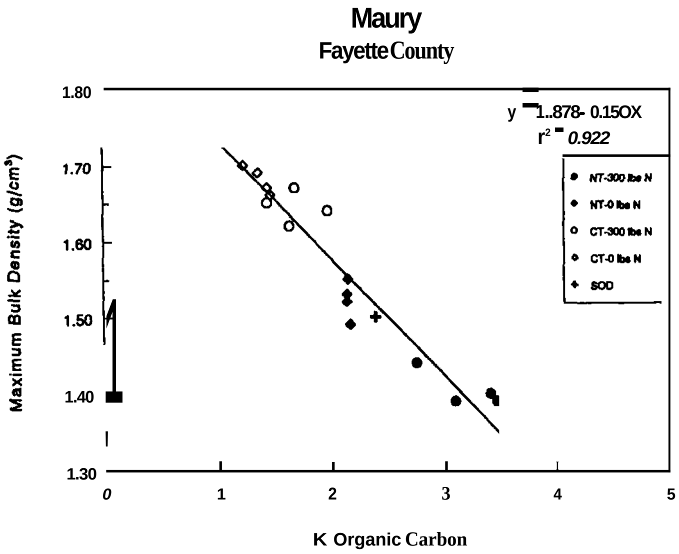

Figure 2. Relationship between maximum bulk density and organic carbon percentage for Maury soils.

Felton and Ali (1991) showed an effect of incorporating organic material (manure) on maximum bulk densities in subsoils of three Kentucky soils. Their results showed changes in bulk density of only between 0.056 and 0.077 g cm-^{3} per

Table 1. Soil, county, land use, maximum bulk density, and percent organic carbon in soils used in the experiments.

Soil	Land Use History		Maximum Bulk Density	% Organic Carbon
Maury silt loam (Fayette County)	**Conventional Corn, 25 years, 0 Nitrogen**	I	1.70	1.23
		11	1.69	1.36
		III	1.67	1.44
		IV	1.66	1.47
Maury	**Conventional Corn, 25 years, 300 lbs N/A**	I	1.65	1.44
		I1	1.67	1.69
		III	1.62	1.64
		IV	1.64	1.98
Maury	**No-tillage Corn, 25 years, 0 Nitrogen**	I	1.53	2.15
		I1	1.49	2.18
		111	1.55	2.16
		IV	1.52	2.15
Maury	**No-tillage Corn, 25 years, 300 lbs NIA**	I	1.40	3.41
		I1	1.39	3.47
		111	1.44	2.75
		IV	1.39	3.10
Maury Lonewood loam **(Russell County)**	**Permanent bluegrass-fescue** sod, **next to Expt.**		1S 0	2.40
	Sod near fence line, Voils, **Hwy 379**		1.50	2.40
	No-tillage soybeans, Voils, Hwy 379		1.58	1.99
	No-tillage soybeans, Voils, **hog manure applied**		1.54	2.19
	No-tillage corn for silage, Halsell		1.70	1.33
	Conventional pepper field, Halsell		1.82	1.27
	No-tillage soybeans, Pyles		1.58	2.12
	No-tillage soybeans, half acre		1.65	1.69
	Conventional corn, John St.		1.77	1.10
Pembroke silt loam (Logan County)	**Permanent fescue sod, Hwy 663**		1.46	2.85
	Conventional Corn, Hwy 663		1.72	I.24
	New alfalfa—formerly conventionally tilled, Hwy 663		1.68	1.30
	No-tillage soybeans, Moore		1.65	1.45

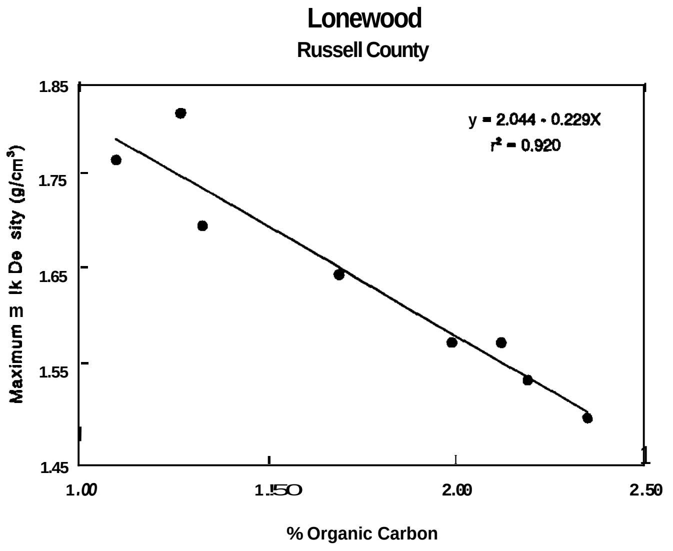

Figure 3. Relationship between maximum bulk density and organic carbon percentage for Lonewood soils.

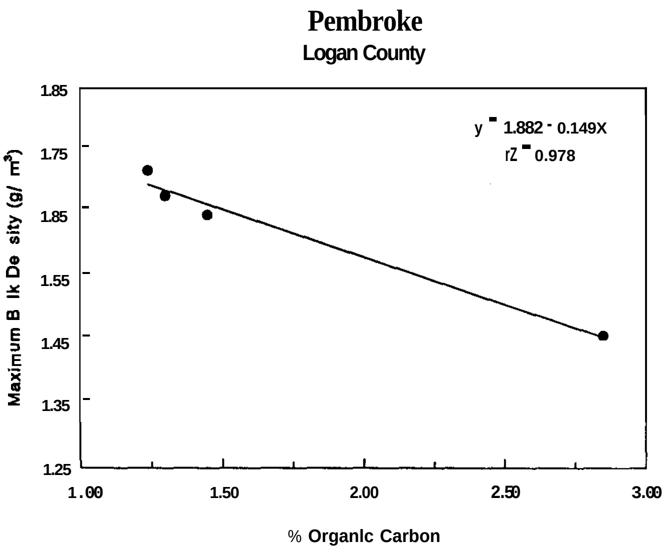

Figure 4. Relationship between maximum bulk density and organic carbon percentage for Pembroke soils.

percent organic carbon, whereas we observed 0.15 in Maury and Pembroke soils and 0.23 in the sandier Lonewood soil. However, both the composition of the organic material and its integration within the soil are different in our case. The organic matter is humus, and it has been thoroughly incorporated in the soil over a period of years. In the case of Felton and Ali, the manure was mixed just prior to the laboratory experiments.

This work has far-reaching, practical consequences. Of all the doubts about continuous no-tillage as a viable practice, the fear of compaction probably looms largest. This work shows clearly that with an adequate organic carbon content (probably around 2.5%) in the surface soil, the fear of compaction is essentially groundless. A prime role of organic matter, in addition to many other favorable effects, is resistance to compaction. Exactly how organic matter accomplishes this is open to question. We may speculate on *two* possible causes. First, organic matter aggregates the soil so that it resists compaction when it is compacted by hammering.

Second, organic matter binds the particles so that sorting does not occur during the compaction process.

Both of these mechanisms would result in less compaction.

Whatever the mechanisms, we have shown that one percent organic carbon lowers the maximum bulk density in three Kentucky soils by 0.15 g cm^{-3} to 0.23 g cm^{-3} which is a very significant effect. Together with the other favorable effects of organic matter on soil properties, this certainly suggests that the maintenance and increasing of organic matter contents in soils is a worthy goal. The use of no-tillage is a practical and efficient means to attain that goal.

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