Soil Science News and Views
Plant and Soil Sciences

1995

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Vol.16. No. 8, 1995

The Effect of Organic Matter on Maximum Compactability of Soil

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Introduction

Bulk density is the weight of a given volume of soil expressed by soil scientists as grams per cubic centimeter (g/cm^3). The higher the bulk density, the lower the volume of soil occupied by pore space, that volume of soil in which air and water reside. Because of this, there is much interest on the degree to which soil can be compacted.

The Proctor test is a means of determining the maximum bulk density that can be attained in a soil sample. This "maximum compactibility" is widely used on highways and building foundations but has had little use in agricultural soils. 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 is a report of the preliminary results.

Materials and Methods

Soils were sampled from 0 to 2 inch depth at the following locations:

1. Maury silt loam was sampled in the long-term (25 yrs.) no-tillage plots at Lexington . Four treatments were sampled: no tillage, 0 and 300 lb nitrogen (N)/A rates and conventional tillage, 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 four fields, all located close together in Logan County. The treatments were fescue sod, no tillage soybeans, conventional corn, and alfalfa recently planted on a soil where conventional tillage had long been practiced.
4. Grenada silt loam was sampled on several farms in Hickman County. Treatments were sod, various years of no tillage

and one conventionally-tilled site.

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 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 was 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^{o}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 linearly 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

Table 1 shows the land use and management of sites sampled, the soil series, the maximum bulk density, and the percent organic carbon. The range in both bulk density and organic carbon is relatively large, 1.4 to 1.8 g/cm^3 and 1.0 to 3.5%, respectively. These data were separated by soil series. Fig. 1 shows the bulk densities of samples of Maury silt loam plotted against % organic carbon. The data gave an r^2 of 0.922 and a slope of - 0.15x. 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 corn production.

Fig. 2 shows the relationship between maximum bulk density and % organic carbon for Lonewood soils. Again, regardless of treatment, the relationship is affected by the 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.

The intercept and slope 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.

The effect of organic carbon was considerably less in the very silty Gre nada soils, but still lowered maximum bulk density by -0.103 per one percent increase in organic carbon. Interestingly, the Grenada soil even without organic carbon, has an intercept of only 1.72 g/cm^3 so that it is a much less compactable soil than any of the others used. The r^2 is also slightly lower at 0.85.

Summary

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 breakdown when it is compacted by hammering. Second, organic matter binds the particles so that vibration induced sorting does not occur during the compaction process. Both of these mechanisms would result in less compaction. It should also be pointed out that the direct effect of lower density organic matter on bulk density is neglible.

Whatever the mechanisms, we have shown that one percent organic carbon lowers the maximum bulk density in four Kentucky soils by 0.10 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 soil organic matter contents is a worthy goal. The use of no tillage is a practical and efficient means to attain that goal.

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

Soil/County	Land Use History and site Location	Rep	Maximum Bulk Density g/cm^3	% Organic Carbon	% H_2O @ Maximum Density
Maury silt loam (Fayette Co)	Conventional Corn, 25 years, 0 Nitrogen	I	1.70	1.23	18.3
		II	1.69	1.36	18.8
		III	1.67	1.44	19.3
		IV	1.66	1.47	19.8
Maury	Conventional Corn, 25 years, 300 lbs N A^{-1}	I	1.65	1.44	19.2
		II	1.67	1.69	18.3
		III	1.62	1.64	19.2
		IV	1.64	1.98	20.0
Maury	No-Tillage Corn, 25 years, 0 Nitrogen	I	1.53	2.15	24.2
		II	1.49	2.18	26.3
		III	1.55	2.16	23.8
		IV	1.52	2.15	25.2
Maury	No-Tillage Corn, 25 years, 300 lbs N A^{-1}	I	1.40	3.41	27.1
		II	1.39	3.47	28.0
		III	1.44	2.75	24.0
		IV	1.39	3.10	29.0
Maury	Permanent bluegrass-fescue sod, next to corn plots		1.50	2.40	25.5
Lonewood loam (Russell Co.)	Sod near fence line, Hwy 379		1.50	2.40	24.0
	No-Tillage soybeans, Hwy 379		1.58	1.99	21.5
	No-Tillage soybeans, hog manure applied		1.54	2.19	21.4
	No-Tillage corn for silage		1.70	1.33	18.0
	Conventional pepper field		1.82	1.27	14.2
	No-Tillage soybeans		1.58	2.12	21.5
	No-Tillage soybeans, half acre		1.65	1.69	18.8
	Conventional corn, John St.		1.77	1.10	14.7
Pembroke silt loam (Logan Co.)	Permanent fescue sod, Hwy 663		1.46	2.85	25.0
	Conventional Corn, Hwy 663		1.72	1.24	18.3
	New alfalfa-formerly conventionally-tilled, Hwy 663		1.68	1.30	18.5
	No-tillage for soybeans		1.65	1.45	19.8
Grenada silt loam (Hickman Co.)	Long-time conventional tillage, no-tilled since 1990		1.62	0.82	18.0
	No-tillage for several years		1.59	1.16	19.3
	Long-time no-tillage soybeans		1.54	1.63	20.7
	Conventionally-tilled corn		1.60	1.34	18.2
	No-tillage corn-wheat-soybeans&chicken manure		1.56	1.57	18.7
	No-tillage for more than 20 years		1.50	1.97	22.3
	Fescue and broomsedge sod		1.59	1.46	18.0

Figure 1.

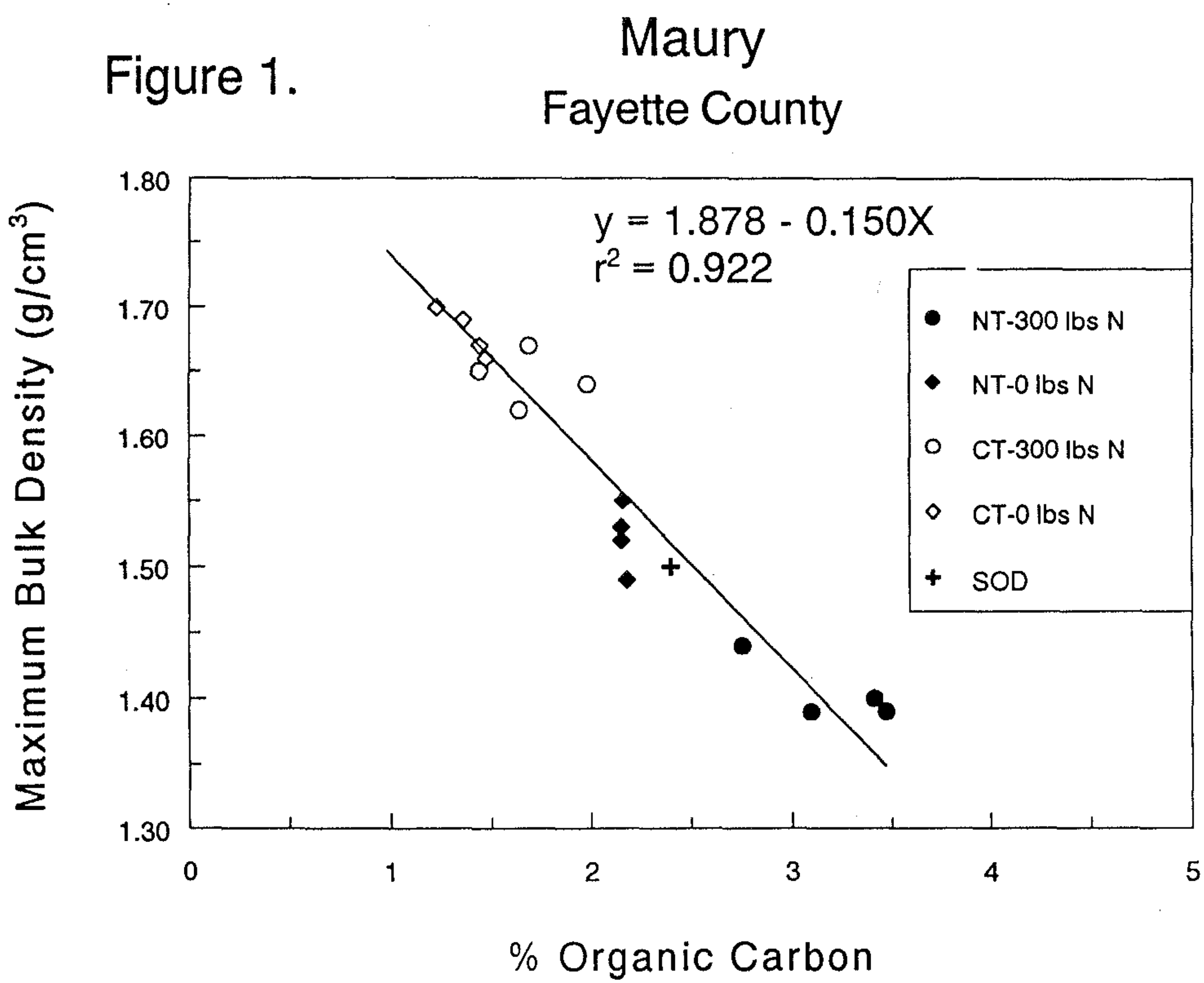
Maury
Fayette County
y = 1.878 - 0.150X
r2 = 0.922
NT-300 lbs N
NT-0 lbs N
CT-300 lbs N
CT-0 lbs N
SOD
Maximum Bulk Density (g/cm3)
1.80
1.70
1.60
1.50
1.40
1.30
0
1
2
3
4
5
% Organic Carbon

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Figure 2.