Bulk Density Measurement Variability with Core Samplers

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ABSTRACT

LABORATORY and field experiments were performed to investigate the accuracy of bulk density measurements taken with soil core samplers. The effects of an auger and Teflon™ coating on the corer tip were evaluated. Bulk density values obtained with a core sampler without an auger are significantly smaller and more variable than bulk density values obtained with an augered core sampler. Also, Teflon™ coating on a core sampler tip did not significantly increase the accuracy of bulk density values.

INTRODUCTION

Core samplers are a common method of obtaining soil samples for bulk density measurements. These devices arc comprised of long tubes that are either hammered (Wells, 1959), driven at a constant speed (Dortignac, 1949), or augered (Kelley et al., 1947). The soil removed from these long tubes can be analyzed in sections for bulk density measurements. Although in common use, these devices are not perfect. Soane (1976) concluded that the core sampling method may have larger errors than the gamma-ray method. In another study, Baranowski (1983) investigated whether estimates with conventional core sampling could secure data of desired accuracy. He found, under favorable conditions even with careful sampling procedures and a sufficient number of replications, that the core method produced intertreatment densities to accuracies no greater than 0.05 Mg/m^3. When the conditions are not as favorable, he mentions that the error can be as much as five times greater.

Compaction of the core seems to account for the largest error inherent to core sampling devices. As the tool is pushed or augered into the ground, very little disturbance seems to occur across the core, but variations in length are found (Wells, 1959). Baver (1956) notes that narrow sampling tubes tend to compress the core. He advises using at least a 7.6.cm diameter tube to minimize compression.

The design of the core sampling device greatly affects its accuracy. A taper inside the tube, starting from the tip and extending back up into the cure sampler (Veihmeyer, 1929) provides clearance between the soil cure and the inside of the soil tube. Soil will be compacted only outside of the sampler where it will not affect the sample.

To remove a soil core from a sampling hole, a certain normal force must exist between the soil sampler and the soil column. This frictional force should, however, be small to minimize compaction of the soil core. If this force is excessive, large deformations of the soil core near the edges can be expected. Coating the soil corer tip with a slippery substance, such as oil or Teflon™, reduces the frictional force on the soil column. This lubricant, ideally, does not affect the moisture content or chemical composition of the soil sample nor does it decrease the frictional force below that necessary to remove the soil sample from the sampling hole.

Research is needed in two areas to reduce the error associated with core samples: to develop core sampling methods that minimize compaction of the soil core and to determine if the frictional force necessary for removal of the soil core from the ground could be reduced. Therefore, the objectives of this research effort were:

1. To compare the augered versus the pushed soil samplers for accuracy of obtained bulk densitv values and
2. To determine if coating the soil corer tip with 3M TFE Lube™* (a form of Teflon™ or polytetraflouroethylene) improved the accuracy of obtained bulk density values.

To evaluate these objectives, a soil sampler similar to one designed by Buchele (1961) was used. His core sampler design incorporated an auger, but its purpose was for removing soil outside the core sampler and not for pulling the core sampler into the ground. Our sampler differed from Buchele's sampler in that his was not tractor mounted. The end of the core sampler was also modified because a problem had been noticed in the field with the original design. Soil became encased around the end of the sampler between the auger tip and the soil corer tip (Fig. 1). Soil flowing past this area was impeded and the resulting action compressed the soil sample. Therefore, the auger was fixed immediately adjacent to the sampler tip so that excess soil was always scraped from around the soil sampler tip. Soil that was trimmed from the soil core would flow smoothly around the sail corer tip and would not cause compression of the sample.

MATERIALS AND METHODS

A tractor-mounted core sampler was used for this study and was composed of a hydraulically powered auger and a stationary center core. The sampler was

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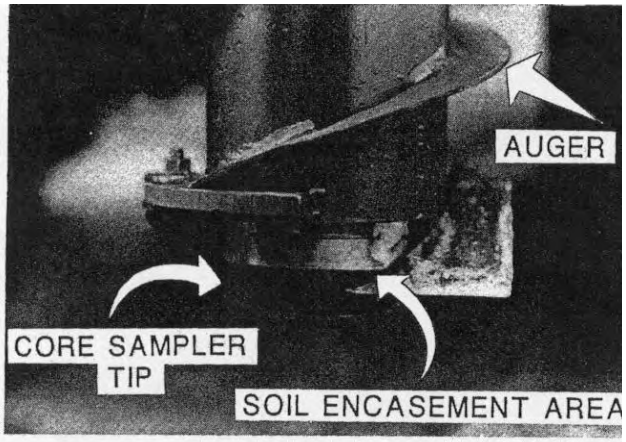

Fig. 1—Soil sampler auger tip, showing area of soil encasement.

pushed downward by a hydraulic cylinder while the auger rotated about the stationary core and removed soil from around it. The sampler took cores that were 7.62 cm in diameter and could be up to 71 cm in length. These soil cores were sectioned into 5.1-cm lengths for measurement purposes. Values of soil bulk density and moisture content were then obtained as a function of depth.

The soil corer tip used for this study was basically the same as the one designed by Buchele. The diameter of the tip decreased 0.04 cm from the bottom edge where soil entered the soil sampler until a point 1.3 cm upward into the soil sampler. This taper was followed by a small amount of clearance inside the soil sampler. The inward taper was used to insure that the soil core sample would remain inside the soil sampler while they both were removed vertically from the sampling hole.

Laboratory Experiment

The soil sampler just described was used to obtain soil core samples from soil placed in containers. These containers were manufactured from 30.cm inside diameter polyvinyl chloride (pvc) pipe. This pipe was sectioned into 35.5-cm lengths, and the sections were glued onto a pvc plate forming a constant diameter pail with a bottom. These pails were sufficiently rigid that compression of the sample was not a problem, and their vertical sides made accurate volume measurements possible.

Four thin plastic rulers were taped perpendicular to the bottom of the pail at 90 deg intervals. The rulers were flush at the bottom of the pail and extended upward. The height of the soil could be measured accurately to within 1 mm by using a magnifying glass and a small pointer. This procedure enabled the volume of the soil to be calculated to within 70.7 cm^3, or with less than a 1% error for a 10.2-cm layer of soil.

The soil used in this experiment was Chequest silty clay loam (fine, montmorillonitic, mesic, Typic Haplaquolls) which was 38% sand, 34% silt, and 28% clay. It contained 2.2% organic matter and had a specific surface of 74.5 m^2/g. The soil was air-dried and ground into small aggregates to assure uniformity. Water was added to the soil to achieve 15%, 18%, and 22% moisture content (dry basis) after equilibrium. The upper and lower values of moisture content were chosen because they seemed to be near the maximum and minimum workable conditions of the soil.

A Riehle tension/compression tester was used to compact the soil. A ram fitted to the crossarm of the tester applied pressures of 7, 34, and 90 kPa to the soil. Applied pressures were held constant for 15 sec. Although the same three pressures were used for each of the three moisture contents, the resulting bulk density values obtained varied among moisture contents.

During pretest trials, the soil at the highest moisture content was consolidated into large clods when subjected to high pressures. The soil was reground when these large clods formed. This practice reduced the variation of sample bulk density between replications to a minima1 amount.

As previously mentioned, the same three bulk density values could not be attained within each of the three moisture contents. For this reason, nine levels of a moisture-density factor were used along with a Teflon™ - no Teflon™ treatment and an auger - pushed treatment. A 9 x 2 x 2 factorial randomized block experiment with two replications was designed to investigate soil core compaction. These treatments were used to determine the effects of the auger and of the corer tip friction on soil core compaction. Samples were taken from four depths to test if compaction of the soil core changed with depth. Only two replications were used for the experiment because of the change in soil properties. Further replications would had to have been performed on soil very much unlike that used for the first two replications. Data were then analyzed using SAS (SAS Institute., Inc., 1982).

Field Experiment

A field experiment was conducted to evaluate the effect of the auger on a soil core sampler in a field situation. Selected plots had been subjected to three different tillage treatments for three years (Elamin, 1983). These were a no-till, a Paraplow™, and a chisel-plow treatment. The soil in these plots was a Canisteo clay loam (tine loamy, mixed calcareous, mesic, Typic Haplaquolls) which was approximately 30% sand, 25% silt, and 45% clay.

Soil core samples were taken in six replications of each tillage system. The soil sampler was used both with and without the auger. Soil cores of 40.8.cm length were taken and split into 5.1-cm sections and these samples were weighed, dried, and the bulk density of each determined.

RESULTS AND DISCUSSION

Laboratory Experiment

It was previously thought that the use of a pushed soil sampler would increase the bulk density of a soil sample due to an increased amount of compaction, but this hypothesis was proved to be incorrect. The average bulk density value over all treatments and all depths was increased by 0.041 Mg/m^3 through the use of an augered soil sampler (Table 1). The effect of the auger on the value of bulk density was found to be significant even at the 1% level. Fig. 2 also shows how the average bulk density values increased with depth through the use of an auger. Near the surface, both the augered and the pushed soil samplers took samples very similar in bulk density, but as the soil samplers penetrated into the soil, the values of bulk density obtained with the augered soil

TABLE 1. RESULTS OBTAINED FROM THE LABORATORY EXPERIMENT

Sampler	Coating		
	No Teflon™	Teflon™	Average
	Bulk density, Mg/m^3		
Augered	1.081	1.059	1.070
Pushed	1.031	1.027	1.029
Average	1.056	1.043	1.049

LSD (0.05) = 0.024 Mg/m^3 used for comparing main effects

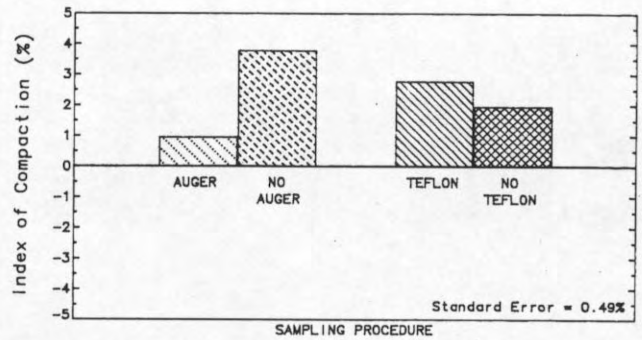

Fig. 3—Mean indexes of compaction for the laboratory experiment.

sampler were consistently greater than the values obtained with the pushed soil sampler.

A marked difference in bulk density occurs as a result of the use of an augered soil sampler. This sampler consistently takes samples with greater bulk density than a pushed soil sampler. But it is not clear whether the augered soil sampler compresses the soil sample more than the pushed sampler or whether the pushed soil sampler disturbs the soil sample sufficiently to decrease its value of bulk density. To clarify what is happening, an index of compaction (Vazin, 1982) was used that took into consideration the bulk density of the soil in the laboratory experiment before it was sampled. This initial bulk density was calculated from the weight of the soil and the volume of the containers used for the experiment. The index of compaction can be defined as:

$$IC = 100 * (Ibd - Fbd)/Ibd \quad [1]$$

where

IC is the index of compaction, %

Ibd is the initial bulk density of the soil, Mg/m^3

Fbd is the final bulk density of the soil, Mg/m^3

Values of the index of compaction should be near zero to maximize the accuracy of bulk density values. Negative values of this index would indicate that some soil core compression is taking place. Positive values would indicate loosening of the soil sample. Large positive or negative values would mean the soil samples were not representative of the initial soil condition.

Small positive values of the index of compaction indicate that some disturbance of the soil core is taking place when either the augered soil sampler or the pushed soil sampler was used (Fig. 3). The augered soil sampler seems to disturb the core less than the pushed sampler, however, and has an index of compaction value of less than 1%. This value would mean that using the augered soil sampler could decrease the average value of bulk density by 0.010 Mg/m^3. The pushed soil sampler has an index value of greater than 3.75% and could decrease the value of average bulk density by 0.040 Mg/m^3. These differences are statistically significant at the 1% level.

Fig. 4 shows the different indexes for each depth and each sampler type. The largest errors with either the pushed or the augered soil sampler occur near the surface. These errors were in excess of 6 %. Below this depth some compaction was expected due to the weight of soil in the upper layers on the layers beneath. The index of compaction with the augered soil sampler decreases to near zero at the 5- to 10-cm depth and gave a very good sample. The augered soil sampler slightly compacted the soil sample at greater depths but still obtained samples within acceptable error tolerances. The compaction index with the pushed soil sampler, however, gradually decreased from above 6% at the surface to just slightly above 2% at the 15.3- to 20.4-cm depth. Soil sample disturbance takes place at each depth.

The bulk density of the soil samples averaged over all depths and all treatments is decreased slightly through the use of a Teflon™ coating (Table 1). The difference is slight, however, and is not significant even at the 25%

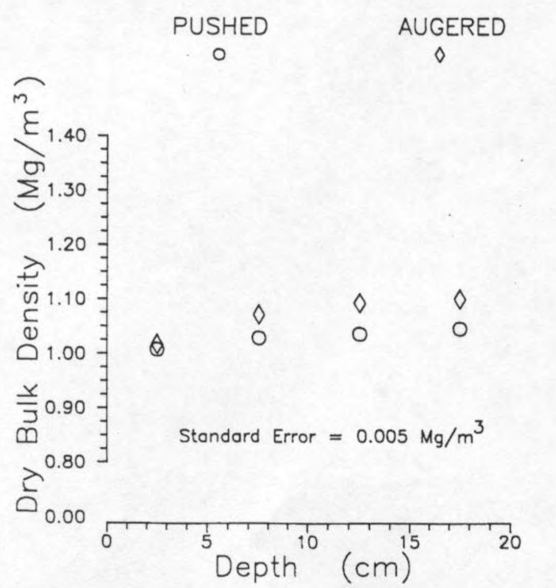

Fig. 2—Bulk density plotted vs. depth for pushed and augered soil samplers.

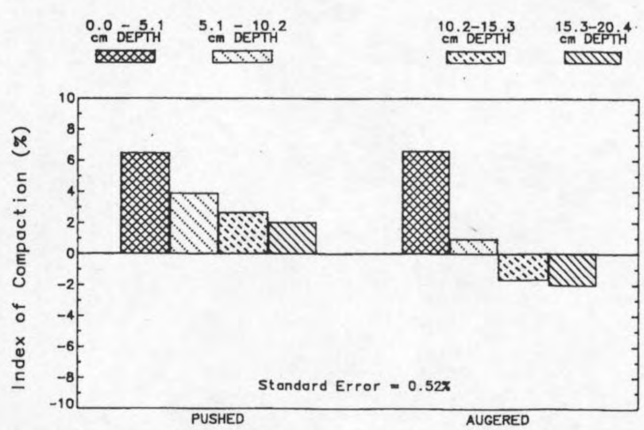

Fig. 4—Indexes of compaction showing effect of sampler type on depth.

TABLE 2. RESULTS OBTAINED FROM THE FIELD EXPERIMENTS

	Moisture content, %	Bulk density, Mg/m^3
Augered	29.22	1.254
Pushed	28.82	1.229
Average	29.02	1.242
LSD (0.05)	0.28	0.023

TABLE 3. BULK DENSITY VALUES OBTAINED FROM FIELD EXPERIMENT SHOWING EFFECT OF AUGER ON TREATMENT RESULTS

	Tillage treatment		
	No-till	Paraplow™	Chisel plow
	Bulk Density, Mg/m^3		
Augered	1.304	1.210	1.249
Pushed	1.283	1.166	1.238

LSD (0.05) = 0.028 Mg/m^3 used for comparing tillage treatment results

level. This lack of a trend seems to be consistent with depth, and no large differences are noticed at any depth.

The effect of Teflon™ was found to be very small and did not have a significant effect on the index of compaction, even at the 20% level. The interaction of Teflon™ and soil sampler type had no significant effect on the index of compaction.

Field Experiment

The results obtained from the field research verified the results obtained from the laboratory research concerning the augered soil sampler. The bulk density values averaged over all depths and treatments showed that the augered soil sampler took samples of 0.025 Mg/m^3 higher bulk density than did the pushed soil sampler (Table 2). This effect was significant at the 5% level. The investigation of bulk density averaged at each of the depths showed larger differences occurring in the upper 20 cm than in the lower 20 cm (Fig. 5). The augered soil sampler seems to show a layer of soil of lower bulk density just beneath the 20-cm depth. The pushed soil sampler shows no such inconsistency, inasmuch as values of bulk density obtained with this sampler gradually increase with depth.

Errors as large as the bulk density differences could mask treatment differences and could reduce the effectiveness of some experiments. Differences in bulk density averaged over all depths from the use of the two samplers range from 0.011 Mg/m^3 in the chisel-plow treatments to 0.044 Mg/m^3 in the Paraplow™ treatment (Table 3). Analyzing the data for each soil sampler separately shows that no matter which sampler was used, tillage treatment effects are still significant at the 5% level. However, the tillage treatment data obtained with the augered soil sampler are slightly more significant ($p = 0.012$) than with the pushed soil sampler ($p = 0.015$).

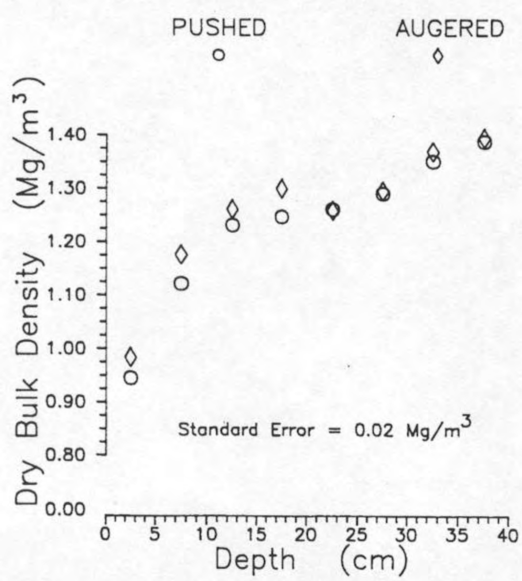

Fig. 5—Bulk density values obtained from field experiment showing effect of auger.

CONCLUSIONS

The conclusions that can be drawn from this experiment are that:

1. Bulk density measurement accuracy can be maximized by using an augered soil sampler to take soil core samples.

2. Coating the soil core sampler tip with Teflon™ does not significantly reduce the frictional forces enough to improve the accuracy of bulk density measurements.

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