A COMPOSITE SAMPLING TECHNIQUE TO ASSESS URBAN SOILS UNDER ROADSIDE TREES[1]

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Abstract. Soils underlying roadside sugar maple (*Acer saccharum* Marsh.) trees in an urban setting were studied to determine the relative advantages of a ten-point composite sampling scheme over the more common practice of averaging analytical results from a few individual samples. The soil samples near the crown periphery were systematically extracted using a hammer-driven tube sampler and composited using equal volumes from each point. Mineral soils were partitioned into 0-15 and 15-30 cm depth components. Duplicate composite samples were obtained for each of 12 trees. Four individual soil samples also were extracted with a larger tube sampler from the same region and depths. Coefficients of variation and numbers of samples needed to estimate the mean within ten percent at the .05 probability level were computed for various chemical and physical measurements. The ten-point composite method consistently displayed a pronounced reduction in variation of analytical results and provides a considerable savings of laboratory time. Specifications for sampler design and utilization are described.

Trees situated in an urban environment are subjected to stress factors not encountered by trees in a forested setting (Tattar 1978). The area encompassed by urban and industrial developments continues to expand at a high rate, making it increasingly necessary to deal with problems specific to metropolitan soils. Frequently, these problems are associated physical or chemical properties (Mader and Thompson 1969). Proper diagnosis of soil conditions is dependent on extracting representative soil samples from the site. Attempts to assess soil parameters are complicated by the disturbed and heterogeneous nature of most urban soils. Urban soils should be sampled by depth increments rather than by soil horizons due to the lack of a distinct vertical profile. Information is needed on the variability of urban soils in order to implement sampling designs that will allow discrimination of appropriate soil properties. This is crucial if valid prescriptions are to be generated (Mader 1974). This study is part of a larger study investigating the decline of roadside sugar maple (*Acer saccharum*) trees. The intent of this study is to demonstrate whether a composite sampling scheme can appreciably lower the variation of analytical results when compared with the more common practice of averaging results from several individual point samples. The description and implementation of a sampling device for urban soils are detailed.

Materials and Methods

Twelve roadside sugar maple trees ranging in size from 50-106 cm (20-42 in) dbh were chosen from a study group of 40 trees. All trees had soil under 60-100% of their crowns. Several assumptions were made concerning feeder root distribution:

1) Roots will not occupy the area under a paved road due to low O_2 status (Van Camp 1961).
2) If a driveway is not paved, roots will occur at a depth where soil compaction no longer impedes root growth (Goss *et al* 1975, Wiersum 1957).
3) When roots encounter the edge of a paved road they tend to branch out and parallel the road (Bernatzky 1978, Horsley and Wilson 1971).
4) The greatest concentration of feeder roots will be in the top 30 cm of mineral soil (Pritchett 1979).
5) Feeder roots of sugar maple will predominate at the crown periphery (Tubbs 1977).

Figure 1 illustrates the typical situation for a tree in this study. The asterisks designate where the ten composite points were taken. If the dripline extended over an unpaved drive, a sample point was located in the drive. Along the road the samples were taken 20 cm (8 in) from the road's

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edge or curb. The four stars indicate where individual point samples were drawn. Two sets of ten-point composite samples were taken for each tree. The second set was taken at the crown periphery from points lying halfway between the first set's points. Analytical results from averaging two composite sets from the 0-15 cm (0-6 in) and two composites from the 15-30 cm (6-12 in) depths were compared to the results obtained from taking four individual point samples from the starred areas and averaging the separate lab results for these samples by depth.

The sampler developed for the ten-point composite scheme is shown in Figure 2. It is essentially a hammer driven, open faced auger that is designed to probe mineral soil to a depth of 30 cm. Organic layers are not analyzed and should be dismissed. Each sample point will yield 125 cc (4 oz) of soil or 62.5 cc (2 oz) for each of the two depth components. It is best to discard a portion of the soil by leveling the cutout trough with a blunt knife. This insures a constant volume per sample point and eliminates contamination of the sample engendered by smearing as the sampler is retrieved from the ground. The net yield is closer to 50 cc (1.5 oz) for each depth. This results in a composited sample of 500 cc (16 oz) per depth component. If a bulk density of 1.2 g/cc is assumed, a 600 g (1.3 lb) sample will be available for lab analysis. Even if the coarse fraction is as high as 50%, a sample of sufficient size remains.

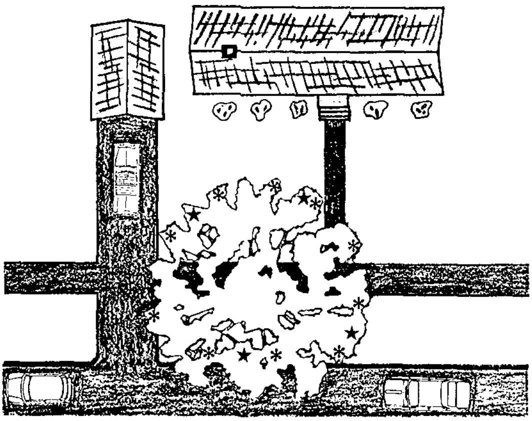

Fig. 1. Typical situation for study tree. The ten asterisks designate composite sample points. The four stars indicate the location of individual point samples.

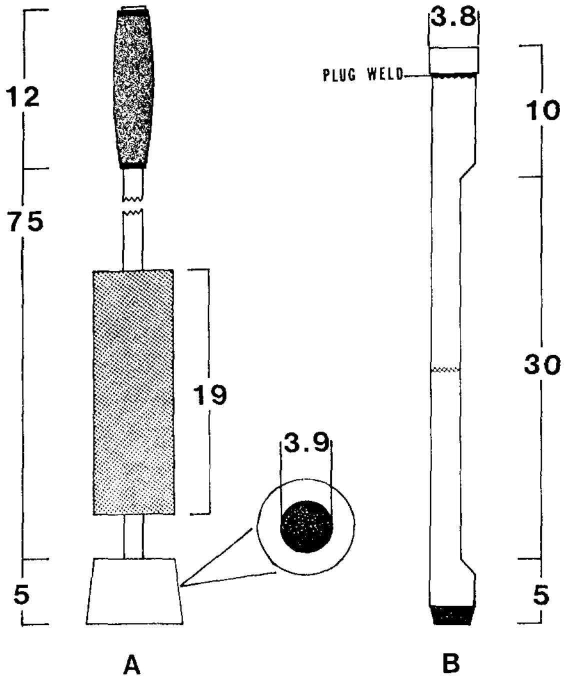

Fig. 2. Diagram of sampling equipment. A = slide hammer; B = composite soil sampler. Units of measure given in centimeters.

The sampler is subjected to extreme stress as it is driven through stones, roots, and soil by the weight affixed to the slide hammer (Fig. 2A). Dimensions for the sampler are given in Fig. 2B. The wall of the pipe should be 3 mm (0.12 in) thick. The sampler can be made either from a piece of hollow pipe which is then plugged at one end or from a solid rod which is then machine hollowed. A high quality oil hardening pipe such as American Industrial Steel Institute (AISI) 4340 will flex well under continual stress. Replaceable oil hardened and drawn tool steel tips can be fashioned from AISI 01 stock. The tips are coarse threaded into the sampler body. The inside diameter (ID) of the tip should be 2.3 cm (0.91 in). The inside diameter of the tube is 2.7 cm (1.06 in). When end milling out the 30 cm long trough make the inside width of the cutout 2.3 cm (the same as the tip ID). This will facilitate sample removal while leaving the sampler strength intact. If a hollow pipe is used, a solid steel plug must be machined. Make the plug long enough so that it fills the length of pipe down to the cutout. The plug is arc welded in place and its head serves as the male coupler to the slide hammer. The diameter of the head is 3.8 cm (1.50 in). The sample head is also where a chain wrench is attached in order to turn and lift the sampler from the ground.

The slide hammer (Fig. 2A) needs a free rod length of about 75 cm (30 in) to allow enough room for the operator to generate the force needed to drive the sampler into compact or stony soils. A 4.5 kg (10 lb) weight was used for our hammer. The rod should be a minimum of 1.5 cm (0.60 in) in diameter. Fine threads should be used to attach the rod to the female coupler. It helps to thread the rod enough so that it can bottom out in the coupler rather than placing the stress on the threads. The ID of the slide hammer coupler is 3.9 cm (1.54 in), corresponding to the sampler coupler. A gnarled pattern machined onto the weight and a wooden handle make the driver easier to use in the field.

Results and Discussion

The results from lab analysis for 15 commonly determined soil properties were first averaged for composite and individual point samples by depth for each tree. The coefficients of variation (COV) were computed to give a standard measure of percent deviation from the sample means for purposes of comparison. The numbers of samples needed to estimate the sample mean within ten percent at the 95% confidence level were computed. A t value of 2.0 was assumed (Alban 1974). The COV and number of samples needed were then averaged for the 12 trees on composite and individual samples by depth. Table 1 shows data for the 15 parameters assayed. They are ranked by order of COV for the 0-15 cm composite samples ranging from lowest to highest. The composite scheme displays an obvious reduction in the COV for all soil properties studied. The reduction is more pronounced for the lower depth component than at the 0-15 cm depth. There is also a pronounced trend for a reduction in

Table 1. Coefficients of variation[1] and number of samples[2] needed to estimate the sample mean of several soil properties within 10% at the 95% confidence level. Results are averaged by depth for twelve trees.

Soil Property	*Coefficient of Variation*				*Number of samples*			
	10-Point composite		*Individual point*		*10-Point composite*		*Individual point*	
	0-15	15-30	0-15	15-30	0-15	15-30	0-15	15-30
pH in $CaCl_2$	0.9	1.4	4.9	5.8	1	1	1	2
pH in H_2O	0.8	1.0	2.5	7.6	1	1	1	3
% sand	2.2	2.4	11.3	13.1	1	1	6	7
% silt and clay	4.5	6.9	20.6	32.2	1	2	17	42
conductivity	5.4	4.9	14.8	29.3	2	1	9	35
% organic matter	5.8	7.5	25.4	38.0	2	4	26	58
carbon/nitrogen	5.9	8.8	11.9	19.6	2	4	6	16
% very fine sand	6.3	6.3	28.0	33.1	2	2	32	44
% nitrogen	6.6	6.6	23.6	35.3	2	2	23	50
cation exchange cap.	8.2	10.3	27.8	35.3	3	5	31	50
magnesium	8.6	8.9	50.7	65.9	3	4	103	174
calcium	9.1	12.2	38.9	58.6	4	6	61	138
potassium	9.5	16.5	34.3	42.8	4	11	48	74
% base saturation	11.8	7.3	40.1	54.3	6	3	65	118
% coarse fraction	13.1	19.3	55.9	83.6	7	15	125	280

[1]COV = std. dev./mean (100)

[2]Number of samples = $t^2(COV)^2/(E)^2$; where t = 2.0 and E = specified error as percent of mean, most often for soils the error is set at 0.10.

COV standard deviation associated with this system.

The easiest parameter to estimate is soil pH; it can be estimated accurately from only one composite sample. In general soil physical properties are less variable than chemical ones. This appears to be the case with sand, silt, clay, and organic matter, but the reverse is seen for the coarse fraction estimate. The determination of coarse fraction 2 mm (0.118 in) poses a problem for both sampling systems. If chemical results are to be converted to an original soil basis large variations can be introduced in the estimates of nutrient statuses. For purposes of comparison the chemical properties reported in this paper are on a sieved soil basis. The number of samples needed corresponds to the COV calculations. There are pronounced reductions in the number of samples needed for both depths with the composite system.

The composite sampler is superior to a screw auger for extracting soil samples by depth increments. For compositing purposes, it allows for a constant volume retrieval for each sample point. This is essential for maintaining the accurate point proportioning necessary to reduce sample variation and increasing accuracy.

Conclusion

The use of a composite sampling design such as the one discussed in this paper will increase the accuracy of both physical and chemical soil property estimates. Soil variation appears to be more pronounced at the 15-30 cm depth than at 0.15 cm. Composite samples give better estimates of soil parameters with fewer samples. This results in a considerable savings in laboratory costs and time. The composite soil sampling system has been demonstrated to be superior to individual point sampling. The sampler, itself, leads to more accurate sampling than the more conventional screw auger.

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