

Correlations between extractable Na, K, Mg, Ca, P & N from fresh and dried samples of two Aquults

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SUMMARY

Significant increases in extractable ions resulted from air-drying and grinding samples of two infertile Aquults. Effects of the sample preparation differed markedly between ions and between the two soils. Regression equations were calculated to predict extractable ions in dried, ground samples from extractable ions in fresh, unground samples and the relationships were compared between the two soil series. Regressions were significantly different between soils for extractable PO_4^{3-} , Mg^{++} , and K^+ , but not for Ca^{++} and Na^+ . Extractable NH_4^+ and NO_3^- in fresh, unground samples were not correlated with those in air-dry, ground samples of either soil. Differences in response to preparation between soil types appeared to be related to the oxidative status of these soils in the field, wherein constituents of more poorly-drained soils may be less stable to the oxidizing conditions of air-drying and grinding. Such complexities suggest that effects of sample preparation should be considered when interpreting soil nutrient data for studies of forest nutrient cycling and forest soil fertility.

INTRODUCTION

Many evaluations of soil fertility are made with highly prepared soils. Extractable cations and phosphate are virtually always determined on air-dried soils that are often subjected to grinding. Better understanding of these effects is important in interpreting soil nutrient data. Although the agricultural literature contains studies of the effects of soil preparation, such effects are not so well documented for extremely acid forest soils.

Sample preparation affects extractability of ions both through changes in inorganic and organic constituents caused by drying, and through alteration of soil particles as a result of grinding. During drying, for example, Al^{3+} may move from clay lattices to exchange sites (Mathers *et al.*, 1955), and exchangeable K^+ may increase by Al^{3+} replacing K^+ in nonexchangeable sites of soil minerals (Carter *et al.*, 1963). Air-drying also may increase the solubility and oxidizing ability of soil organic matter (Raveh & Avnimelech, 1978). Changes caused by drying in the chemistry of soil N and P, usually associated with changes in organic matter, are well-documented (Gilliam & Richter, 1985).

Soil grinding causes physical breakdown of soil microaggregates. Since N mineralization rates (and thus N extractability) have been shown to increase with decreasing particle size (Waring & Bremner, 1964; Sollins *et al.*, 1984), it appears that both drying and grinding soils may alter the extractability of ions through sample preparation procedures.

In an earlier paper (Gilliam & Richter, 1985) we presented results of soil sample preparation effects on extractable ions. All ions analysed (NH_4^+ , NO_3^- , PO_4^{3-} , Ca^{++} , Mg^{++} , K^+ , and Na^+) exhibited some degree of increased extractability in response to air-drying and grinding of soil. Concentrations of most ions were correlated between dried and ground samples and those that were field-moist and unground. Such correlations were based on data for samples taken from different soil series. The objective of this study was to examine quantitative relationships of extractable ions between prepared and fresh soil samples as they varied in two soil series.

Table 1. Regression equations for extractable ions from dried, ground versus fresh, unground samples from low-lying Bethera and upslope Wahee soils

Ion	Bethera			Wahee		
	Intercept	Slope	r^2	Intercept	Slope	r^2
Ca ⁺⁺	-19.34	1.33	0.93	0.35	1.25	0.90
Mg ⁺⁺	-18.26*	1.58*	0.90	3.10*	1.09*	0.87
K ⁺	20.22*	0.91	0.30	10.73*	0.82	0.76
Na ⁺	5.95	1.15	0.92	4.16	1.15	0.38
PO ₄ ³⁻ -P		NS†		0.35	1.25	0.90
NH ₄ ⁺ -N		NS			NS	
NO ₃ ⁻ -N		NS			NS	

*Significant differences ($P < 0.05$) between soil series for intercepts or slopes indicated by an asterisk

†NS = not significant at $P < 0.05$.

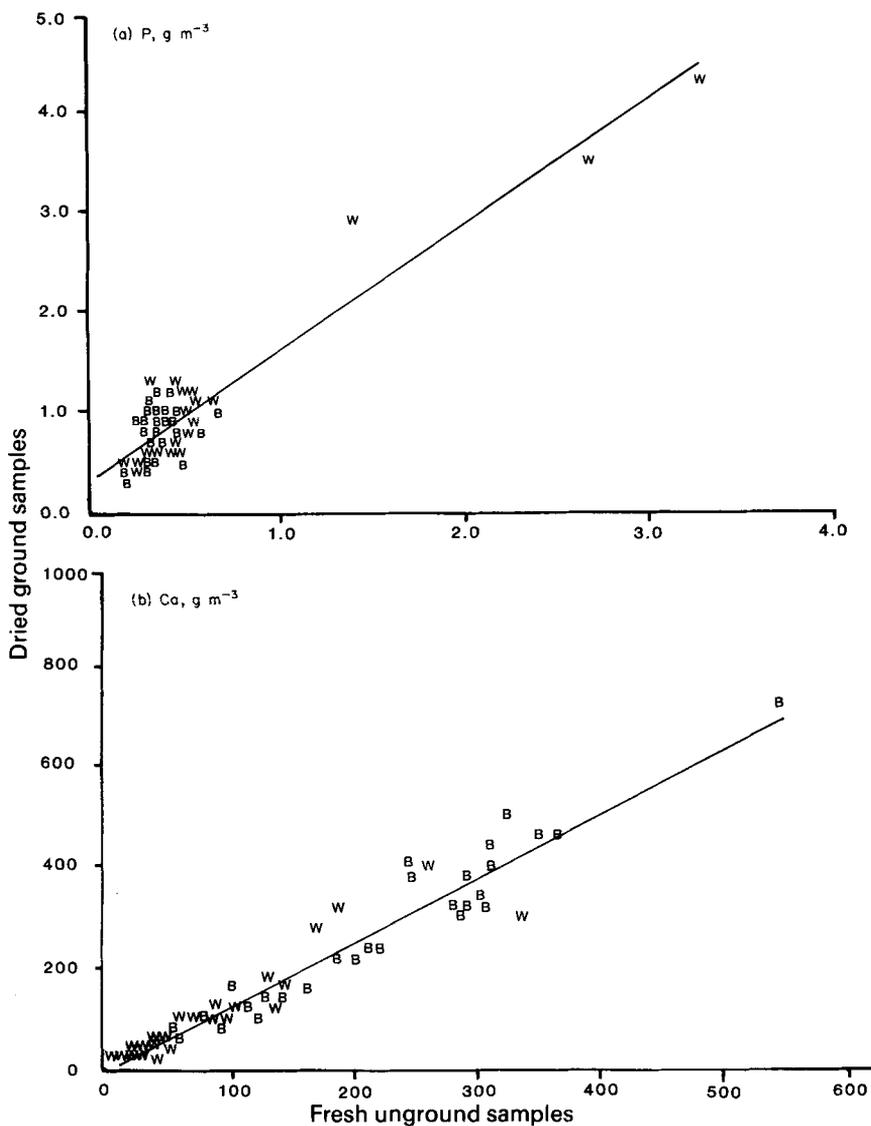
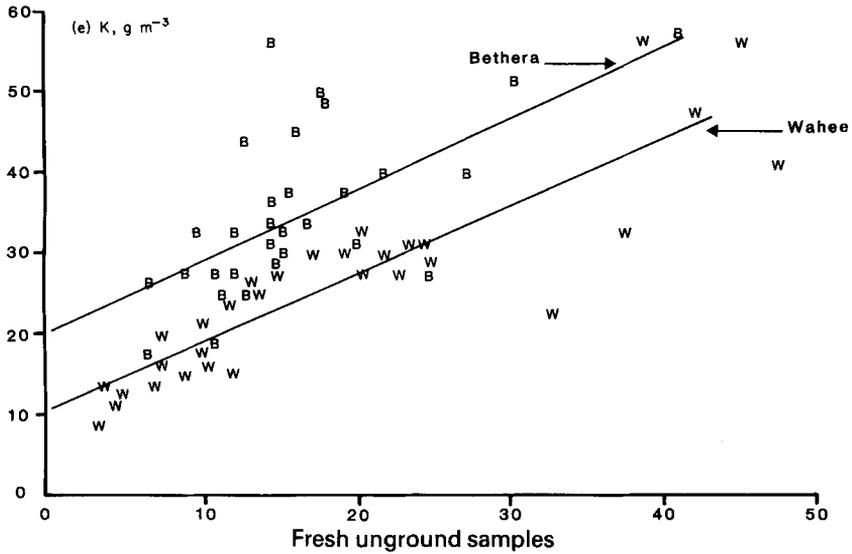
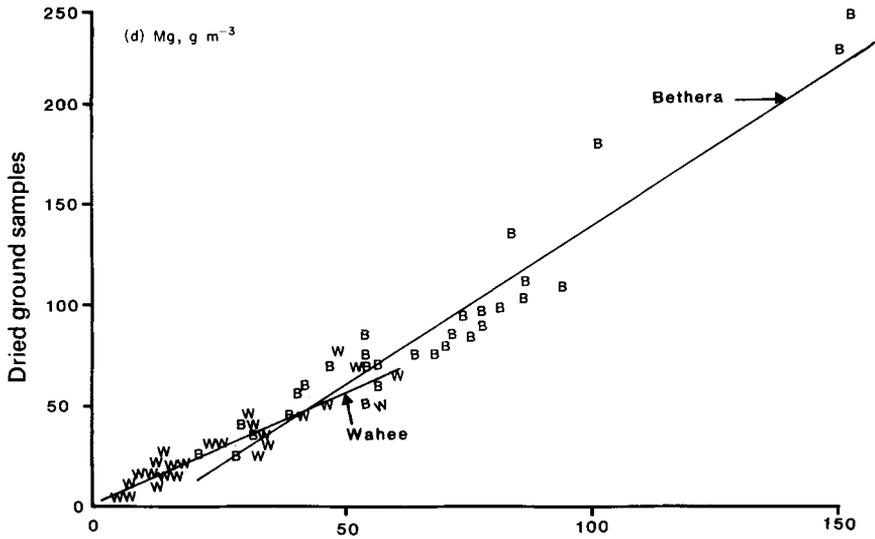
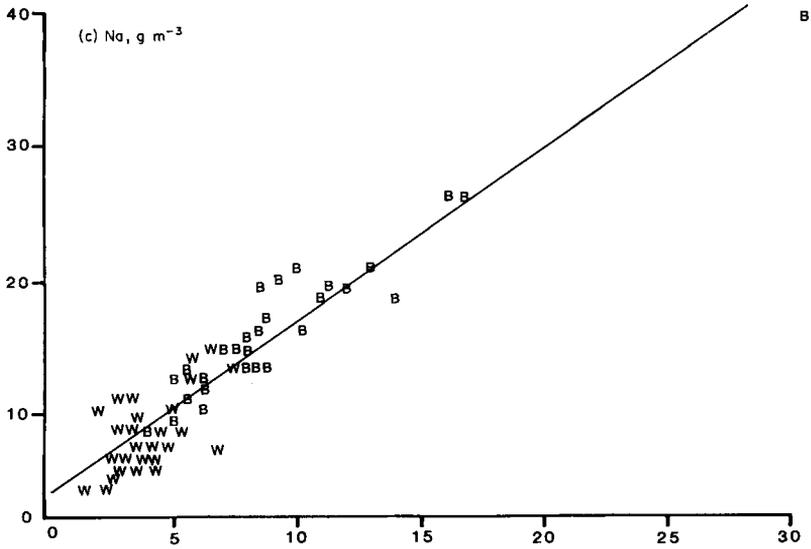


Fig. 1. Relationships between concentrations of extractable ions (g m^{-3}) from fresh and prepared soil samples of Bethera (B) and Wahee (W) series. The regression equations for P (Wahee only), Mg & K are given in Table 1. Pooled soil data for Ca & Na give the expressions: Ca $y = 3.45 + 1.27x$, $r^2 = 0.94$; Na $y = 4.27 + 1.27x$, $r^2 = 0.89$. All regressions are significant at $P < 0.05$. Coincident points are represented by a single symbol.



METHODS

Study site

Soils were sampled at the Santee Experimental Forest in Berkeley County, South Carolina in the lower Atlantic Coastal Plain. Although topographic relief within first-order watersheds in the area varies by less than about 5.5 m, soil conditions (particularly moisture) vary greatly with topographic position. Soils representing extremes of these conditions were sampled from two areas. The Bethera series (clayey, mixed, thermic Typic Paleaquults) occurs along low-lying drainages and has strongly gleyed subsoils. The Wahee series (clayey, mixed, thermic Aeric Ochraqults) occurs on upslope, nearly level terraces and has distinctly mottled subsoils. Bulk density in the 0–5 cm of soil averages 1.1 g cm^{-3} for both soils, and pH (1:1 water) averages about 4.5 (Gilliam, 1983; Richter, 1980). Further details of the site, including climate and vegetation, have been given in Gilliam & Christensen (1986).

Soil sampling and chemical analysis

Paired samples were taken in the field from 10 plots ($10 \times 10 \text{ m}$) in each of the two soil types. Samples were separated into 0–5, 5–10, and 10–20 cm depths (Gilliam & Richter, 1985). One set of samples of each pair was dried for 20 d and ground to reduce the size of larger clay aggregates formed during drying; these are referred to as 'prepared' samples. The other set was stored in plastic bags at 3°C and separated (for large aggregates) with a spatula before extraction; these are termed 'fresh' samples. Both sets of samples were then extracted with a dilute acid solution (0.05 M HCl with 0.0125 M H_2SO_4) following Mehlich (1953). This technique is well suited for acid clay soils and is commonly used for soil fertility studies in the Coastal Plain (Gilliam & Richter, 1985). Extractable phosphate was determined by molybdenum blue colorimetry (Mehlich, 1953) and extractable Ca^{++} , Mg^{++} , K^+ , and Na^+ were determined by atomic absorption spectrophotometry (Isaac & Kerber, 1971). NH_4^+ and NO_3^- were measured by the method of Gilliam & Richter (1985).

RESULTS

Concentrations of most extractable ions were correlated strongly between prepared and fresh samples (Table 1 & Fig. 1). Regression coefficients were not significantly different between sampling depths for extractable ions. Data for all sampling depths were pooled to test differences between the Bethera and Wahee series.

Comparisons of regression coefficients between soil series were inconsistent among extractable ions (Table 1). Regression equations were not significant for predicting NH_4^+ - and NO_3^- -N in dried, ground samples using appropriate measurements in fresh, unground samples. Regressions of extractable ions in prepared versus fresh soils were significant ($P < 0.05$) for all other comparisons except P in the Bethera series. The regression line in Fig. 1a thus represents the relationship for P in the Wahee series only. Intercepts were significantly different between soil series for both Mg^{++} and K^+ . Furthermore, differences between regression coefficients (slopes) for the two series were significant for Mg^{++} (Table 1). Relationships for each soil series are given for Mg^{++} and K^+ in Figs. 1d & 1e, respectively. Neither the intercepts nor regression coefficients for Ca^{++} and Na^+ were significantly different between series. Relationships for Ca^{++} and Na^+ , representing both series combined, are shown in Figs. 1b & 1c, respectively.

DISCUSSION

Table 1 & Fig. 1a-e indicate that the extractability of some ions for the two soils differed in response to sample preparation. These differences were probably related to topographic factors, specifically the influences of redox conditions associated with groundwater fluctuations, of leaching, and of parent materials. Although both soils are Aquults, seasonally dry conditions are much more pronounced in Wahee soils, which are noted for their distinctly mottled profiles. Bethera soils, found in low-lying drainages, are not as mottled and are markedly gleyed. Preparation, particularly air-

drying, of samples of low-lying Betheria soils may release more extractable ions than preparation of Wahee samples because organic and inorganic constituents in Betheria soils are less stable to oxidizing conditions.

Topographic position affects leaching characteristics, which may also contribute to differences between soil series in extractable ions. Betheria soils occur in receiving positions along drainages and thus receive runoff and leached materials from Wahee soils which are located upslope. These differences seemed particularly important for extractable K^+ , Ca^{++} , Mg^{++} , and Na^+ (Fig. 1b-e).

In these Coastal Plain sites, topographic position affects the sedimentary deposits from which soils are formed. Calcareous marine deposits underlie many of these local regions (USDA, 1980). First-order drainages are occupied by Betheria soils which are often replaced by soils of the Meggett series characterized by marl fragments throughout the profile. The high Ca^{++} and high pH of the Meggett series result from exposure to calcareous substrata at lower elevations. These calcareous marl layers may influence Betheria soils and may account for the higher exchangeable Ca^{++} and Mg^{++} in Betheria soils compared with upslope Wahee soils.

Although there was total net mineralization of N of 2.5 and 3.2 g m⁻³ in Wahee and Betheria soils, respectively, in response to drying (Gilliam & Richter, 1985), concentrations of both NH_4^+ -N and NO_3^- -N in prepared samples were not significantly related to those in fresh samples (Table 1). Available N in intact soils of this watershed is low and, indeed, these flatwood ecosystems appear to be N-limited (Gilliam, 1983). Factors limiting N mineralization and nitrification, such as low pH and high C/N ratios, may influence the N dynamics of these soils to a greater extent than the effects of sample preparation.

Changes in extractability of ions in these forest soils, due to sample preparation, are to some degree predictable. Such effects, however, may vary greatly between different soils. The sources and mechanisms of ion release during drying and grinding of samples are complex. Potentially antagonistic effects, for example, may result from preparation, particularly for PO_4^{3-} in these clay soils, since grinding simultaneously exposes more soil surface to acid extraction (increasing concentrations in the extract) and makes more adsorption sites available (decreasing concentrations).

Studies on a variety of soil types have reported increases in extractable N and P in response to drying and other storage and handling methods (Bartlett & James, 1980; Patten *et al.*, 1980; Anderson & Beverly, 1985). Results from this study, and from that of Gilliam & Richter (1985), confirm conclusions that these increases are related to changes, such as rapid decomposition and subsequent increased solubility, in soil organic matter, particularly in response to drying. Mack (1963) concluded that increases in biological activity following freezing/drying were directly related to initial organic matter content of Canadian forest and solonetz soils. In addition, cation data in our study and those of Bartlett & James (1980) suggest that mineral fractions may respond similarly.

Anderson & Beverly (1985) examined the effects of drying on extractable P and K from organic and mineral soils of the Florida Everglades. The most substantial increases in extractability occurred in the more poorly-drained organic soils: this conclusion supports our observation that the Typic Paleaquults (Betheria) were more sensitive to preparative drying and grinding than the Aeric Ochraqults (Wahee). It is a reasonable hypothesis that soil's response to oxidative drying depends on the instability of mineral and organic components produced under natural drainage conditions. Thus, many forest soils should show appreciable changes in ion extractability upon drying and grinding, such as those presented here. Conversely, more well-aerated agricultural soils should exhibit much smaller changes.

The complexities in soil response discussed here indicate the importance of recognizing the potential effects of sample preparation when interpreting soil nutrient data for nutrient cycling and soil fertility studies. Agronomic experience has detailed many of these effects; thus the need to quantify soil preparation effects is particularly important in fertility studies of forest soils.

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