2002

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Nutrient Cycling in Agroecosystems **63:** 251–254, 2002.

The effect of soil moisture on mineral nitrogen, soil electrical conductivity, and pH

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Key words: ammonium, inorganic nitrogen, nitrate, water-filled pore space

Abstract

Inorganic nitrogen in the soil is the source of N for non-legume plants. Rapid methods for monitoring changes in inorganic N concentrations would be helpful for N nutrient management. The effect of varying soil moisture content on soil mineral nitrogen, electrical conductivity (EC), and pH were studied in a laboratory experiment. Soil NO_3-N increased as soil water-filled pore space (WFPS) increased from 0 to 80 cm^3 cm^{-3}. At soil moisture levels greater than 80 cm^3 cm^{-3}, NO_3-N concentration declined rapidly and NH_4-N concentration increased, likely due to anaerobic conditions existing at higher WFPS levels. Soil pH did not change as soil moisture increased from 100 g kg^{-1} to 400 g kg^{-1} and increased from 6.2 to 6.6 at higher levels of soil moisture. Soil EC was correlated with soil mineral N concentration when measured *in situ* with a portable EC meter (R^2=0.85) or in the laboratory as 1:1 soil water slurries (R^2=0.92). Results suggest that EC can be used to rapidly detect changes in soil inorganic N status in soils where salts and free carbonates are not present in large amounts.

Introduction

Soil electrical conductivity (EC) is useful as a relative measure of the total quantity of ions in the soil solution. Soil EC has no direct effect on crop growth or yield, but it is frequently observed that there are close relationships between EC and a variety of other soil properties that are highly related to crop growth and yield (Olson, 2000). Soil EC has also been used to indicate groundwater nitrate contamination (Drommerhausen et al., 1995), and for soil assessment and management. The ease and low cost of determining EC make it useful for monitoring nutrients in greenhouses and hydroponics (Adams and Winsor, 1973; Patriquin et al., 1993). Irrigation water EC is also monitored for salinity management.

The standardized method for determining soil EC is on a 1:1 soil water extract using a conductivity bridge or EC probe (Rhoades, 1982). Instruments such as four electrode and time domain reflectometry equipment and electromagnetic induction techniques are also available for determining bulk soil EC directly in the field (Rhoades and Oster, 1986). Field determination of soil EC can also be accomplished using portable electrical conductivity meters. Many of these meters can be calibrated and are inexpensive. Soil EC is known to be influenced by a number of factors including: Soil moisture content, concentration of ions in the soil, type and amount of clay, the soil bulk density (Brune and Doolittle, 1990).

The objective of this study was to determine the effect of soil moisture on soil inorganic N, pH, and EC. We also assessed the potential for using changes in EC, as measured using a portable EC meter, to detect changes in soil inorganic N concentrations. Use of EC as an indicator of changes in soil inorganic N will have utility for soil and fertilizer management in the field.

Table 1. Select soil chemical properties

EC(1:1) dS m^{-1}	pH(1:1)	NH_4-N mg kg^{-1}	NO_3-N mg kg^{-1}	Mineral N mg kg^{-1}
0.47 ±0.01	6.21±0.03	5.10±0.10	27.34±0.40	32.45±0.30

Materials and methods

Soil collection and incubation study

A Hastings silt loam soil (Fine, smectitic, mesic Udic Argiustoll) was collected from the 0–20 cm depth at the University of Nebraska South Central Research and Extension Center near Clay Center, NE. The field had been cropped to corn (*Zea mays* L.) prior to sampling. The soil was air dried and passed through a 2 mm sieve. Select soil chemical properties are given in Table 1.

Soil samples were incubated under a range of soil moisture conditions created by packing 100 g of soil to a bulk density of 1.15±0.1 g cm^{-3} and adding distilled water (10, 15, 20, 25, 30, 35, 40, 50, 60, and 70 ml). This resulted in soils having WFPS levels of 20.3, 30.5, 40.6, 50.8, 61.0, 71.1, 81.3, 101.6, 121.9, and 142.2 cm^3 cm^{-3}. The soil was incubated at 25 °C for 32 days. The experiment was replicated three times. Soil EC was measured *in situ* with a modified portable EC meter after 32 days. After 32 days, the soils were air dried and analyzed for EC, pH, NO_3-N, and NH_4-N. For *in situ* measurement of EC heavy copper wire was attached to the pins of a commercial EC meter (Dist WP 4, Hanna Instruments, Portugal). To make a measurement the copper wires were inserted into the soil and the EC was read from the meter. Laboratory determination of EC and pH were made on 1:1 slurries of air dried soil and water (Smith and Doran, 1996). Inorganic N concentrations were determined on 2 *M* KCl extracts colorimetrically using a flow injection analyzer (Quikcheml' 8000, Zellweger Analytics Inc., Lachat Instruments Div., Milwaukee, WI).

Result and discussion

Effect of soil moisture on mineral N

After 32 days of incubation, total inorganic N and NO_3-N concentration increased as soil moisture increased from 0 to 80 cm cm^{-3} WFPS (Figure 1).

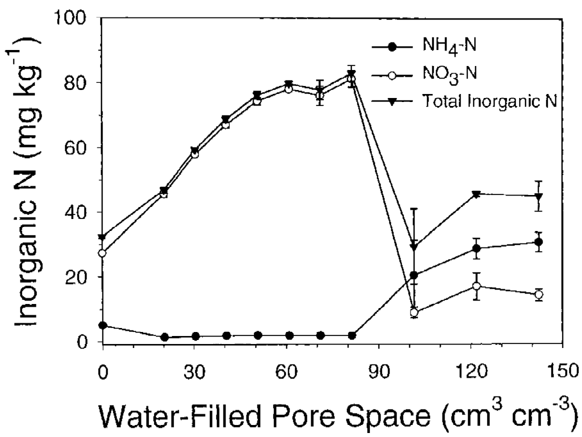

Figure 1. Soil inorganic N concentration as a function of water-filled pore space after 32 days of incubation.

At WFPS greater than 80 cm cm^{-3}, total inorganic N and NO_3-N concentrations declined. Ammonium-N concentrations were very low until WFPS values exceeded 80 cm^3 cm^{-3} and then NH_4-N became the dominant form of inorganic N in these soils. As soil WFPS increased from 0 to 80 cm^3 cm^{-3} conditions for aerobic soil microbes improved and reached an optimum near 80 cm^3 cm^{-3} with nitrification being the dominant microbial process. At WFPS levels greater than 80 cm^3 cm^{-3}, anaerobic conditions developed and ammonification became the dominant microbial process in these soils. Lower total inorganic N concentrations at WFPS levels greater than 80 cm^3 cm^{-3} are likely due to lower mineralization rates under anaerobic conditions, volatilization losses of ammonia, or denitrification losses of N under these conditions (Firestone, 1982).

Effect of soil moisture on pH

Under aerobic conditions, pH remained essentially unchanged in this soil during 35 days of incubation (Figure 2). When WFPS levels exceeded 80 cm^3 cm^{-3} and anaerobic conditions became established, pH increased likely due to the presence of NH_4-N. While nitrification is an acidifying process the 0.1 pH unit

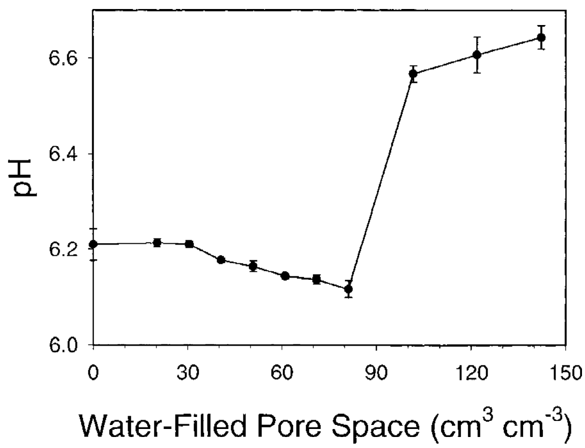

Figure 2. Soil pH as a function of water-filled pore space after 32 days of incubation.

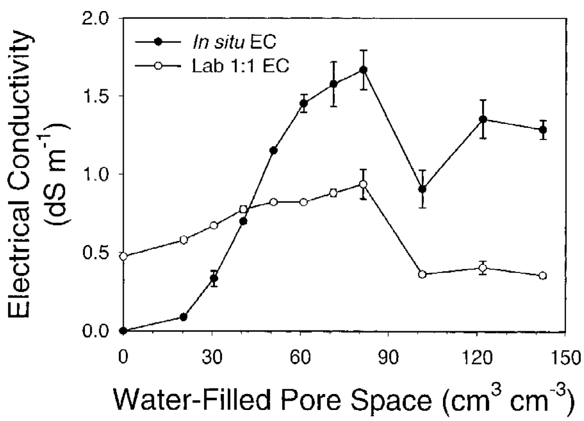

Figure 3. Soil electrical conductivity as a function of water-filled pore space measured *in situ* and in a 1:1 soil water slurry.

change observed in this study is modest (Raveh and Avnimelech, 1973). A greater change in soil pH occurred when NH_4-N became the dominant form of inorganic N in this soil. None of the pH changes associated with mineralization across the range of moisture contents used in this study were large enough to affect nutrient availability or plant growth.

Effect of soil moisture on electrical conductivity

Laboratory and *in situ* measured EC increased as WFPS increased from 0 to 80 cm^3 cm^{-3} and decreased at higher levels of WFPS (Figure 3). Differences in EC across WFPS treatments were much greater when measured *in situ* than when measured in the laboratory. Type and amount of clay, water content, temperature, and ion concentration all effect soil EC measurements. Laboratory measurements of EC

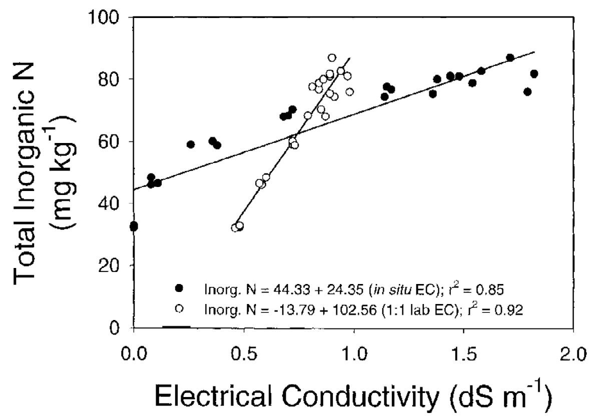

Figure 4. Linear relationship between soil inorganic N and electrical conductivity measured *in situ* and in a 1:1 soil water slurry.

are made under standardized conditions, 1:1 soil water slurry and 25 °C, so that water content and temperature effects are removed. When a single soil type is used across treatments the type and amount of clay is similar and changes in laboratory measured EC are due to changes in ion concentrations. *In situ* measured EC is taken under varying moisture conditions across WFPS treatments and *in situ* measured EC reflects differences in water content as well as ion concentration.

Under aerobic conditions, there is a linear relationship between NO_3-N concentrations and EC in this soil (Figure 4). These results suggest that EC may be used to estimate increases in NO_3-N concentration in soils due to mineralization and decreases in NO_3-N concentration due to immobilization and plant uptake. Use of EC to estimate NO_3-N concentrations will only work in soils that do not have high salt concentrations or free carbonates present.

Use of EC to estimate NO_3-N concentration is much more rapid than soil sampling and laboratory analysis and will be useful in improving our understanding of N dynamics in soils. *In situ* EC measurements may also have utility in N fertilizer management programs where sidedress applications of N are made after the crop is established. Rapid estimation of soil NO_3-N concentration using EC would allow timely N applications. Use of EC in N fertilizer management programs would reduce labor (soil sampling) and cost (laboratory analysis) and may increase the adoption rate of N management practices that are known to improve N use efficiency and reduce the potential for environmental contamination.

Acknowledgement

The authors thank Spencer Arnold and Susan Wagner for laboratory assistance.

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