Soil Nitrogen and Phosphorus Behavior in a Long-Term Fertilization Experiment

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ABSTRACT

Accurate fertilizer recommendations rely on quantitative estimation of nutrients supplied by soil and fertilizer nutrients immobilized by soil. Understanding variation in these processes over space and time is critical for site-specific nutrient management. Our objective was to characterize spatial variability in N and P cycling for a corn [Zea mays L.]–soybean [Glycine max (L.) Merr.] rotation in southern Minnesota glacial-till soils. Soil samples and grain yield measurements were taken annually from 0.014-ha cells within two 16-ha fields. We determined effects of fertilizer P additions and crop P removal on soil test phosphorus (STP) and determined relationships between STP changes and soil variables. We also determined temporal stability of soil mineralizable N and inorganic N. The spatial patterns of mineralizable N were consistent over time. The spatial pattern of soil NO₃–N was consistent with mineralizable N at a well-drained site, but not at a poorly-drained site. Change in STP per kg P net addition or removal exhibited spatial autocorrelation. Declines in STP under net P removal were directly related to initial STP values. Increases in STP under net P addition were significantly related to pH at both sites and mineralizable N at one site. Temporal stability in mineralizable N suggests that predictive approaches to site-specific N management may succeed when the environment for mineralization is uniform. Within-field variability in the relationship between STP and net P addition may substantially affect fertilizer P rates required to attain critical STP values and should be accounted for in variable-rate P applications.

VARIABLE-RATE APPLICATION of crop fertilizers has become one of the most widely-used site-specific management practices for agricultural fields. By accurately matching fertilizer application rates to crop requirements, this practice has the potential to enhance economic returns to farmers by optimizing use of resources at each point on the landscape (Lambert et al., 2006; Wolf and Nowak, 1995). In addition, environmental impacts associated with excessive fertilization or poor crop growth may be minimized. Adoption of variable-rate fertilizer application has been driven by numerous reports in recent years indicating that a great deal of variability exists in the levels of soil nutrients, and that this variability is spatially correlated at distances of tens to hundreds of meters (Cahn et al., 1994; Cambardella et al., 1994; Robertson et al., 1997). Variability over scales of meters to hundreds of meters is amenable to management by current precision agriculture equipment (Pierce and Nowak, 1999).

For relatively immobile nutrients such as P, current strategies for planning variable-rate applications consist of soil sampling that is both extensive and intensive, using soil test results to map nutrient availability across the field to create a fertilizer application map designed to attain a particular critical soil test value considered optimum for crop production. Many researchers have worked to develop efficient soil sampling designs that allow accurate mapping of soil nutrient levels (Franzen and Peck, 1995; Kravchenko, 2003; Mallarino and Wittry, 2004; Mueller et al., 2004; Wollenhaupt et al., 1994). However, current fertilizer rate recommendations for given soil test levels are designed to be broadly applicable on a regional or state-wide basis (Mallarino, 2009; Rehm et al., 2006; Sawyer et al., 2008). There are sound reasons to expect that the quantity of nutrient addition required for a unit change in soil test level may differ among soils. These reasons include differences in sorption capacity, mineralization, and fixation capacity, and nutrient loss or accumulation due to runoff and erosion. While a number of researchers have reported soil test incline or decline rates on uniform plots in response to fertilization (Barber, 1979; Dodd and Mallarino, 2005; Leikam, 1992; Randall et al., 1997; Webb et al., 1992), we are not aware of studies that report on differences in soil test incline or decline rates within fields. Lack of such information hinders the optimization of site-specific management for two reasons. First, both accuracy and precision of fertilizer P rate recommendations are reduced, potentially leading to higher variability in soil P (Wittry and Mallarino, 2004) and associated environmental consequences (Mallarino et al., 2001), and also reducing the ability of the producer to rapidly attain the most profitable soil test value (Lowenberg-DeBoer and Reetz, 2002). Second, lack of site-specific information on soil test incline or decline rates prevents site-specific economic

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Abbreviations: AIC, Akaike information criterion; DAP, diammonium phosphate; DEM, digital elevation model; OM, organic matter; PBMN, phosphate–borate mineralizable nitrogen; STK, soil test potassium; STP, soil test phosphorus; TOC, total organic carbon; +ΔP/ΔSTP, net kg phosphorus addition per 1 mg kg⁻¹ increase in soil test phosphorus; −ΔP/ΔSTP, net kg phosphorus removal per 1 mg kg⁻¹ decrease in soil test phosphorus.