PLANT ROOT SIMULATORS: AN EFFICIENT TOOL FOR IN-FIELD NUTRIENT MAPPING

K.J. Greer and J.J. Schoenau
Saskatchewan Centre for Soil Research,
University of Saskatchewan.

Introduction

Plant Root Simulator (PRS) technology is based on the principle of ion exchange between the soil and a synthetic resin membrane. The name Plant Root Simulator was given to this technology because the mode of action of this type of test is, in many ways, analogous to nutrient ion movement and uptake by plants (Schoenau et al., 1993). The ion exchange mechanism between synthetic resin beads or membranes has been of great utility in assessing the availability of a wide variety of ions existing in the soil (Olness and Rinke, 1994; Van Raij, 1994). The main advantage of this type of testing is that multiple ions can be determined from a single test on a given soil sample. Our research using the PRS technology has further advanced this method of testing by developing a system where the ion exchange testing can be done on undisturbed soil, thereby eliminating soil sampling and handling. Such an efficient method of mapping nutrient variability within a field has immediate appeal to those who wish to make variable rate fertilizer application. This concept of “Farming by Soil” or “Precision Farming” is hampered for the most part by the high cost of intensive soil testing (Anonymous, 1994). The purpose of this paper is to describe how the PRS system can be used to create nutrient maps and how these levels could guide fertilizer application to obtain a balanced nutrient supply.

How Well Do Plant Root Simulator levels Relate to Plant Uptake?

Numerous greenhouse studies have compared resin exchangeable ions to those taken up by plants (Schoenau et al., 1993; Qian and Schoenau, 1995). Recent field data has shown similarly good relationship between the total N uptake of wheat and the PRS-nitrate level of the surface (0 to 10 cm) tested several days after seeding and fertilizing (Fig. 1). Typical field studies relating pre-emergence soil test levels to plant uptake commonly have much lower correlation coefficients ($R^2$ ranging from 0.04 to 0.34) (Gelderman et al., 1988). Our study was conducted under optimal moisture conditions with incremental levels of fertilizer, hence uptake of N was not confounded with limitations due to other factors. Such conditions should result in an optimal prediction of plant nutrient uptake.

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Figure 1. Relationship between post-seeding and fertilizing Plant Root Simulator nitrate (PRS-N) and Total N uptake of wheat at harvest from a plot study at Saskatoon.

For nitrogen, capturing the dynamics of mineralization may be as important as the residual soil levels. The PRS, buried for up to 2 weeks, can be used to measure the biological turnover since the sink for ion exchange is typically much larger than ion supply of the contacting soil. Field results from 2 week burials across two transects on both an Elstow and Hamlin soil association (Acton and Ellis, 1978) revealed a mineralization pattern which mirrored other productivity data on similar slope classes (Dennis, 1993; Pennock and Anderson, 1992). Footslopes mineralized from 3 to 4 times more $\text{NO}_3^-$ than convex shoulder slopes on the Dark Brown Elstow fields and up to 9 times more on the Black Hamlin field (Dennis, 1993).
Mapping Spatial Trends in Nutrient Levels

Proper mapping of nutrient levels across variable landscapes will require intensive sampling. Utilizing standard soil collection methods, significant effort is required to collect, maintain and extract such numbers of samples. In an attempt to reduce this workload, McGrath et al. (1994) have engineered an automated system for soil collection, bagging and extracting. Our approach is to utilize the PRS probe to allow collection of only the desired ions from the intact field soil.

In May 1994, we constructed a field unit to allow easy transport of the PRS testing equipment. Based on a Honda ATV, we added a self-contained, pressurized water supply for wetting and washing the soil from the PRS probes. Other modifications included: 1), a container for PRS probe storage prior to use, 2), a box for supplies and collected PRS samples, and 3), a knife-styled, slot opening probe. Using this system we placed and retrieved 104 PRS probes across a 40 acre site located west of Assiniboia which was to be used as part of a variable rate fertilizer study.

Nitrate levels followed a typical trend as related to topography and previous cropping history (Fig. 2). Little spring residual $\text{NO}_3^-$ was found in many of the low slope and depressional areas, since good growing conditions in 1993 depleted the soil nitrate pool. As well, wet conditions early in 1994 may have contributed to losses of nitrate in the depressional areas. Level footslope positions had the highest levels of nitrate, while nitrate on the knolls was generally intermediate to low.

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**Figure 2.** PRS map of plant available nitrate and phosphate map at a stubble wheat site west of Assiniboia (May, 1994).

Phosphate levels were also somewhat lower in the depressional areas (Fig. 2). As expected, the strongly eroded diverging shoulders and crests had the lowest available P. Patterns of N and P availability were not closely related on the level and midslope areas of the field. As a result varying the amount of a blended N and P fertilizer with the soil levels of either N or P alone would lead to fertility imbalances.

Recent research using the PRS probes has shown that the relative amounts of N and S adsorbed from the soil can be used to predict the ratio of N:S in the plant tissue (Qian et al., 1995). If a similar case can be made for N:P, then a balanced ratio should be 10 parts N to 1 part P. Using a color overlay of the N (orange) and P (blue) maps it is possible to visibly differentiate the high, yet balanced, N and P (deep green) areas from the low-balanced (light green) and the imbalanced (more orange or blue) areas. This technique might be useful in making variable fertilizer rate application since a balance of nutrients is as important as choosing an optimal fertilizer rate of one nutrient at any location. Using a computer simulation to predict the interactive crop response to water, N and P on each location could be a useful tool to optimize rates wherever the available soil water varies with soil type and location (Greer et al., 1993).

Field mapping of nutrient variation is much more time efficient using the PRS system. We calculate that the total person*hours required for the Assiniboia site was 3 to 7 times less than conventional soil sampling and extracting. Using the PRS system to create field maps is a significant development in terms of saving time and, therefore, cost.
References


Qian, P., J.J. Schoenau, K.J. Greer, and W. Wu. 1995. Yield and uptake of N to S by Canola and Wheat in the growth chamber as influenced by N and S supply from soil and fertilizer. Proceedings of the Soils and Crops Workshop, this issue. Extension Division, University of Saskatchewan, Saskatoon, Sk.


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Fig. 2. PRS map of plant available nitrate and phosphate map at a stubble wheat site west of Assiniboia (May, 1994).