FORECASTING CROP NUTRITION NEEDS USING THE PLANT ROOT SIMULATOR (PRS™) TECHNOLOGY

K.J. Greer
Western Ag Innovations Inc. Saskatoon, Canada.

ABSTRACT

Conventional soil testing is based on the premise that a chemical extraction will reflect the soil nutrient supply to plants. The shortfalls of this approach have been evidenced by the numerous studies conducted over the past 50 years aimed at improving soil test methods. Radiotracer studies in the 1960's where pivotal in shifting thinking away from nutrient concentration and toward mechanisms of nutrient supply. Barber (1995) first coined the term *soil nutrient bioavailability* to describe the flux of ions to plant roots. Forecasting crop nutrition using an ion exchange membrane as a plant root simulator (PRS™) is squarely built on this concept. This simple absorbing surface affords a new tool to integrate the factors controlling ion supply allowing us to 'see what the plant sees'. Ion supply over time from biologically active soils allow for a much more realistic picture of the soil nutrient supply. These plant root simulators also account for ion movement dynamics that impact the supply to the plant root. Combing this powerful functional test of soil nutrient supply with simulation models of root growth and plant demand has given ecosystem managers of the 21st Century a new way of "getting to the root of crop nutrition".

INTRODUCTION

Simultaneous extraction of plant nutrient ions from soils with ion exchange resin membranes provides a relatively underutilized but reliable alternative to conventional soil testing. Ion exchange resins closely simulate the nutrient removal action of plant roots over time, yielding assessments of nutrient supply that are generally more strongly correlated with plant nutrient uptake than that from traditional chemical extractions. Synthetic ion exchange resins were first used in agriculture in 1942 when pre-loaded ion exchange resins were used as a source of nutrient ions for plant growth in sand culture systems. The first use of ion exchange resins as a means to assess soil nutrient status was in 1951. Since then, the use of ion exchange resins to measure nutrient bioavailability in soils has become more widely accepted. Its use in research has been documented in thousands of referred journal articles.

HOW RESINS WORK

Ion exchange resins act as an ion sink based on the principle of Donnan exchange. The permanently charged functional groups on the resin are initially saturated by a counter-ion of opposite charge, such as sodium or bicarbonate. When placed in intimate contact with the soil, the counter-ions of the resin are exchanged for ions from the soil solution and labile nutrient pools. The quantity of ions accumulated on the ion exchange resin is dependent upon the biological, chemical, and physical properties of the soil. The biological component involves the slow release of nutrients from organic sources as mediated by microorganisms and influenced by soil moisture and temperature conditions. Chemical properties such as ion concentration, ion activity, and size of the slowly available pools that buffer the soil solution concentration of ions all influence the ion supply from the soil to the ion exchange resin. Physical factors that affect the rate of ion diffusion include the texture, moisture, temperature, and structure of the soil. It is in integrating the impact of these key soil processes that control ion adsorption by plant roots that allow the PRS™ technology better ‘see what the plant sees’.

Good contact between the soil and the resin is crucial to achieve accurate results. After the burial period, the soil must be thoroughly washed from the resin with deionized or distilled water. The adsorbed ions then can be eluted from the resin with a weak acid or salt solution and measured analytically.

Ion exchange resins yield a dynamic measure of ion flux to a sink. Standardization of the sink size is based on the adsorbing surface area of resin. This measurement is called the nutrient or *ion supply rate* (Greer et al. 2003). Nutrient supply rates are expressed as the weight of a nutrient adsorbed per surface area of ion exchange membrane or oven-dry weight of resin over time (duration of the burial). Short-term burials of ion exchange resin primarily measure the labile pool. During long-term burials and/or when re-inserting fresh resin membrane into the same soil slot, the labile-ion pool becomes depleted, resulting in the release of ions from the more slowly supplying nutrient pools, providing an assessment of mineralization and/or dissolution throughout the growing season. The ability of ion exchange resins to account for the effects of mineralization and/or immobilization makes them a valuable tool for assessing nutrient release from organic amendments or other systems with a high organic component.

FUNCTIONAL BASIS FOR FORECASTING CROP NUTRITION

As early as the 1960s researchers began to investigate improved methods for assessing release of available plant nutrients. The importance of nutrient flux in the dynamic mechanisms controlling soil fertility and the central role of rooting volume in potential uptake of plant nutrients was established. A need to identify the relevant soil properties affecting release of residual nutrients was also recognized. Various simple and more mechanistic models for forecasting plant nutrient needs were developed.

Models are small-scale representations of a larger entity and in soil science and agronomy they are often mathematical equations calculated to emulate dynamic processes in real soil-plant-climate systems. Most soil test recommendations in use with conventional chemical extractions have acknowledged that other knowledge is needed to estimate or predict N fertilizer needs. Typically, conventional soil test have three separate organic sources or pools; soil organic matter, legume residues, and manure; that provide inorganic N at different rates and amounts to crops. In these “N credit” calculators, the kinetics of N release from the three pools is assumed to be a specified average value which in reality is unlikely to remain constant since soil conditions such as moisture and temperature can significantly influence the quantities of inorganic N mineralized during the growing season. Therefore, simple N credit calculators often fall short or only marginally improve predictions of fertilizer N requirements.

More complex mathematical models have been developed to reflect important biological and chemical pathways influencing life in the soil. These are referred to as mechanistic models with each variable affecting another through the known biological or chemical pathways or processes. An important feature of the mechanistic model approach is the linking of soil-plant-climate processes. Because of the compartmentalization of processes and sources of variability that influence yield and associated plant nutrient demand, incorporation of changes such as new cultivars or tillage practices are more readily managed than the collection of voluminous data required for the alternative calibrated database approach.

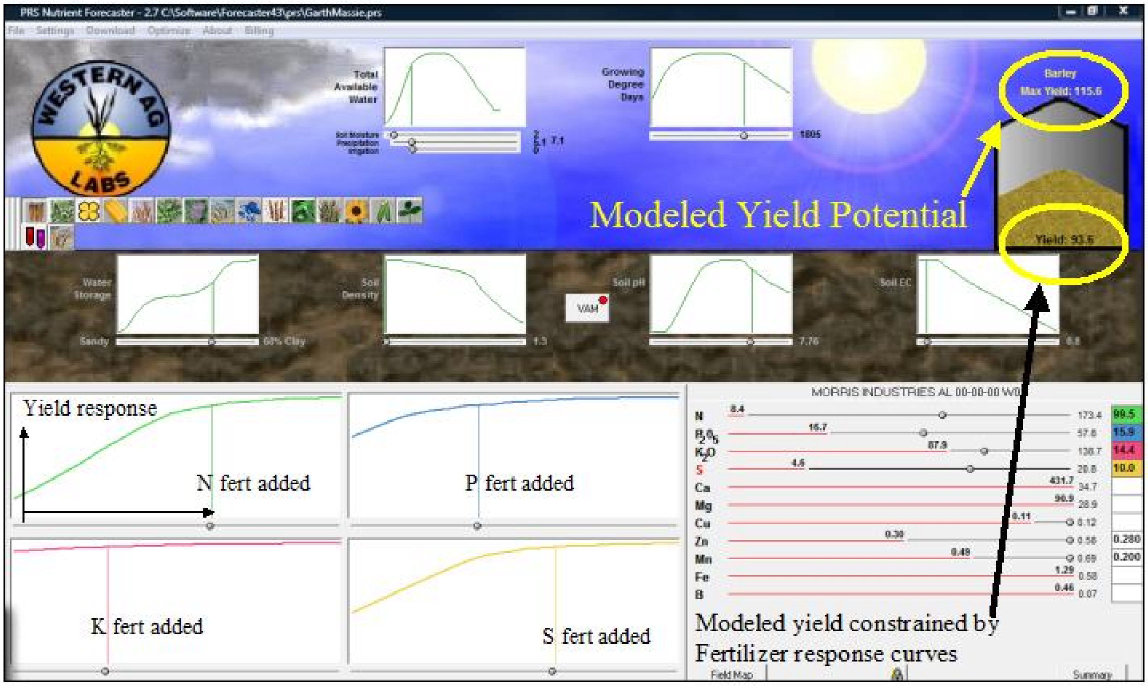

Figure 1. Screen capture of the PRS™ Nutrient Forecaster showing the key controls (inputs) and outputs all in one interface.

The PRS™ Forecaster (Fig. 1) is proven working example of this more powerful inference method for fertilizer recommendations and crop nutrition planning. The Forecasters' mechanistic model integrates conditions over time for a growing crop thus supplying a more realistic feedback between variables and processes. Such models provide quantitative predictions or forecasts of future conditions and, therefore, provide a much broader inference space for developing fertilizer recommendations. Simply put the model estimates fertilizer needs as the difference between **soil nutrient supply** and **predicted crop demand** for the given soil-plant-climate system specified as input variables. Accuracy of the model can be checked using a method known as 'back-casting'. This is done when one compares actual crop yields with the model output forecast for the known model inputs corresponding to that particular soil-plant-climate system. Feedback from users is encouraged to identify model deficiencies that should be explained and appropriate improvements made.

With over ten years of track record, the PRS™ Forecaster has emerged as the premiere tool for forecasting crop nutrition (Wildfong et al. 2011). Agronomists have improved knowledge transfer to growers and growers in turn have greatly improved crop nutrient management, crop yields and farm profits. Over 2.2 B dollars of additional economic output in Western Canada can be traced directly back to this new way of "*Getting to the Root of Crop Nutrition*".

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RENO, NEVADA

Program Chair:
Robert Flynn, Program Chair
New Mexico State University
67 E Four Dinkus Road
Artesia-NM 88210
(575) 748-1228
rflynn@nmsu.edu

Coordinator:
Phyllis Pates
International Plant Nutrition Institute
2301 Research Park Way, Suite 126
Brookings, SD 57006
(605) 692-6280
ppates@ipni.net