WESTERN U.S.

Exchange Resins Measure Rotation Effect on Nutrient Availability

By Steven E. Salisbury and Neil W. Christensen

Differences in nitrogen (N), phosphorus (P), and potassium (K) availability resulting from crop rotation were measured using ion exchange resins. Resin probes quantitatively measured differences in availability of the yield-limiting nutrient and detected differences in non-limiting nutrients.

One of the more promising methods for estimating nutrient availability involves ion exchange technology. This technology offers a way to eliminate problems inherent in chemical extraction of soil. Its use could lead to more refined fertilizer recommendations and benefit growers and the environment.

Ion exchangers are insoluble inorganic or organic synthetic materials that contain labile ions that can exchange with other ions in the surrounding medium. Similar natural processes include cation exchange by soil colloids and nutrient uptake by plants. Cation and anion exchangers are available in the form of resin beads, membranes or capsules.

One advantage of ion exchange resins over traditional soil extracts is the mechanistic relation between nutrient recovery by exchange resins and nutrient availability to plants. Ion diffusion is the primary mechanism controlling nutrient concentration at the plant root surface, especially for immobile nutrients such as P and K. Likewise, ion accumulation on exchange resins depends on ion concentration and rate of ion diffusion. Unlike chemical extracts of soil, ion accumulation by exchange resins depends on soil temperature and water content which affect both biological activity and ion diffusion. Because ion exchange resins buried in soil are exposed to the same conditions as plant roots, their nutrient recovery should reflect nutrient availability to plants.

Resin probes used to measure availability of cations and anions in soil solution.

Conventional soil testing measures the quantity of a nutrient available at the time of sampling, but may not account for factors affecting subsequent availability of a nutrient. Exchange resins can integrate the effects of biological, chemical, and physical processes influencing conversion of nutrients from organic to mineral form, transformation from one mineral form to another, and diffusion of ions to roots. They are useful in assessing differences in the nutrient supplying capacity of soil as affected by long-term

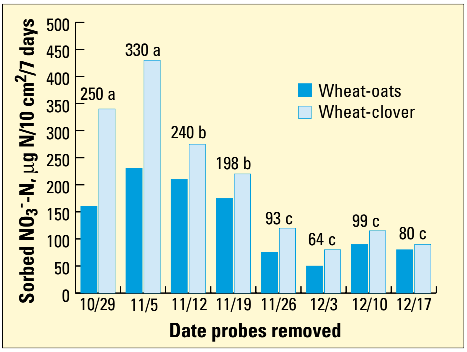

Figure 1. Nitrate N adsorbed by probes during seven-day intervals in fall 1998. The mean NO_3^--N adsorbed was significantly less (P = 0.05) for wheat following oats (132 µg/10 cm^2/7 days) than for wheat following clover (207 µg/10 cm^2/7 days).

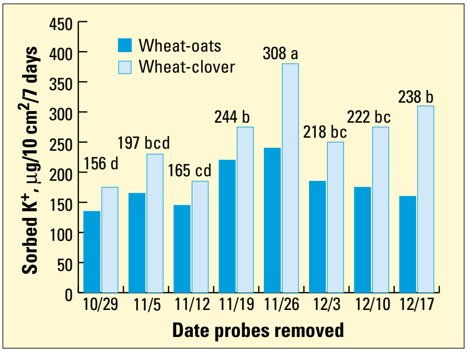

Figure 2. Potassium adsorbed by probes during seven-day intervals in fall 1998. The mean K^+ adsorbed was significantly less (P = 0.05) for wheat following oats (177 µg/10 cm^2/7 days) than for wheat following clover (260 µg/10 cm^2/7 days).

management such as crop rotation or fertilization history. Repeated measurements provide an assessment of the dynamics of nutrient supply over time.

Our study was designed to evaluate ion exchange resin technology for assessing nutrient availability to winter wheat grown in a crop rotation study where N was the only limiting nutrient. The Plant Root Simulator™ (PRS™) system, consisting of ion exchange resin membranes encapsulated in plastic probes (Western Ag Innovations, Saskatoon, SK, Canada), was used. The system includes two types of probes. Cation probes adsorb positively charged ions...ammonium (NH_4^+), K^+, calcium (Ca^{2+}), magnesium (Mg^{2+}), etc. Anion probes adsorb negatively charged ions... nitrate (NO_3^-), phosphate (PO_4^{3-}), sulfate (SO_4^{2-}), etc. Probes were installed in four replicate plots of unfertilized winter wheat that followed either spring oats or crimson clover. Measurements were made over an eight-week period beginning when wheat was planted on October 22. In each plot, three pairs of probes were installed at planting and removed one week later. This process was repeated each week over the next seven weeks. Probes removed from the soil were rinsed with distilled water and extracted with 0.5 M hydrochloric acid (HCl). Extracts were analyzed for NH_4^+-N, NO_3^--N, K^+, PO_4^{3-}, Ca^{2+}, and Mg^{2+}.

Plant and soil samples were also collected. One plant sample was taken at eight weeks after planting to estimate total biomass accumulation and nutrient uptake. Conventional soil samples were taken from the 0 to 4-inch depth at one, four, and eight weeks after planting. Plant and soil samples were analyzed for the same six nutrients as the probes.

On average, probes adsorbed significantly more NO_3^--N where winter wheat followed clover as compared to oats (**Figure 1**). However, NO_3^--N recovery by the probes depended on when measurements were made. Both NO_3^--N recovery and the difference between rotations were greater in the first few weeks after planting. Lowest levels of NO_3^--N were measured in weeks four through eight. Rainfall in excess of 7 inches during the last week of November probably leached NO_3^- below the probes. In addition to differences in NO_3^--N, significantly more NH_4^+-N was recovered where wheat followed clover (9.1 µg N/10 cm^2/7 days) as compared to oats (7.8 µg N/10 cm^2/7 days). Temporal effects on NH_4^+ were much less pronounced than for NO_3^-, but the lowest recovery of NH_4^+ was measured in week three when the soil was driest (data not shown).

While N was the only nutrient limiting wheat growth in the field, the previous crop

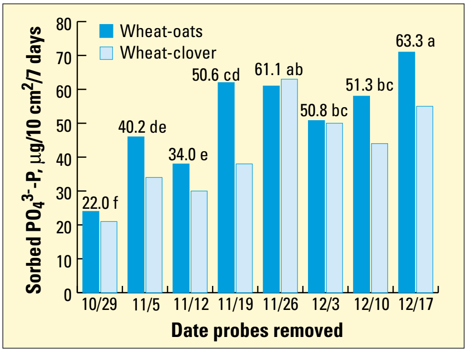

Figure 3. Phosphate-P adsorbed by probes during seven-day intervals in fall 1998. The mean PO_4^{3-}-P adsorbed was significantly less ($P = 0.05$) for wheat following clover (42 µg/10 cm^2/7 days) than for wheat following oats (51 µg/10 cm^2/7 days).

significantly influenced the amount of K^+ adsorbed by PRS™ probes (**Figure 2**). Probes recovered an average of 47 percent more K^+ where wheat followed clover than where wheat followed oats. Differences due to rotation were measured on all sampling dates, but were larger late in the sampling period (December 17) and when soil water content was very high (November 26). The crop rotation effect on K^+ availability was unexpected because K fertilizers had not been applied for at least four years, let alone applied differentially. Rotational differences in K^+ are most likely related to differences in the quantity, K content, and/or placement of residue from the previous crop.

In contrast to N and K, average PO_4^{3-}-P recovery by probes was significantly lower where wheat followed clover than where wheat followed oats (**Figure 3**). Probes recovered more PO_4^{3-}-P late in the sampling period when soil water content was at its highest. We are uncertain why PO_4^{3-}-P was more available after oats, but speculate that crimson clover may have been more efficient than oats in depleting soil P reserves.

Exchange resin recovery of N compared favorably with N uptake by winter wheat plants. Wheat plants grown after oats accumulated 63 percent as much N as wheat plants grown after clover by eight weeks of age. In comparison, probes in plots following oats adsorbed an average of 64 percent as much NO_3^--N as did probes in plots following clover. Even though K did not limit wheat growth, K concentration in wheat tissue and plant uptake of K were both greater where wheat followed clover. Phosphorus concentration in wheat tissue was unaffected by the previous crop, but P uptake was significantly greater following clover because of the growth response to increased N availability. Conventional soil tests detected crop rotation effects on NO_3^--N and K^+, but provided less sensitive measures of availability than did exchange resins. BC

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