COMPARING NUTRIENT AVAILABILITY IN LOW FERTILITY SOILS USING ION EXCHANGE RESIN CAPSULES AND PLANT BIOAVAILABILITY UNDER GREENHOUSE CONDITIONS

Mary C. Pletsch, Daniel A. Cook, Matthew Vickery,
Bruce L. Webb, Von D. Jolley, and Bryan G. Hopkins
Brigham Young University, Provo, UT

ABSTRACT

Commonly used soil resin analysis procedures have generally been developed to determine nutrient levels in agriculture soils. The purpose of the resin capsule procedure is to determine the amount of nutrient that correlates to that which is plant available. Desert soils contain lower levels of nutrients than agricultural soils, thus the validity of using resin capsules for desert soils is uncertain. In a previous incubation study it was determined that ion exchange resin capsules can be used as an accurate measure of nitrogen and phosphorous levels in desert soils. A second follow up study was conducted to determine if the amount of nutrient absorbed by resin capsules can be correlated to actual plant available nutrient. Two native, desert soils were collected from different locations in Utah. The soils were treated with five rates of nitrogen as ammonium nitrate (34-0-0), and four rates of phosphorous as phosphoric acid (0-46-0). Soils were placed in 20.3 cm (8 inch) diameter pots and watered to approximately one-half field capacity. Two resin capsules were placed in each pot. The pots were seeded with Squirrel-tail Grass *(Hordeum jubatum L.)*, and placed in a greenhouse. The treatments were consistently watered over the duration of the experiment. One resin capsule from each treatment was removed at 60 days, the other at 120 days, and each resin capsule was extracted with 2 N HCl. Nitrate, ammonium and phosphorus levels were determined in this extract. At 120 days, the grass was harvested and yield measured. The results of this experiment indicate that resin capsules are not as sensitive in determining the soil nutrient status under greenhouse conditions with growing plants when compared with those incubated in soil only (performed in a previous study). Ammonium and nitrate levels in the resin capsule correlated with fertilizer application but only at high fertilizer rates. Phosphorus was not significant at any level. Plant yields correlated with the level of nutrient applied to the soil as well as the level of nutrient extracted from the resin capsule.

INTRODUCTION

Forty years ago the ion-exchange resin capsule system for testing soil nutrient values was introduced and it has become widely accepted for use in agricultural soils. It was developed to provide a simple, convenient, repeatable resin methodology (Skogley et al., 1996) to measure soil nutrient supplying capacity. Resin capsules are small elliptical balls, slightly larger than a marble that contain resin beads that equilibrate with ions in soil solution in a manner similar to plants absorbing nutrients. The capsules are buried in the soil for a specified time and then are analyzed to determine the nutrients absorbed.

The majority of the research and commercial use of resin capsules has been carried out in fertile soils. The use of resin capsules, however, has extended to areas where the soil attributes and climatic conditions do not match those in which the resin capsules were originally studied; thus creating a concern regarding the validity of their use in such areas. While general concerns have been raised about the difficulty of comparing resin-based techniques and traditional soil measurements (Johnson et al., 2004), there are even greater concerns regarding their use in low-nutrient arid soils, such as those in Southern and Western Utah. These soils are quite different from those generally tested using resin capsules. Studies in these conditions have shown that measurements from resin capsules and traditional soil testing methods are not comparable and that they should not be considered interchangeable; furthermore, interpretive differences between resin and traditional methods are poorly understood (Sherrod et al., 2002; Sherrod et al., 2003). Before extensive use with arid soils, further research should be performed on the comparative values of these two approaches to soil testing and on the use of ion exchange resin capsules before they are a viable approach for gathering data from these low-nutrient arid soils.

We conducted a study to measure if resin capsules can reflect application rates of nutrients when used on low-nutrient arid soils. Previous studies (Sardi et al, 1996) have shown a correlation between resin capsule contact time with the soil, fertilizer rate and resin content. This experiment was conducted to determine if resin capsules could predict the nutrients available for native grasses growing on low fertility soils under greenhouse conditions. Resin capsules were placed in two different soils. The soils were treated with five rates of nitrogen, four rates of phosphorous and planted to Squirrel-tail Grass (*Hordeum jubatum L*.). The resin capsules were removed at 60 and 120 days and analyzed for nitrate, ammonium and phosphorous. At 120 days the grass yield was measured.

METHODS

Two native, desert soils were collected from Rush Valley, Utah and Moab, Utah. The soils were dried, sieved and mixed in preparation for the experiment. 2 kg (4.4 lb) of Rush Valley soil and 2.5 kg (5.5 lb) of Moab soil were used to fill 20.3 cm (8 inch) diameter pots. A solution was prepared to deliver NH_4NO_3 and H_3PO_4 in sufficient quantities for the desired treatments. The soils were treated with five rates of nitrogen as ammonium nitrate (34-0-0) applied at 0 kg/ha, 5.6 kg/ha, 11.2 kg/ha, 22.4 kg/ha, 44.8 kg/ha (0 lbs/acre, 5 lbs/acre, 10 lbs/acre, 20 lbs/acre and 40 lbs/acre). Soils were treated with four rates of phosphorous as phosphoric acid (0-46-0), applied at 0 kg/ha, 11.2 kg/ha, 22.4 kg/ha, 44.8 kg/ha (0 lbs/acre, 10 lbs/acre, 20 lbs/acre, and 40 lbs/acre). Each application rate of nitrogen was applied with the varying rates of phosphorus for a total of 20 treatments. The treatments were replicated 3 times, randomized and placed in a completely randomized block design in the greenhouse. Water was added to bring each soil to approximately one-half field capacity. Two resin capsules were placed in each pot, approximately 6.35 cm (2.5 inch) from soil surface. The pots were seeded (4 per container) with Squirrel-tail Grass *(Hordeum jubatum L.)* The treatments were consistently watered over the duration of the experiment. At 60 days the first resin capsules were removed and individually washed with distilled water in preparation for extraction and analysis. At 120 days the same procedure took place with the second resin capsule. The squirrel tail grass was harvested and yield measured at the time the second resin capsule was removed. Each treatment was replicated three times with two soils, two resin capsules and two time periods. The total number of resin capsules extracted was 240. Nutrients were extracted from the Resin capsule with 2 N HCl. The capsules were placed in 50 mL centrifuge tubes, 20 mL of HCl added, shaken for 20 min, and then filtered. The process was repeated twice more for a total of 60 mL of extract. The extract was then analyzed using a LACHAT flow injected analyzer for $NO3^-$ and $NH4^+$, and inductively coupled plasma (ICP) spectroscopy for phosphorous. The grass was harvested, dried and weighed to determine yield.

RESULTS AND DISCUSION

Correlation of the resin capsule extract and applied nutrient was significant at higher fertilizer applications. For the 5 nitrogen treatments, resin capsules were able to extract ammonium proportional to the fertilizer applied only at 22.4 and 44.8 kg/ha respectively. The nitrate was proportional to the fertilizer applied at the 44.8 kg/ha rate (Graph 1). The phosphorus extracted by the resin capsules did not relate to the treatment levels, even though at the highest treatment there was a two-fold increase in extracted phosphorus (Graph 2). The resin capsule phosphorus was extremely variable and therefore not significant.

In the soil, the resin capsules extracted more nitrate from the fine textured Rush Valley soil than from the coarse textured Moab soil. The opposite was true for ammonium. The phosphorus extracted was not significant due to the high variability (Table 1). The variability of the nitrate may be due to the movement of nitrate within the soil profile. In the case of the coarse textured, Moab soil, it is probable that the nitrate moved below the resin capsule. In the case of ammonium the nutrients may have been held more tightly to the exchange sites of the finer textured, Rush Valley soil. The amount of time that the resin capsule was buried (60 verses 120 days) was found to be significant for ammonium. More ammonium was extracted by the resin capsule at the 120 day incubation period. Neither nitrate nor phosphorus treatments were affected by length of incubation.

All treatments of nitrogen and phosphorus correlated with the yield of Squirrel-tail Grass (*Hordeum jubatum L.*) Yield was a better indicator of nutrient availability than the resin capsule extraction (Graph 3 & 4). This may have been due to the competition of the roots and resin capsules for nutrients within the limited space of greenhouse pots.

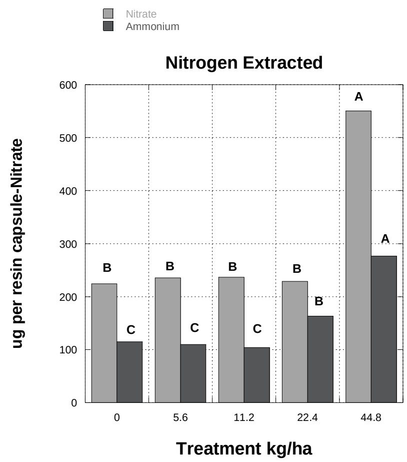
SUMMARY

Resin capsules are effective in predicting yield in greenhouse studies. However, the concentration of the nutrients applied did not correlate for all application rates. The resin capsules were only an accurate indicator of soil fertility at higher rates of fertilizer applications. Resin capsules are able to predict soil nitrogen fertility, at rates of 22.4 kg/ha and higher. Phosphorus soil fertility was variable and did not correlate to the applied amounts. Resin capsules appear to be accurate across a range of soil textures. This research justifies more experimentation in the field.

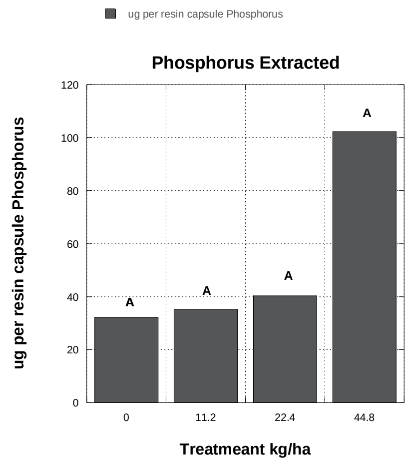
Table 1. Comparison of Soils and Incubation Times

Variable	Moab	Rush Valley	60 Days	120 Days
NH_4 ug/capsule	215.18*	92.69	142.68*	165.19
NO_3 ug/capsule	68.92*	521.47	301.06 NS	289.33
P ug/capsule	13.06 NS	91.93	76.92 NS	28.07
Yield kg/ha	100.18 NS	155.2		127.69
For comparison between soils or between days, * indicates significant at $P<0.05$ and NS as not significant at $P<0.05$				

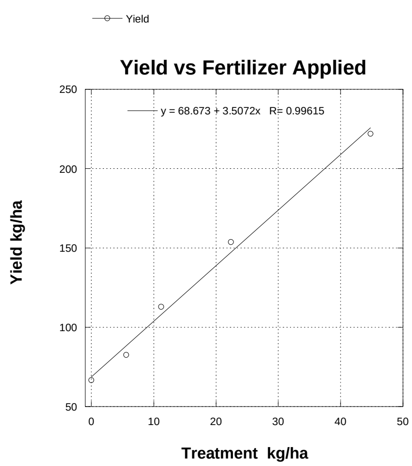
Graph 1.



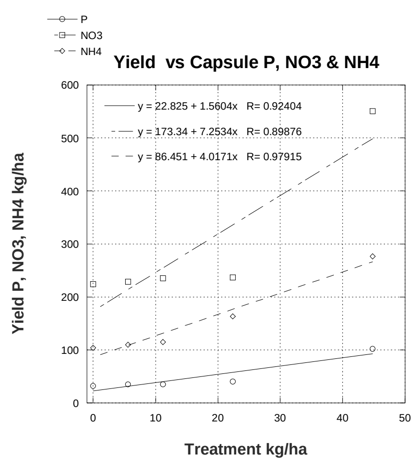
Graph 2.



Graph 3.



Graph 4.



REFERENCES

Johnson, D.W., 2004. Soil Extraction, Ion Exchange Resins, and Ion Exchange Membrane measure of Soil Mineral Nitrogen during Incubation of a Tall Grass Prairie Soil. Soil Science Society ofAmerica Journal, 2005 Jan-Feb, v. 69, no. 1, p. 260-265.

Sardi, K., Sabbe, W.E., and Wolf, N.A., 1996. Nutrient Absorption Characteristics of Resin Capsules For the Photoavailabiltiy Soil Test (PST) In Four Arkansas Soils. Communications in Soil Science and Plant Analysis, 1996 January, v. 27, no 3-4, p. 713-726.

Sherrod, S.K., Belnap J., and Miller, M.E., 2002. Comparison of Methods for Nutrient Measurement in Calcareous Soils: Ion-Exchange Resin Bag, Capsule, Membrane, andChemical Extractions. Soil Science, 2002 October, v. 167, no 10, p. 666-679.

Sherrod, S.K., Belnap J., and Miller, M.E., 2003. Comparison of Ion-Exchange Resin Counter ions in the Nutrient Measurement of Calcareous Soils: Implications of Correlative Studies of

Plant-Soil Relationships. Communications in Soil Science and Plant Analysis, 2003 July, v. 34, no 13-14, p. 1981-2001.

Skogley, E.O., Dobermann, A., Warrington, G.E., Pampolino M.F., and Adviento, A., 1996. Laboratory and field methodologies for use of resin capsules. Science of Soils, Rel. 1,1996- http://www.hintze-online.com

PROCEEDINGS
OF THE
WESTERN NUTRIENT
MANAGEMENT CONFERENCE

Volume 8

MARCH 4-5, 2009
SALT LAKE CITY, UTAH

Program Chair:
Grant Cardon
Utah State University
4820 Old Main Hill
Logan, UT 84322-4820
(435) 797-2278
Grant.cardon@usu.edu

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