Evaluation of Cation Exchange Resins as Indicator of In-Season Potassium Supply to Soybean

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ABSTRACT

The use of ion-exchange resins to measure soil nutrient availability has potential applications for fertilizer recommendations. The objective of this study was to evaluate the relationship between potassium (K) adsorption by cation exchange resins (CER) and K uptake by soybean (*Glycine max*) in field conditions. The study was conducted at two locations in Kansas during 2019. Two treatments were selected to evaluate the CER. Treatments included a check (0 lbs K_2O acre^{-1}) and a high K rate with 150 lbs K_2O acre^{-1} applied pre-plant and incorporated. The Plant Root Simulator® (PRS®) was used as an indicator of in-season K supply to soybean. Number, length, and time between burial periods were defined in order to cover most of the soybean growing season. In addition, whole plant samples were collected at V4, R2, R4, and R6 stages to measure plant K uptake. Soil moisture content was calculated based on soil samples collected at the beginning and end of each burial period. CER were able to adsorb more K (measured as cumulative adsorption) when K fertilizer (150 lbs K_2O acre^{-1}) was applied. Data showed a positive relation between CER values and soil moisture content. Preliminary results from this study suggest that CER can be used as an indicator of K supply, particularly in soils with low soil test K levels.

INTRODUCTION

Some soil test methods used to estimate K availability (e.g. 1 M NH_4OAc) are not always good indicators of K uptake by plants. Since the 1950s, synthetic ion exchange resins have been used for assessing the bioavailable fraction of soil nutrients (Qian and Schoenau, 2002). Compared to soil test methods, ion exchange resins can be used to measure nutrient supply rates during specific adsorption periods. Therefore, soil processes such as nutrient release and transport can be considered. In CER, membranes are negatively charged in order to adsorb positively-charged ions, like K^+. Exchange membranes were capable to assess immediate nutrient supply rate by selecting short burial periods (1 hour) (Qian et al., 1996). Also, long periods are used to capture nutrients released from mineral and non-exchangeable forms (Cooperband and Logan, 1994). This technology has potential applications in numerous areas (including agronomic research) because of its ability to simulate plant root activity in undisturbed conditions. However, there are still limitations such as unfamiliarity of units used to express results (Qian and Schoenau, 2002), and reduced calibration studies related to crop response. Commonly, K management is based on pre-plant soil sampling to assess nutrient supply for the entire season. Finding an indicator that considers the kinetics of K release from the soil could be useful to improve future management. The objective of this study was to evaluate whether K adsorbed by CER could be used as an indicator of in-season K supply to soybean (*Glycine max*) in field conditions.

MATERIALS AND METHODS

Field experiments were conducted at two locations throughout eastern Kansas during 2019 (**Table 1**). Sites were located at Ashland Bottoms Research Farm (Manhattan, KS) and East Central Experimental Field (Ottawa, KS) under a conventional tillage crop system. The experiments were a randomized complete block design and two treatments and two replicates were selected to evaluate the CER. Treatments included a control (check) with no K application and one with application of 150 lbs K_2O acre^{-1} (high K rate). Both treatments had an application of 80 lbs P_2O_5 acre^{-1}. The fertilizer applications were a surface broadcast at pre-plant using triple superphosphate (TSP) and potassium chloride (KCl) as a P and K sources, respectively. For this study, we used a commercial CER (Plant Root Simulator® (PRS®, Western Ag Innovations, Saskatchewan, Canada) as an indicator of in-season K supply to soybean. This product consists of an exchange resin membrane held in a plastic frame that is inserted into the soil to measure *in situ* ion supply. Variables such as number, length, and time between burial periods were defined in order to cover most of the soybean growing season (V4 to R7). Ottawa location had six burial periods compared to Ashland that had seven. Burial length consisted of 7 days with a time between burials of 15 days. A total of 4 probes were distributed within the plot to obtain a composite sample. The CERs were inserted vertically into the soil (facing plant row), between 2-4 inches soil depth at a distance of 3 inches from the soybean row during all the sampling season. For every new burial period, the CERs were buried 5 inches apart from the previous period (parallel to the row) to avoid sampling the same portion of soil. Aboveground plant samples were collected at V4, R2, R4, and R6 stages in order to measure plant K uptake. The samples were dried at 140°F, ground to pass through a 2 mm screen, weighed and digested by nitric-perchloric acid digestion. Total K concentration of the extractant was determined by inductively coupled plasma (ICP) spectrometry. Soil samples were taken at pre-plant (one per replicate), air dried at 104 °F, and ground to pass through a 2 mm screen. All samples were analyzed for soil pH (soil:deionized water; 1:1), Organic Matter (OM) (loss on ignition method), extractable P and K (Mehlich-3), exchangeable cations (1 M NH_4OAc pH 7.0, Flame Atomic Absorption), and Cation Exchange Capacity (CEC) (displacement method). Soil samples were taken at the beginning and end of each burial period to calculate soil moisture content (air-dried at 104 °F). Statistical analysis (ANOVA) was performed using the GLIMMIX procedure in SAS 9.4.

RESULTS AND DISCUSSION

Plant K uptake measured at reproductive stages (R2, R4, and R6) was increased by K fertilization in both locations. However, differences were not statistically significant ($p < 0.05$) at location 1 (**Fig. 1**). This result was likely due to its high soil K levels. Based on Kansas State University recommendations, this location had soil K levels that was above the critical level of 130 ppm, and no K fertilizer was needed (**Table 1**). In contrast, location 2 had significantly higher plant K uptake measured at R2 ($p < 0.05$), R4 ($p < 0.10$), and R6 ($p < 0.05$) stages when 150 lbs K_2O acre^{-1} was applied (**Fig. 2**). At the R6 stage, fertilized plots had 50% more K uptake and 40% more K adsorption (cumulative) by CER compared to the control. This observation suggests the potential use of CER as indicator of K supply to soybean in field conditions, but further research is needed to confirm these findings. In both locations, CER were able to adsorb more K (measured as cumulative adsorption) at high K rate. The amount of K that was adsorbed by the CER was influenced by soil moisture content, particularly in location 1 (**Fig. 3**). A similar trend was observed between these two variables. Plots without K fertilization were less affected and minor fluctuations were measured compared to those with high K rate. However, data from location 2 did not show a clear pattern (**Fig. 4**). Preliminary results from this study suggest that CER can be used as an indicator of K supply particularly in low K soils.

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Table 1. Selected soil properties for 0-6” samples

Location	County	Soil texture	pH	OM	P-M	K-M	K	Ca	Mg	Na	CEC
				%	------------------	----------	ppm	----------	----------	----------	(meq/100g)
1	Riley	silt loam	7.7	3.2	55	350	324	2749	117	11	14.6
2	Franklin	sandy clay loam	5.7	3.4	14	102	94	2399	322	29	20.9

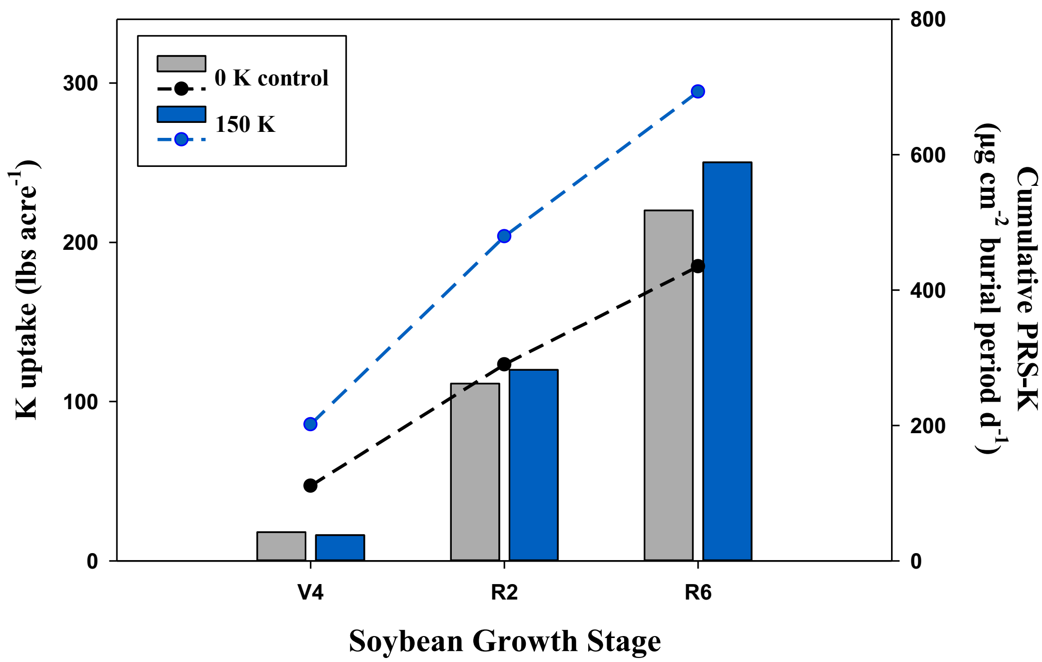

Figure 1. Soybean plant K uptake (represented by bars) and cumulative PRS K adsorption as affected by two levels of K application at Location 1. Pairwise comparisons of K fertilizer application rate within each stage are indicated by “*” when statistically significant at the $p<0.05$.

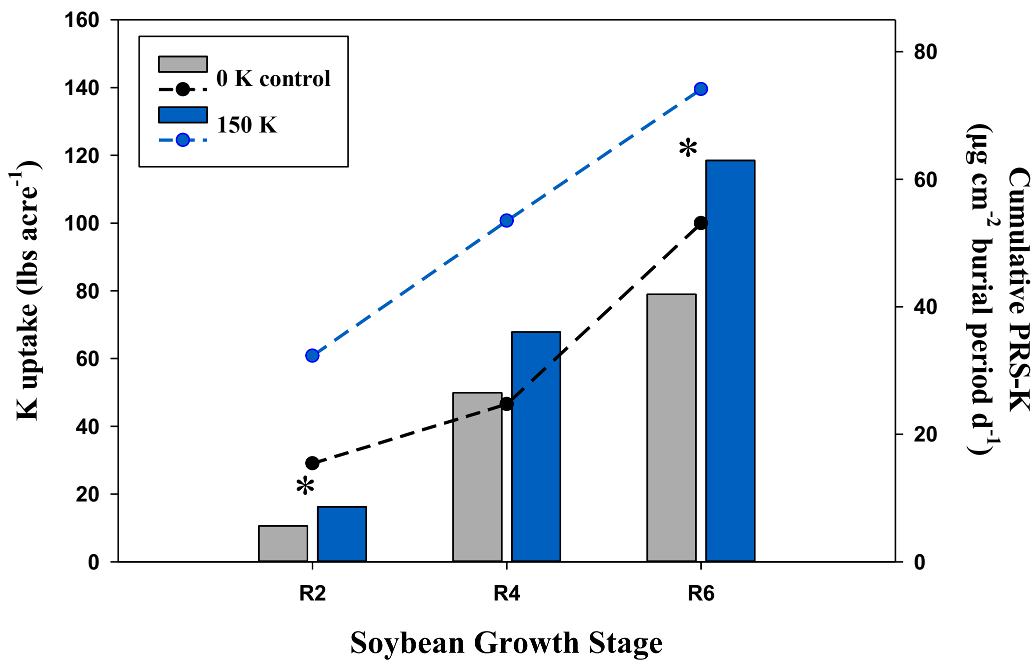

Figure 2. Soybean plant K uptake (represented by bars) and cumulative PRS K adsorption as affected by two levels of K application at Location 2. Pairwise comparisons of K fertilizer application rate within each stage are indicated by "*" when statistically significant at the $p<0.05$.

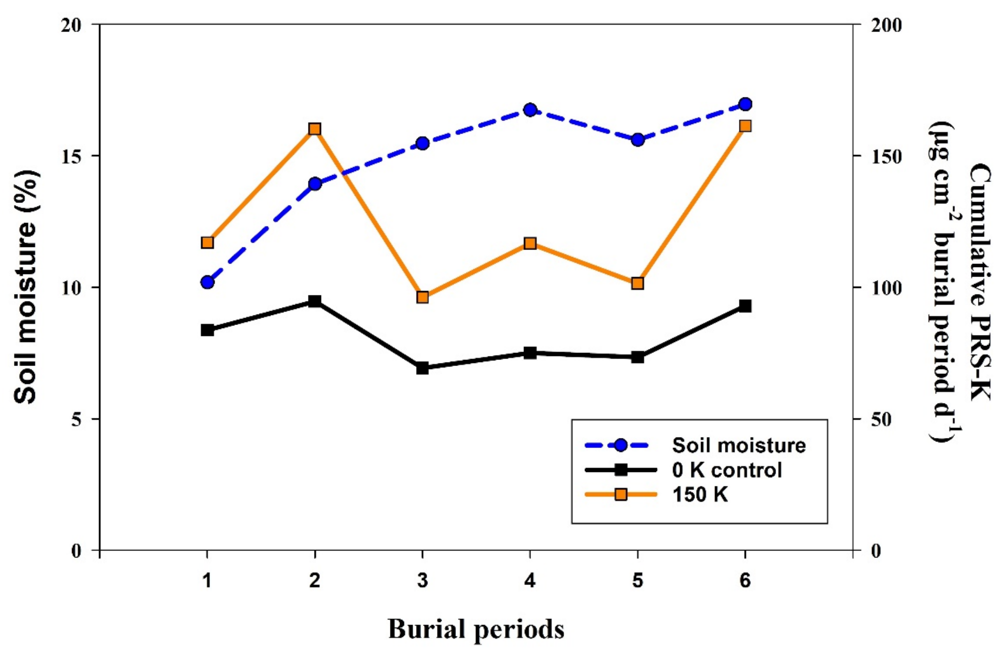

Figure 3. PRS K adsorption as affected by two levels of K application compared to soil moisture content at Location 1.

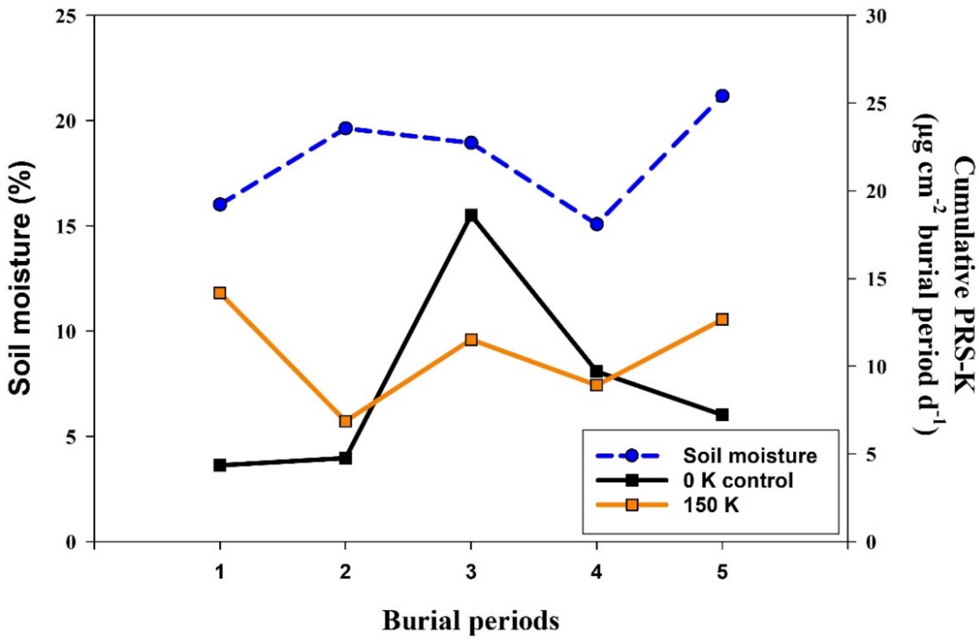

Figure 4. PRS K adsorption as affected by two levels of K application compared to soil moisture content at Location 2.