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Potential Soil Potassium Supply Capacity as Related to Wheat Potassium Demand

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ABSTRACT

We examined soil potassium (K) supply capacity as related to wheat response to K fertilization, using a cation exchange membrane (CEM) burial technique to measure potential K supply rate. A growth chamber experiment was conducted to determine soil and plant response relationships. Canadian Prairie Spring wheat (*Triticum aestivum* 'Biggar') was grown on three soils of different initial K fertility with three rates of added K. Wheat response to K fertilization was well related to the amount of exchangeable K and K supply rate in the soil. Soils with high initial K supply rate demonstrated an adequate K release rate which was associated with low response to added K fertilizer. A soil K supply rate less than 5 $\mu g\ cm^2\ hr^{-1}$ represented soil K supply power that is less than optimal for wheat nutrition.

INTRODUCTION

The amount of soil solution K at any one point in time is too low to meet the total K demand by a crop during a growing season. For satisfactory plant growth, exchangeable K and sometimes fixed K have roles in replenishing soil solution K. A successful prediction of K requirements for a crop should include consideration of potential soil K supplying power over the growing season in relation to crop demand.

A variety of extracting solutions can be used to assess K supplying ability of a soil. However, it is difficult to relate these measurements to all factors controlling K availability to plants in the field. Measurement of potential soil K supply rates using cation exchange membrane (CEM) burial (Qian et al., 1996) has the advantage of providing a dynamic measure of K supply encompassing many of the factors controlling K availability to plants in the field. The objective of this study is to use CEM burial techniques to examine K dynamics and K-supplying capacities of soils as related to wheat response to K fertilization under growth chamber conditions.

MATERIALS AND METHODS

Soils

Soils were chosen from the Black (Meota Association), Dark Brown (Bradwell Association), and Brown (Haverhill Association) in Saskatchewan, Canada. Soils were air dried, ground, passed through a 2-mm sieve, and stored at room temperature until use. The physical and chemical properties of the three soils used are listed (Table 1).

Soil Potassium Extraction and Determination

The two CEM methods, batch and burial, described by Qian et al. (1992, 1996) were used to assess K supply power. Briefly, a CEM strip of 8.5 cm^2 was shaken with 3 g of soil in 20 mL of water for 1 hour in the batch extraction to measure amount of resin exchangeable K (Qian et al., 1992). In the burial method (Qian et al., 1996), a CEM fixed to a plastic probe (CEM PRS™, Western Ag Innovations, Saskatoon, Canada) was inserted directly into the soil at field capacity for 1 hour to measure K supply rate. After burial the membrane was eluted in 0.5M HCl for an hour to induce K desorption from the CEM into the HCl. Extraction with 1M NH_4OAc (Chapman, 1930) was used as a reference extraction method for available K. The K concentration in the extracts for the methods were determined by flame emission spectrometry.

Growth Chamber Experiment

The experiment was carried out in a growth chamber with three different rates (0, 60, and 120 mg K kg^{-1} of soil) of K fertilizer (KCl) added to the three soils.

TABLE 1. Soil physical and chemical properties.

Soil	Batch CEM-K $\mu g\ g^{-1}$	NH_4OAc-K $\mu g\ g^{-1}$	$NaHCO_3$-P $\mu g\ g^{-1}$	OC* %	pH 1:1 (w/s)	EC dS m^{-1}
Bradwell sandy loam	18.8	316	21.8	1.10	6.8	0.30
Meota loam (midslope)	20.5	540	24.5	3.64	6.6	0.20
Haverhill clay loam (footslope)	44.8	999	60.2	2.44	6.8	0.18

*OC denotes organic carbon.

Three replicates of each treatment were prepared. The treatment without K included plant harvests at three intervals over the growing period along with "in-pot" measurement of K supply rate at each interval. Four hundred grams of air-dried soil (<2 mm) were used in each pot. The crop used was Canadian Prairie Spring wheat (*Triticum aestivum* 'Biggar'). A basal application of nitrogen (N), phosphorus (P), and sulfur (S) at 100, 80, and 50 mg kg $^{-1}$, respectively, was made to each pot before seeding. A blanket micronutrient treatment of copper (Cu), zinc (Zn), Mn, molybdenum (Mo), and boron (B) was also applied to each pot before seeding at rates of 0.6, 4, 5, 0.6, 1.5 mg kg^{-1}, respectively.

Approximately ten seeds of wheat were sown into each pot and thinned to six plants after emergence. All pots were watered twice a day to keep soil moisture at 90% of field capacity. The growth chamber temperature was 25°C in daytime and 12°C at night. The pots were completely randomized and rotated every week. After four weeks, additional N and S were applied in solution to each pot at rates of 50 mg N kg^{-1} and 25 mg S kg^{-1} to ensure that deficiency did not limit wheat growth.

In the treatment without K addition (K_0), plants (aboveground) were harvested at 15, 25, and 60 days after emergence. In the two treatments with K addition, plants were harvested at 60 days. Soil K supply in the K_0 treatment was assessed by CEM burial after each harvest. The plant tissue collected at harvest was dried at 60°C and weighed to determine plant yield. Plant K was measured by digesting plant tissue in sulfuric acid-peroxide using a temperature-controlled digestion block (Thomas et al., 1967), followed by flame emission spectrometry.

Statistical Analysis

Statistical analysis included an F test to test for effects due to soils and interaction of soil and fertilizers. For each soil, Duncan's Multiple Range Test was used to

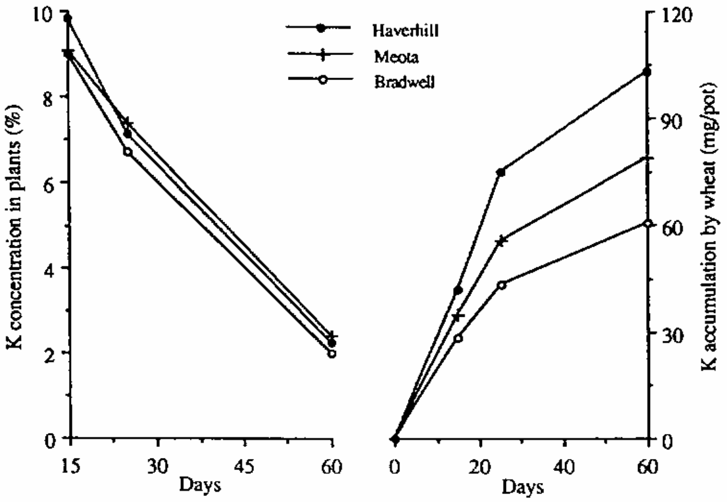

FIGURE 1. Potassium concentration and K accumulation at 15, 25, and 60 days after emergence in control (K_0) soils.

TABLE 2. Plant yield, K concentration, and K accumulation at different rates of K fertilization in the three soils.

Soils	Added K mg kg^{-1}	Available K + fert. K mg kg^{-1}	Plant yield g pot^{-1}	Plant K conc. %	Plant K accumulation mg pot^{-1}
Bradwell	0	316	3.05a	1.99a	60.6a
	60	366	3.73b	2.35b	87.6b
	120	436	4.06c	2.27ab	92.2b
Meota	0	540	3.31a	2.39a	79.1a
	60	600	4.30c	2.57a	110.5b
	120	660	3.95b	2.33a	92.2b
Haverhill	0	999	4.57a	2.26a	103.1a
	60	1059	5.03b	2.07a	104.2a
	120	1119	4.98b	2.00a	99.9a

Values followed by the same letter for each soil in each column are not significantly different (P=0.05) according to Duncan's New Multiple Range Test.

determine if fertilizer K addition produced a significant yield response and K accumulation in the plant.

RESULTS AND DISCUSSION

Changes in Plant Potassium Concentration and Potassium Accumulation During Wheat Growth

Potassium concentration (Figure 1) in the spring wheat plants was highest at the first sampling time (15 days) and decreased thereafter. Decreasing K concentration in the plant with time results from dilution by high biomass production in the early growth stages. Plant K accumulation increased over time, with the largest increases associated with the early stages of plant growth when K demand is high.

Plant K concentrations were not significantly different among the three soils. However, the Haverhill soil gave rise to the highest plant K accumulation, followed by Meota and Bradwell soils. These difference in plant K accumulation are consistent with the predicted differences in K availability among the soils as shown in CEM batch and NH_4OAc extractable K (Table 1).

Plant Response to Potassium Fertilization

Potassium application led to yield and K accumulation responses that were significantly different ($p<0.01$) among the three soils (Table 2). In Bradwell sandy loam, fertilizer K added at 60 mg kg^{-1} significantly increased plant dry matter yield and plant K accumulation, with the highest yield and K accumulation obtained at 120 mg kg^{-1} addition. In Meota loam soil, 60 mg K kg^{-1} was sufficient to produce the highest plant yield and plant K accumulation. In the Haverhill clay loam soil, a significant yield response to fertilizer K was observed with the addition of 60 mg K kg^{-1}, but the magnitude of the response was less than in Bradwell and Meota soils. Added KCl had no effect on K accumulation in the Haverhill soil. The differences in K fertilizer response observed among the soils reflect the differences in K availability as predicted by CEM and NH_4OAc extraction, with greatest response on the Bradwell sandy loam and lowest response with high K Haverhill clay loam (Table 2). Based on the K fertilizer response data (Table 2), the critical plant K concentration for spring wheat at 60 days after emergence is about 2.1 to 2.3% K on a dry matter basis.

Changes in Soil Potassium Supply Rate During Wheat Growth

The Bradwell sandy loam experienced an initial sharp decrease in K supply rate from day 15 to day 25 (Figure 2). From day 25 to day 60 K supply rate remained at a low, relatively constant level in this soil. The low supply rates encountered from day 25 to day 60 likely reflect an inadequate K release rate from exchangeable and fixed K pools to satisfy plant K demand. In the Haverhill

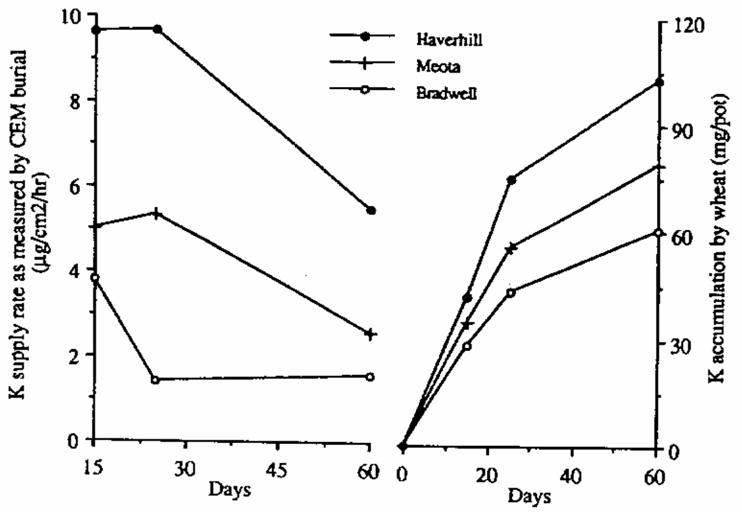

FIGURE 2. Potassium supply rate in three Saskatchewan soils during the growth of wheat.

clay loam soil, K supply rate started out at a much higher level and even after 60 days did not approach the low levels encountered in the Meota and Bradwell soils. The high initial K supply rate in the Haverhill soil and the ability of this soil to maintain the K supply rate in the face of plant demand is consistent with high exchangeable K content (Table 1) and a higher content of clay minerals capable of releasing fixed K to solution. The higher supply rates in the Haverhill soil are consistent with the lack of K fertilizer response. Based on these results, it appears that a K supply rate less than about 5 µg cm^2 hr^{-1} represents soil K supply power that is less than optimal for wheat K nutrition.

CONCLUSIONS

Spring wheat response to K fertilization is closely related to the amount and supply rate of available K in the soil. Inadequate soil K supply power was associated with NH_4OAc and batch CEM extractable K amounts less than about 500 µg K g^{-1} and 20 µg K g^{-1}, respectively, and wheat plant K concentration less than 2.2%. Potassium supply rates to CEM less than about 5 µg K cm^2 hr^{-1} indicate less than optimal K supply. Measuring decline in soil K supply rate over time in a growing crop may be a useful tool in revealing soil K depletion patterns.

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