Assessing Soil K Supply Capacity for Wheat Growth

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Introduction

It is well known that the amount of soil solution K present in the soil 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 plays an important role and sometimes K in fixed forms also plays a role in replenishing soil solution K. A successful prediction of K requirements for a crop should include consideration of potential soil K supply power over the growing season in relation to crop demand. There are a variety of extracting solutions which can be used to assess K supplying ability of a soil. However, it is difficult to relate these measurements mechanistically 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). 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 in Table 1.

Table 1. Soil physical and chemical properties.

Soil	Batch CEM-K μg/g	NH_4OAc-K μg/g	Available P μg/g	O.C.* %	pH	EC ds/m
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

*O.C. denotes organic carbon

Soil K extraction and determination

The two CEM methods, batch and burial, described by Qian et al. (1992 and 1996) were used to assess K supply power. Briefly, a CEM strip of 8.5 cm* was shaken with 3 g of soil in 20 ml of water for 1 hour in the batch extraction (Qian et al., 1992). In the burial method (Qian et al., 1996), a CEM in probe form (CEM PRS™, Western Ag Innovations, Saskatoon, SK) was directly inserted into the soil at field capacity for 1 hour to measure K supply rate. After burial the membrane was eluted in 0.5 M HCl for an hour to induce K desorption from the CEM into the HC1. Extraction with 1 M NH_4OAc (Chapman and Kelly, 1930) was used as a reference extraction method for available K. The K concentration in the extracts for the methods were determined using 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 of soil) of K fertilizer (KC1) added to the three soils. 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) was used in each pot. The crop used was Canadian Prairie Spring wheat ***(Triticum aestivum var. Biggar).*** A basal application of nitrogen (N), phosphorus (P), and sulfur (S) at rates of 100, 80 and 50 mg/kg, 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, respectively.

Approximately ten seeds of wheat were sown into each pot and thinned to 6 plants after emergence. All pots were watered twice a day to keep soil moisture at 90% of field capacity. The growth chamber temperature was set at 25°C daytime and 12°C at night. The pots were completely randomized and rotated every week. After 4 weeks, additional N and S were applied in solution to each of the pots at rates of 50 mg N/kg and 25 mg S/kg 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 were 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.

Results and Discussion

Changes in plant K concentration and K uptake during wheat growth

Potassium concentration (Fig. 1) in the spring wheat plants was highest at the first sampling time (15 days), and decreased thereafter. Decreasing K concentration in the plant over time results from dilution by high biomass production in the early growth stages. Plant K uptake increased over time, with the largest increases in uptake 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 uptake, followed by Meota and Bradwell soils. These difference in plant K uptake are consistent with the predicted differences in K availability among the soils as shown in CEM and NH_4OAc extractable K (Table 1).

Plant response to K fertilization

Potassium application led to yield and K uptake response that was different in the three soils. In Bradwell sandy loam, fertilizer K added at 60 mg/kg significantly increased plant dry matter yield and plant K uptake, with the highest yield and K uptake obtained at 120 mg/kg addition. In Meota loam soil, 60 mg K/kg was sufficient to produce the highest plant yield and plant K uptake. In the Haverhill clay loam soil, a significant yield response to fertilizer K was observed with the, addition of 60 mg K/kg, but the magnitude of the response was less than in Bradwell and Meota soils. There was no effect of added KC1 on K uptake 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,

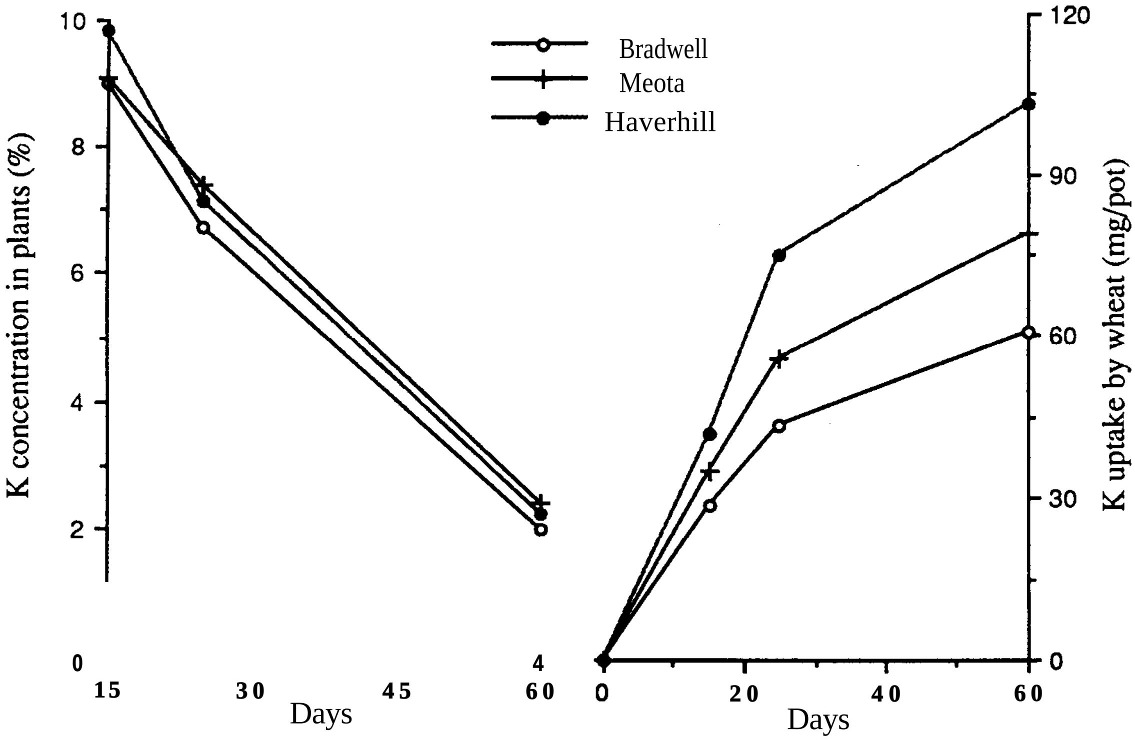

Fig. 1. K concentration & K uptake at 15, 25 & 60 days after emergence in control (Ko) soils

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

Soils	Added K mg/kg	Available K+Fert. K mg/kg	Plant yield g	Plant K conc. %	Plant K uptake mg/pot
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	74.1a
	60	600	4.30c	2.57a	110.5b
	120	660	3.95b	2.33a	92.2b
Haverhill	0	999	4.57a	2.26a	99.8a
	60	1059	5.03b	2.07ab	104.2a
	120	1119’	4.98b	2.00b	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.

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 depicted in Table 2, the critical plant K concentration for spring wheat at 60 days after emergence is about 2.1 - 2.3 % K on a dry matter basis.

Changes in soil K supply rate during wheat growth

The Bradwell sandy loam experienced an initial sharp decrease in K supply rates from day 15 to day 25 (Fig. 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 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 consistant with the lack of K fertilizer response.

Based on these results, it appears that a K supply rate less than about 50 $\mu g/10cm^2/hr$ represents soil K supply power that is less than optimal for wheat K nutrition.

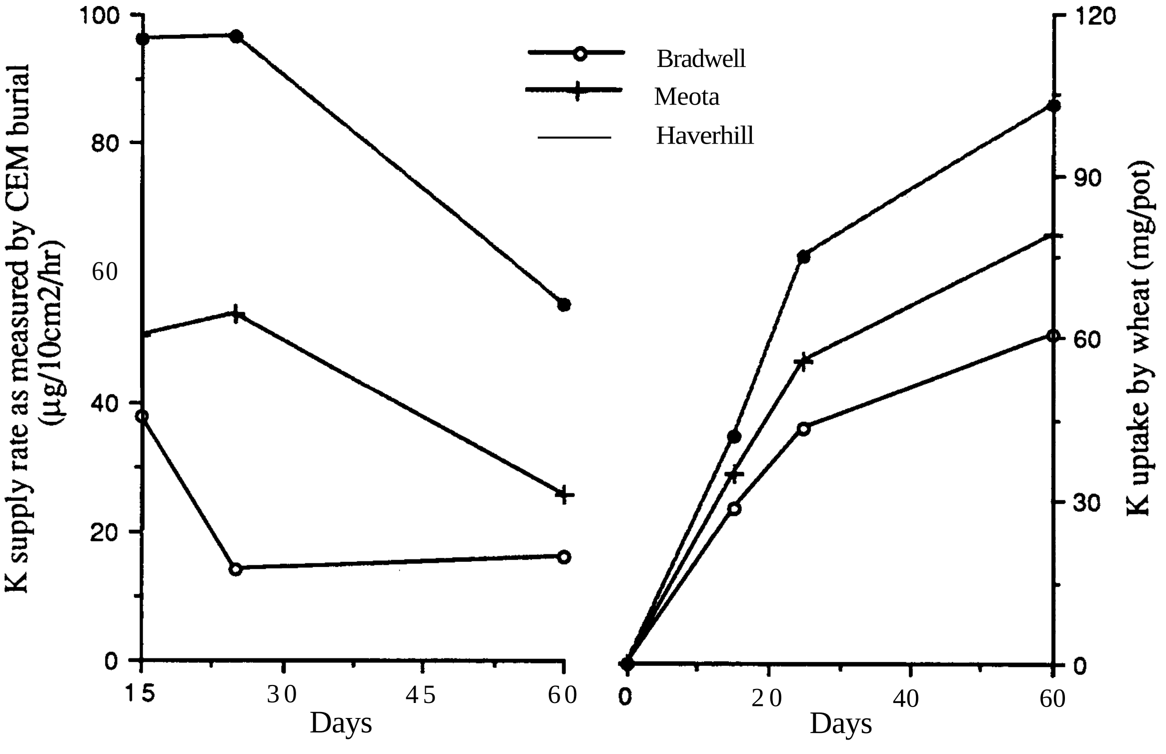

Fig. 2. Potassium supply rate in three Saskatchewan soils during the growth of wheat.

Conclusion

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 and 20 µg K/g, respectively, and wheat plant K concentration less than 2.2%. K supply rates to CEM less than about 50 µg K/10cm^2/hr indicate less than optimal K supply. Measuring the decline in soil K supply rate over time in a growing crop may be a useful tool in revealing soil K depletion patterns.

References

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