EVALUATION OF SOIL TEST POTASSIUM GUIDELINES IN MINNESOTA

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ABSTRACT

The objective of these experiments was to determine whether soil clay mineralogy impacts corn potassium (K) requirements. New and historica research trials were combined to correlate soil potassium concentration extracted by 1M ammonium acetate for samples collected at a six-inch sampling depth. Soil samples from current and historica studies were analyzed for clay species, specifically the relative abundance of illite and smectite. Soils were divided into groups with smectite:illite ratios above or below 3.5:1. Soils in central and western Minnesota tended to have a greater abundance of smectite in the clay fraction while illite abundance was greater in the southeastern and central areas of Minnesota dominated by silt loam or sandy textured soils. Critical soil test K concentration for soils with a ratio below 3.5:1 was 85 ppm which the critical soil K test was 106 ppm when the ratio of smectite:illite was 3.5 or greater. The data provided indicates a potential for different K guidelines for K based on the relative abundance of illite or smectite.

INTRODUCTION

Management of potassium in corn (*Zea mays* L.) can be challenging due to uncertainties in the availability of the nutrient. Potassium is present in the soil and is taken up by crops as a cation (K^+). While the chemistry of K in the soil is simple, the availability to crops is not due to the impacts of cation exchange capacity (CEC) and retention of the K^+ ion between layers of clay. In addition, drying of soil samples can result in over or under estimation of the availability of K to crops. Most soil testing labs dry samples as soon as they receive them to aid in throughput of the large number of samples. Past research in Iowa has shown a better prediction of the availability of K to corn and soybean based on extraction from moist soil (Barbagelata and Mallarino, 2013). Many labs are not set up to extract moist soils and most other nutrients tested are not impacted by drying of soil samples. Adoption of analysis of soils on a moist basis would be challenging to most labs and would increase the cost of soil tests.

Soil clays impact the ability to retain cations. Soils in Minnesota contain three major types of clays. Kaolinite which is a 1:1 clay with a low CEC, and illite and smectite which are both 2:1 clays. One major difference between illite and smectite is CEC which is greater for smectite than illite. Smectite also has a greater shrink-swell capacity but has less affinity to trap and retain K^+ ions in the clay interlayer spaces than illite. The radius of the K ion is the perfect size to fit within pockets in the outer layers of the tetrahedral sheet of 2:1 clay. Potassium ions in the interlayer space are often considered to be ‘fixed’ potassium. Illite tends to have a greater affinity to ‘fix’ potassium than smectite. It can be questioned whether K guidelines vary for soils dominated by illite compared to smectite.

Soil clay mineralogy has not been considered as an important factor in Minnesota to be used for generating K fertilizer guidelines (Kaiser et al., 2022). More recent work in North Dakota concluded that the ratio of smectite:illite can vary what the critical soil test level (the soil tests at which crop response to fertilizer ceases) is for corn (Breker et al., 2019). Current corn guidelines for North Dakota suggest that K fertilizer need vary for corn based on a smectite to illite ratio of above or below 3.5. In contrast, K fertilizer guidelines for Iowa have changed over the past ten years to account for the variability of K from soils dried before analysis. Work is ongoing in Minnesota comparing K extracted with 1*M* ammonium acetate solution on both field moist and air-dried soil samples. However, no extensive work has been done to study the variation in clay mineralogy across Minnesota. The objectives of this work were to 1) provide a survey of clay mineralogy for Minnesota; and 2) determine if clay species impact potassium requirements for corn.

MATERIALS AND METHODS

Table 1. Summary of field K response trials established in Minnesota from 2019 to 2021.

Year	Location	Trial[1]	STK	Optimal K Rate[2]
			--ppm--	-lb K_2O ac^{-1}-
2019	Mentor	FF	104	40
2020	Sauk Centre	FF	140	40
	Sauk Centre	FF	118	66
	Morris	FF	161	nr
	Marshall	FF	160	nr
	Granite Falls	FF	185	nr
	Benson	FF	123	79
	Lamberton	FF	171	nr
	Le Sueur	SP	138	93
	Rosemount	SP	81	107
2021	New Ulm	FF	151	71
	New Ulm	FF	113	nr
	Lakefield	FF	162	nr
	Eyota	FF	152	nr
	Belgrade	FF	192	nr
	Belgrade	FF	215	61
	Grand Forks	FF	211	nr
	Rochester	SP	98	78
	Becker	SP	99	66
	Lamberton	SP	109	37
	Rosemount	SP	90	nr

[1/] FF, Farmer Field; SP, Small Plot.

[2/] nr, no response

A total of 21 farmer field and small plot trials (Table 1) were established to gather K response data to be combined with previously collected data. Field trials consisted of five rates of K_2O per acre, 0, 40, 80, 120, and 160 lbs. Farmer field trials were established using a Latin square design with five replications. Small plot trials ranged from four to six replicates. Fertilizer potassium was applied at potash (0-0-60). Fertilizer was applied using commercial equipment by establishing blocks in each field where the fertilizer treatment structure was superimposed within fertilizer prescription maps. As applied maps were checked following application to verify fertilizer was applied correctly. Yield data from farmer field trials was collected using combines equipped with calibrated yield monitors.

Soil samples were collected from each replicate as a composite of 10 cores collected to a depth of six inches. Farmer field samples were collected from 0 K plots in June. Soil samples were collected from small plot trials as a composite across each replication before treatment application. Soil samples were dried at air temperature and ground to pass through a 2 mm sieve prior to analysis. Soil was analyzed for extractable potassium by the ammonium acetate procedure (Warncke and Brown, 2011). Semiquantitative mineral identification and clay speciation was conducted using the Rietveld method (Rietveld, 1969). Soil samples for mineralogical analysis were collected from the field trials outlined in Table 1 as well as additional non-trial locations located in areas of Minnesota to represent major landforms and soil associations.

RESULTS AND DISCUSSION

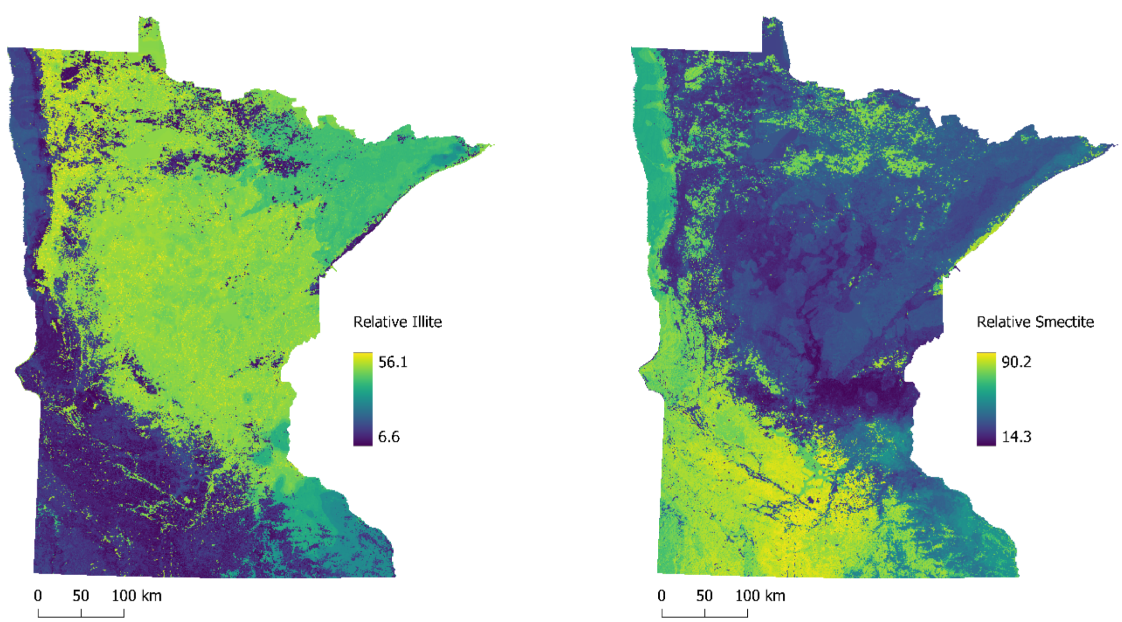

Figure 1. Semi-quantitative abundance of illite and smectite estimated for Minnesota soils.

The relative abundance of illite and smectite in soils is estimated across the state of Minnesota in Figure 1. Soils in the southern and western part of the state which are higher in clay tended to have relatively higher smectite concentrations which was expected. Illite abundance was greatest in the SE and the majority of north central Minnesota which corresponds to silt loam and sandy soils where crops historically have responded to K. Major inclusions higher in Illite in Central and Western MN were estimated around major rivers, the Minnesota river valley. Figure 2 summarizes the ratio of smectite:illite which was higher in Central and Western Minnesota and lower in the Southeastern and Central and Northcentral parts of the state.

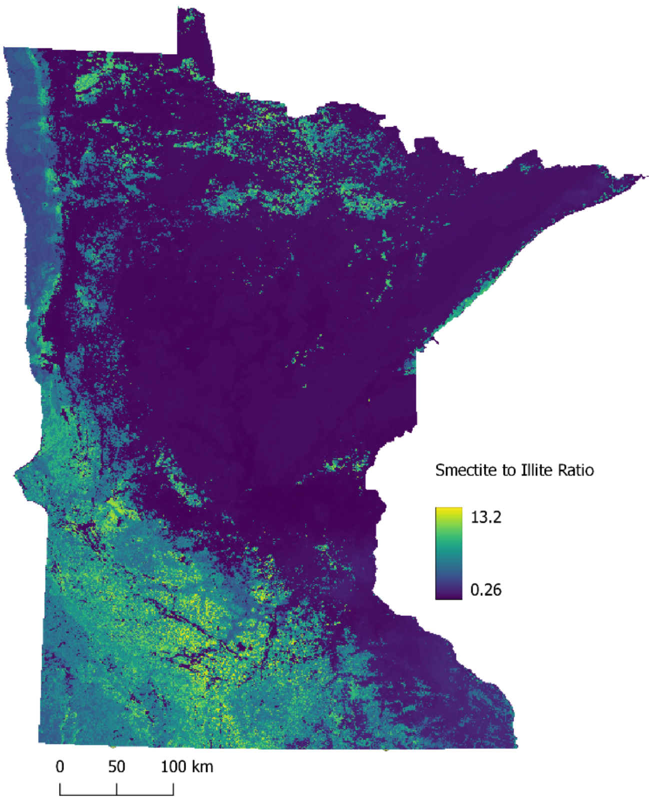

Figure 2. Ratio of smectite:illite for 0-6" soil sampling depth based on a semi-quantitative analysis.

A summery of the field trial response data is given in Table 1. Yield of individual treatments is not show for any of the trial locations. Table 1 contains the average soil test K (STK) and the rate of K that provided maximum yield at sites where a K response occurred. Corn grain yield was increased by K at 11 of the 21 locations. Corn grain yield responses occurred at sites ranging from 80 to 140 ppm with one exception, one site responded with a K test near 260 ppm. Corn grain yield was increased by 80-140 lb K_2O per acre.

Current trial data was combined with past research to form a database of K response (not shown). The ratio of smectite:illite was calculated for each location along with corn grain yield response. Figure 3 summarizing corn grain yield response for soils with a smectite:illite ratio of above or below 3.5. Data are summarized in Table 3. Overall, there was only a very small difference in where corn relative grain yield achieved maximum in both cases. The critical K concentration was determined after fitting a quadratic plateau curve and is defined as the soil test value where 95% of maximum yield was achieved. For soils with a smectite:illite ratio below 3.5, the critical soil K test was 85 ppm (or mg kg^{-1}). For ratios 3.5 or above the critical soil test K concentration was 106 ppm. The 85 ppm value corresponds the bottom of the previously used STK classification for the state of Minnesota. The STK classes were increased and for the new STK ranges the 106 ppm value is close to the bottom of the current STK class.

The data provided may indicate a lower critical level for soils with a greater abundance of illite. Anecdotally, many field trial locations in the Southeastern part of Minnesota and for irrigated sandy soils have not shown a strong response to K even for Low or Very Low K testing soils. A lower critical level may explain some of the differences that have been observed. It is unclear whether any differences would exist between silt loam versus sandy soils which comprise the bulk of the higher illite soils. This data provides a basis for revision of the corn K guidelines for Minnesota.

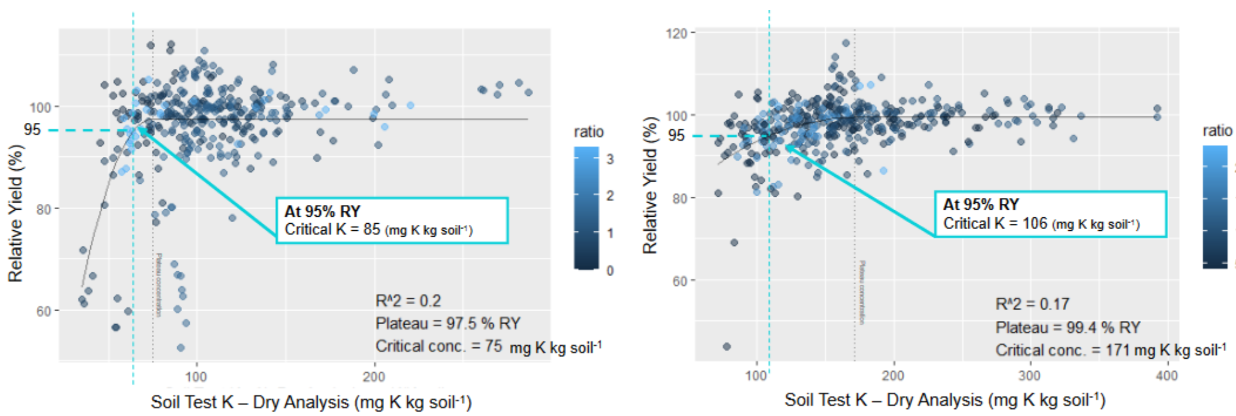

Figure 3. Relationship between relative corn grain yield and soil test potassium for a 0-6" soil sampling depth based on soils with a smectite:illite ratio of less than or greater than 3.5:1. Soil test K was made on dry samples and concentration is given at mg K kg^{-1} soil which directly equates to ppm.

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