Recalibration of Soil Potassium Test for Corn in North Dakota, U.S.A. and Effect of Sampling Time

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Introduction

- Current potassium (K) fertilizer recommendations for corn in North Dakota developed in late 1970s and early 1980s, when soil test K (STK) levels well above 200 ppm were nearly ubiquitous (Dahnke et al., 1982). Potassium deficiencies were seldom observed due to high native K fertility and low K removal in spring wheat-dominated production systems.
- The recent change to intensive corn and soybean production systems, particularly in eastern North Dakota, without maintenance K fertilization has resulted in more low STK values being reported. In 2010, 17% of soil samples had STK levels below 150 ppm critical level (Fixen et al., 2010).
- The standard soil K test method using NH_4OAc has come under scrutiny:
  - Soil sample drying often increases NH_4OAc-extractable K from its field-moist level, and NH_4OAc-extractable K from dried soil correlates poorly with yield response to K fertilization (Barbagelata and Mallarino, 2012).
  - Soil test K levels change throughout the year, often highest in spring and lowest in late summer (Franzen, 2011).
  - Yield response to K fertilization may be inconsistent on low and high soil test K soils (Rakkar et al., 2015).

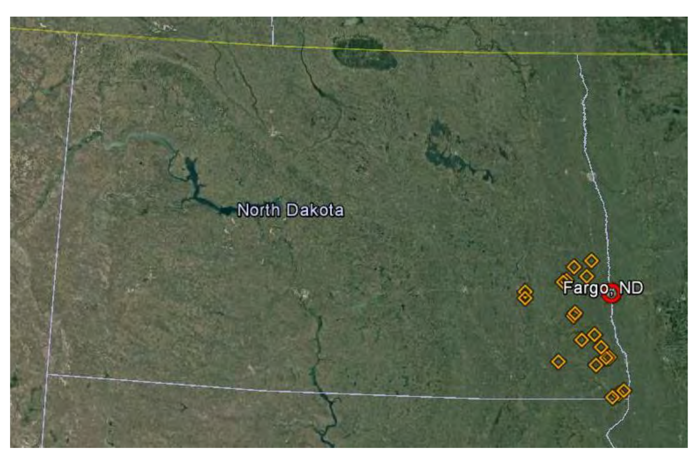
Justification and Objectives

- This research is important to corn producers in North Dakota because low STK levels are more common and the yield potential of modern corn hybrids is higher, posing increased risk for potential K deficiencies. The standard NH_4OAc soil testing method may not accurately assess plant-available K and seasonal variation in soil K makes soil test interpretation difficult. Therefore, a better understanding of (1) the K requirements for modern corn hybrids, (2) the methods for assessing plant-available K, and (3) the role of soil sampling date on soil K is needed for profitable K management in modern corn production systems.
- The objectives of this field study are to:
  1. Evaluate corn yield response to K fertilization
  2. Identify an accurate plant-available K testing method
  3. Assess seasonal soil K variation for soil test interpretation

Materials and Methods

LOCATION

- Southeastern North Dakota
  - 2015: Thirteen sites
  - 2016: Six sites



EXPERIMENT DESIGN

- Randomized complete block design with split-plot in time arrangement
  - Four replications (3.0 m x 9.1 m plots)
- Plot treatments
  - Fertilizer grade potassium chloride (0-0-60 K_2O), broadcast
    - Rates: 0, 34, 67, 101, 135, and 168 kg K_2O ha^{-1}
    - Shallow incorporation (5-8 cm), except for no-till sites
  - Non-fertilized fallow treatment to assess soil K change without plant uptake
- Soil samples collected from non-fertilized check and fallow plots from 0- to 15-cm biweekly until grain harvest

SOIL ANALYSIS

- 1.0 M NH_4OAc (pH 7), 2 g soil with 20 mL NH_4OAc, shaken for 5 minutes
  - Air-dried soil ground to pass 2-mm sieve
  - Field-moist soil passed through 2-mm sieve, moisture content determined
- Sodium tetraphenylboron (Cox et al., 1999), 5-minute and 168-hour extractions
- Ion-exchange resin capsule (UNIBEST, Inc., Walla Walla, Washington, U.S.A.)
  - 30-g air-dry equivalent mass of field-moist soil and 30 mL deionized water
  - Incubated with resin capsule for 168 hours at constant 20 °C
- Mineralogical analysis and clay speciation (ACT Laboratories, Ancaster, Canada)

Results: Soil Test Methods and Yield Response

Table 1. Frequency of yield response prediction by dry soil K test.

	Soil K test class (mg kg^{-1})†				
	VL‡ 0-40	L 41-80	M 81-120	H 121-160	VH 161+
Number of sites in soil test class	0	3	6	5	5
Number of sites with significant yield response	---	2	2	2	1
Probability of significant yield response	---	67%	33%	40%	20%

† Soil K test classes for NH_4OAc-extractable K on dry soil from North Dakota soil fertility recommendations for corn (Franzen 2014)

‡ VL, very low; L, low; M, medium; H, high; VH, very high

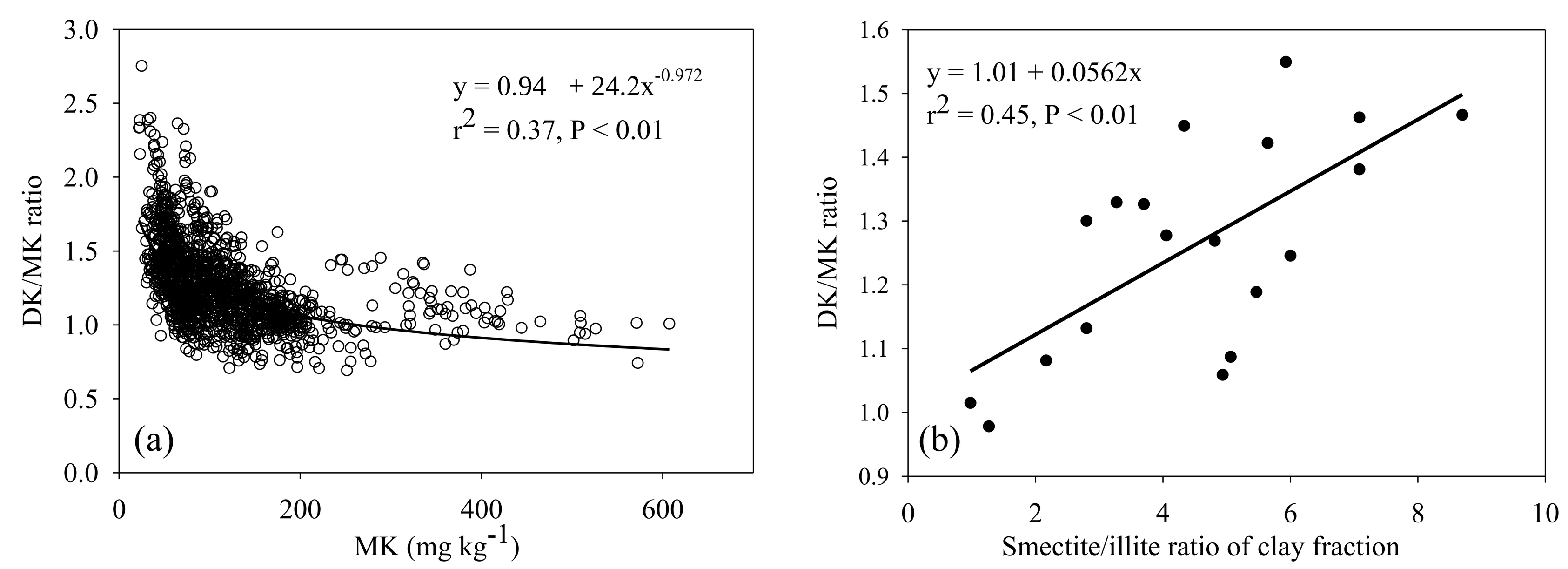


Fig. 1. (a) Relationship between the ratio of air-dry soil K (DK) and field-moist soil K (MK) regressed against the field-moist soil K (MK). (b) Average DK/MK ratio of a site related to smectite-to-illite ratio of its clay fraction.

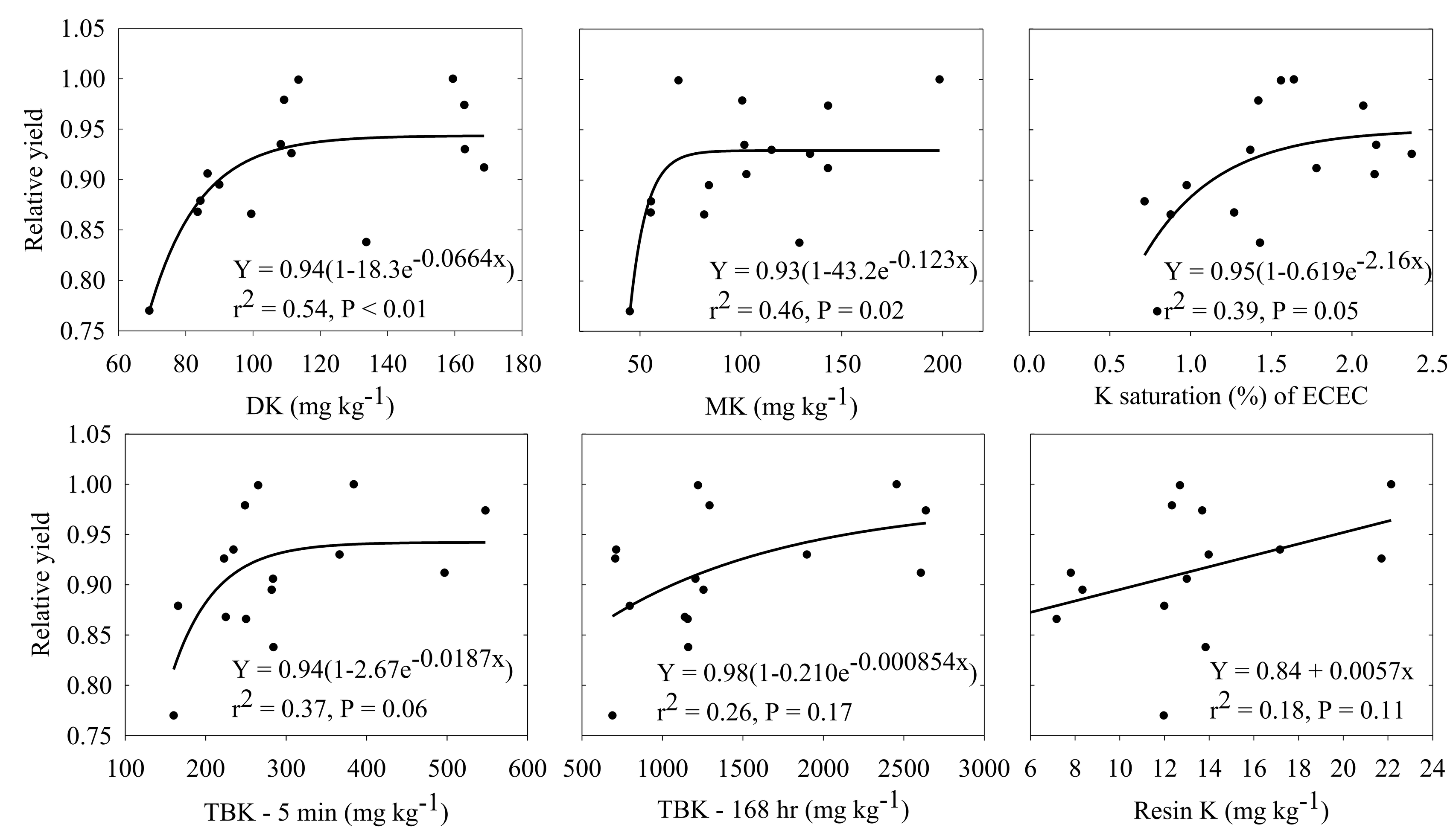


Fig. 2. Relative grain yield of unfertilized treatment to maximum yield compared with NH_4OAc-extractable K from air-dry soil (DK), field-moist soil (MK), K saturation of estimated cation exchange capacity (ECEC), tetraphenylboron-extractable K (TBK) for 5-minute and 168-hour extractions, and ion-exchange resin extractable K.

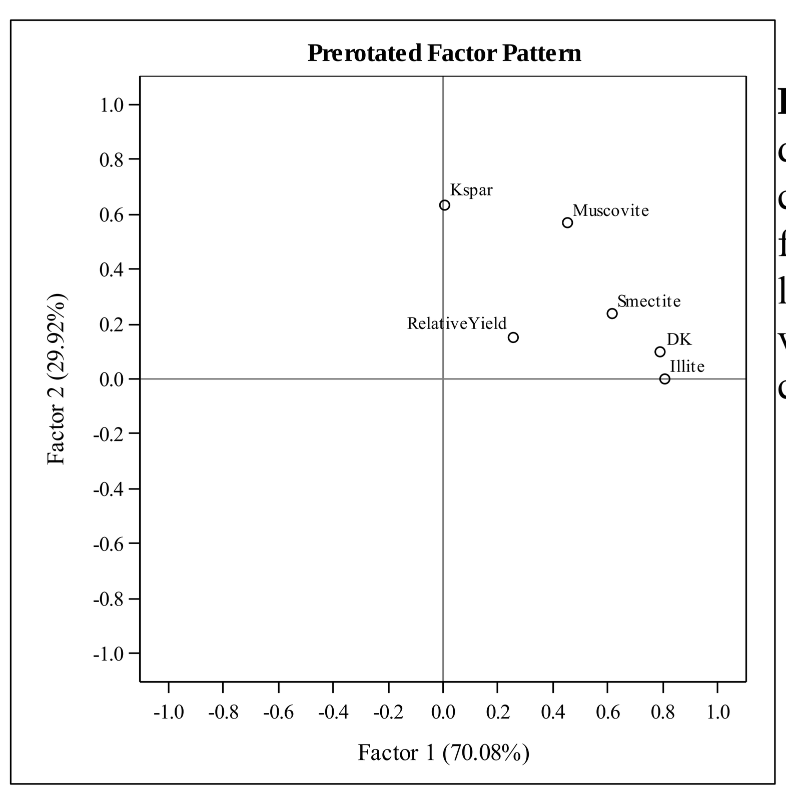
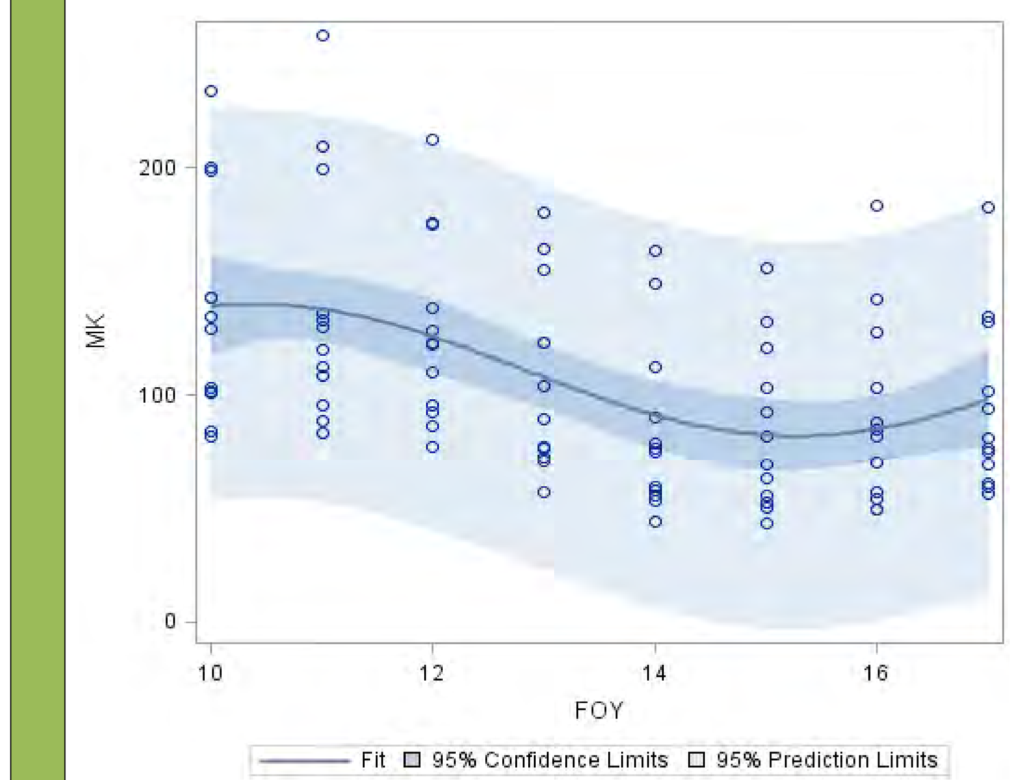


Fig. 3. Orthogonally-rotated principal factor solution of air-dry soil NH_4OAc-extractable K (DK) and mineral components related to relative yield response to K fertilization. Axis-position of variable represents factor loading score on common factor. Proportion of common variance for each factor shown in parenthesis. Mineral components expressed as fraction of whole soil.

Results: Sampling Time



- Sampling time significant at 18 of 19 sites ($P < 0.05$)
  - Highest in late May or early June, lowest in late summer
  - Fallow plot trends more variable due to no crop K uptake or water use
- Sinusoidal modeling of STK and sampling time significant ($P < 0.1$) for:
  - DK: 10 sites
  - MK: 15 sites

Fig. 4. Field-moist soil K (MK, mg kg^{-1}) and sampling time (fortnight of year, FOY) fit to a sinusoidal regression model ($MK = 111 + 29.1*\sin(0.6425*FOY + 1.185)$, $r^2 = 0.21$, $P < 0.01$) for 12 of 13 combined cropped, unfertilized treatments from 2015.

Summary and Discussion

- Only six of 14 sites with STK below the current 150 mg kg^{-1} DK critical level had significant yield responses to K fertilization (Table 1). One site above the critical level (201 mg kg^{-1} DK) responded to fertilization. The standard testing method using dry soil and current critical level predicted less than half of yield responses.
- Sample drying increased NH_4OAc-extractable K by 1.26 on average (range: 0.8-2.4) from its field-moist condition. Relative amount of K released upon drying was greater for low STK soils (Fig. 1a). Potassium release was greater in smectite-rich soils (Fig. 1b).
- The NH_4OAc extraction on dry soil had the best predictive relationship with relative yield response (Fig. 2), in spite of predicting less than half of significant responses (Table 1). Field-moist soil K and %K saturation were inferior predictors of yield response. Nonexchangeable K methods (i.e., sodium tetraphenylboron and ion-exchange resin) were not significant related to yield.
- Yield response was positively albeit minimally associated with DK, K-bearing minerals, and clay species (Fig. 3). No mineralogical component exhibited a distinct relationship with yield response, suggesting that the mineralogical controls on plant-available K are multifaceted.
- Soil test K levels were highest in spring and lowest in late summer, following crop K uptake and soil moisture patterns. The change in STK was describable by a sinusoidal pattern for most sites (Fig. 4).
- An adequate plant-available K determination procedure remains to be identified in North Dakota.

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