Relationship Between Soil-Test Potassium and Crop Yield

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Introduction

The main objectives of this ongoing research have been (1) to study the variability in soil-test potassium (K) and corn response to K fertilization and (2) to evaluate soil tests for K currently used in the Midwest and a new soil test for K with potential to improve the prediction of crop response to K fertilization. The research is based on evaluation of conventional, long-term trials at three research farms and several on-farm, replicated strip trials harvested with yield monitors.

Field Trials and Laboratory Methods Used

Field trials.

Two of the conventional long-term trials that were in corn in 2002 continued to be evaluated as in the past (one trial was in soybeans). Four of the on-farm strip trials comparing uniform-rate and variable-rate fertilization that were in the corn part of the cycle in 2002 were also evaluated as in the past. In addition, four new strip trials with corn were established for the 2002 season using a different, less expensive design. Treatments in these new trials consisted of a check and a K fertilizer amount of at least 150 lb K_2O/acre. These treatments were applied to strips 60 feet wide and as long as the fields were replicated three to four times across each field. Initial soil-test K before applying the fertilizer treatments is measured on soil samples collected from cells approximately 0.5-acre in size. As for other strip trials, grain was harvested with yield monitors. After harvest this fall, soil samples were collected from each strip and cell (0.25-acre cells). It must be noted that corn in all trials is always grown in rotation with corn, and that soybeans yields are also evaluated with complementary funding from the Iowa Soybean Promotion Board although soybean data are not presented in these reports.

Laboratory analyses.

The work continued as before by collecting and analyzing soil and plant-tissue samples for K. The soil tests included the routine ammonium-acetate K test (AA-K) and Mehlich-3 K test (M3-K) for all plots, the sodium tetraphneyl-boron test (TB-K) for selected replications (to reduce costs) of all trials, and a field-moist based AA-K test for selected replications (to reduce costs) of all trials. In addition, in samples from five fields with contrasting soil types, AA-K was measured by drying the sample at different temperatures (air dried, 40 °C, and 50 °C). The plant parts collected were the above-ground part of small plants at the V5 to V6 growth stage and the leaf blade of ear leaves at the silking growth stage. All these tissue samples were analyzed for total K.

Summary of Progress

Although much effort was dedicated to field and laboratory work for this year's trials, the most significant effort was dedicated to summarize all available relationships between yield response and soil-test K to determine if a change in the Iowa K fertilizer recommendations was justified at this time. The latter effort was based on results of this project and also previous projects, and delayed the analysis of other results for this year (such as plant-tissue K responses to K and of relationships between K rates or soil-test K with plant-tissue K).

The conclusion was that the recommendations should be changed, even though major questions remained and research should continue to revise them within two or three years. The new recommendations are being published at this time, and are being shared to producers and agronomists at numerous meetings. Thus, this report emphasizes the basis for the new recommendations because they should markedly affect K fertilizer use across the state.

New Interpretations for Soil-Test Potassium.

A need to update Iowa soil-test K interpretations was first suggested during the late 1990s by an increasing frequency of K deficiency symptoms in corn, and that was the main reason to develop this project. These symptoms occurred mainly when spring rainfall was below normal, but were observed in other conditions even in some soils that tested Optimum according to current interpretations. Also, field experiments designed to evaluate K placement methods often showed larger than expected yield response in soils testing Optimum (90 to 130 ppm, 6-inch depth, AA-K test), and smaller responses in soils testing High. In previous decades, deficiency symptoms and large yield responses were seldom observed for the Optimum category.

The results for corn from this project, additional results for corn from trials funded by the Iowa Corn Promotion Board, and complementary data for soybeans from a project funded by the Iowa Soybean Promotion Board confirmed that current soil-test K interpretations often would recommend too little or no K fertilizer for soils with a high probability of yield response.

Figure 1 shows the relationship between relative corn yield response and ammonium-acetate soil-test K across all sites and years. Results for the M3-K test were not available for some sites but were similar to AA-K results for most other sites and are not shown. The white data points represent data for soil series where crop responses would deviate slightly from expected responses according to existing interpretations. These data suggest that the test is a reasonably good predictor of the corn response to K fertilizer, and that the Optimum class should be increased by about 20 ppm to an upper limit of 140 to 150 ppm.

However, the black points identify data for soil series in which the response to K fertilizer often was much larger and at higher soil-test levels than current interpretations would predict. Although all soils represented by black points have low subsoil K, the white points represent soil series with either low or high subsoil K. Thus, the current sets of interpretation categories (two) used in Iowa based on subsoil K concentration would explain only partially the differences in responses. These data suggest that the test predicts rather well a lack of yield response at soil-test levels higher than about 170 ppm, but is a very poor predictor of response below that level.

The results for all sites suggest two contrasting groups of soil series for which soil-test K interpretations should be different. However, because of the wide data spread below soil-test K values of about 170 ppm and a need to study crop responses for other conditions, the new interpretations were made to apply across all Iowa soil series. Data in Table 1 show, as an example, the current and new interpretations and K fertilizer recommendations for corn and soybean grown in soils with low subsoil K. Yield response data from several field trials harvested in 2002 that were not summarized at this time and new trials planned for 2003 should provide information useful to develop specific interpretations for different soil series or Iowa regions.

Impact of Soil Moisture and Sample Drying on Soil-Test K

Several reasons could explain increased soil-test K requirements for many soils and large response variation across soils with similar soil-test K values. The research continues to collect more information for other fields and to address these issues, and no firm conclusions are possible at this time. However, a very likely reason relates to a 1989 change from interpretations based on analyses of field-moist samples to dried samples. Interpretations were adjusted to oven-dried samples (35 to 40 °C) using an average factor for all Iowa soil series and conditions. This factor was derived from analyses of soil samples collected from many fields, but from very few field response trials. Ongoing research suggests that the average K extraction ratio used to adjust previous field calibrations was not appropriate for many conditions.

Data in Fig. 2 show the difference in extracted K for samples dried at different temperatures relative to a field-moist ammonium-acetate K test for contrasting soil series. Differences in amounts of K extracted from air-dried or moist samples and the effect of drying samples at 40 or 50 °C varied markedly across soils with contrasting soil series and soil moisture content. These results confirm that a uniform drying temperature across labs is critical to achieve comparable test results. However, interpretations are complicated because research also suggests that the sample drying effects vary with the initial field moisture, the soil, and history of K fertilization. Preliminary data suggest that soil properties such as texture, clay mineralogy, or cation exchange capacity do not completely explain sample drying effects on extracted soil K or differences in crop response. Moisture relations partly associated with internal soil drainage and landscape position seem important.

Samples collected before fertilizing for the 2002 crops were analyzed based on field-moist and dried methods, and will allow for field calibrations of a field-moist based test once the yield data summary is completed. Soil samples collected this fall also are being analyzed based on moist and dried samples so that the 2003 yield responses can be added to the calibrations.

Results for the Tetraphenyl-Boron Test

Study of amounts of K extracted by the AA-K and M3-K showed that both tests are affected similarly by soil moisture and sample drying. However, lab research conducted Dr. Brad Joern (Purdue University) suggested that a modification the TB-K test developed by Dr. Scott in Iowa during the 1960s could improve estimates of plant-available K because it partially extracts nonexchangeable K and is less sensitive to sample drying. The modification made the test faster and relatively easier for routine analyses, although it is still a complicated method because a hot digestion is required.

In this project we used a selected numbers of sites to compare field calibrations for corn for the three tests. For this data set (Fig. 3), the AA-K and M3-K tests measured similar amounts of K and were highly correlated across all sites ($R^2 = 0.95$). Correlations between amount extracted by the TB-K and the AA-K or M3-K tests were lower than correlations between the AA-K and M3-K tests ($R^2 = 0.57$ to 0.63). The TB test, as expected, measured much more K than the two routine tests.

Relationships between corn yield response and either AA-K, M3-K, or TB-K tests across all these fields shown in Fig. 4 were poor (which was also shown for the AA-K test in the more complete data set used for Fig. 1). In contrast to results for corn, soybean yield response (not shown in this report) was well correlated to the TB-K test. This difference between crops could not be explained, although it may have been related to variation in soil conditions between sites planted to corn and soybean. Study of the distribution of yield vs. soil-test K data points and of correlations between tests suggest that the yield response data could be grouped in two clusters based on soil series. In the Nicollet and Webster soils proportionally more K was extracted by the AA-K or M3-K tests compared with the TB-K test, and higher AA-K and M3-K values were required to maximize yield in these soils. Excluding the few sites with Nicollet-Webster soils improved relationships for the AA and M3 tests considerably. Texture, CEC, K saturation, percentage organic matter, and available information of soil mineralogy did not differ consistently between the two groups of soils. Undetermined site characteristics often resulted in large variation across sites with the same soils.

Year 2003 Research Plans

I decided to go ahead with the change in K recommendations this fall, although the results obviously show that the new interpretations are a temporary remedy. Although both the AA-K and M3-K tests seem to correctly identify a value of approximately 170 ppm as the upper limit for responses across all soils and conditions, the predictive value of the tests below that value was extremely poor. Both tests perform very poorly at identifying both the magnitude and probability of response below that level.

The results suggest that some soil series (usually soils in low landscape positions and with poor permeability) need higher soil-test K values than other soils. To better understand this problem, new strip trials and conventional small-plot trials are being established at six locations, and most of the previous experiments are being continued. The new small-plot trials include five K fertilizer rates, something that was not included in previous years, and will provide information about the K rates needed to attain or maintain yields. In addition, plant-tissue tests will be correlated with yield response, and all relationships will be compared with basic soil properties such as texture, CEC, and percent K saturation.

The new trials will also provide better information about the impact of soil moisture and sample drying on extracted K, and the contrasting performance of the TB-K for the corn and soybean sites. To better understand this problem, soil K of the new trials will be measured with the field-moist AA-K test and the TB-K in addition to the common AA-K on dried samples. Plant-tissue test data and basic soil properties will also be used to understand differences between the relationships.

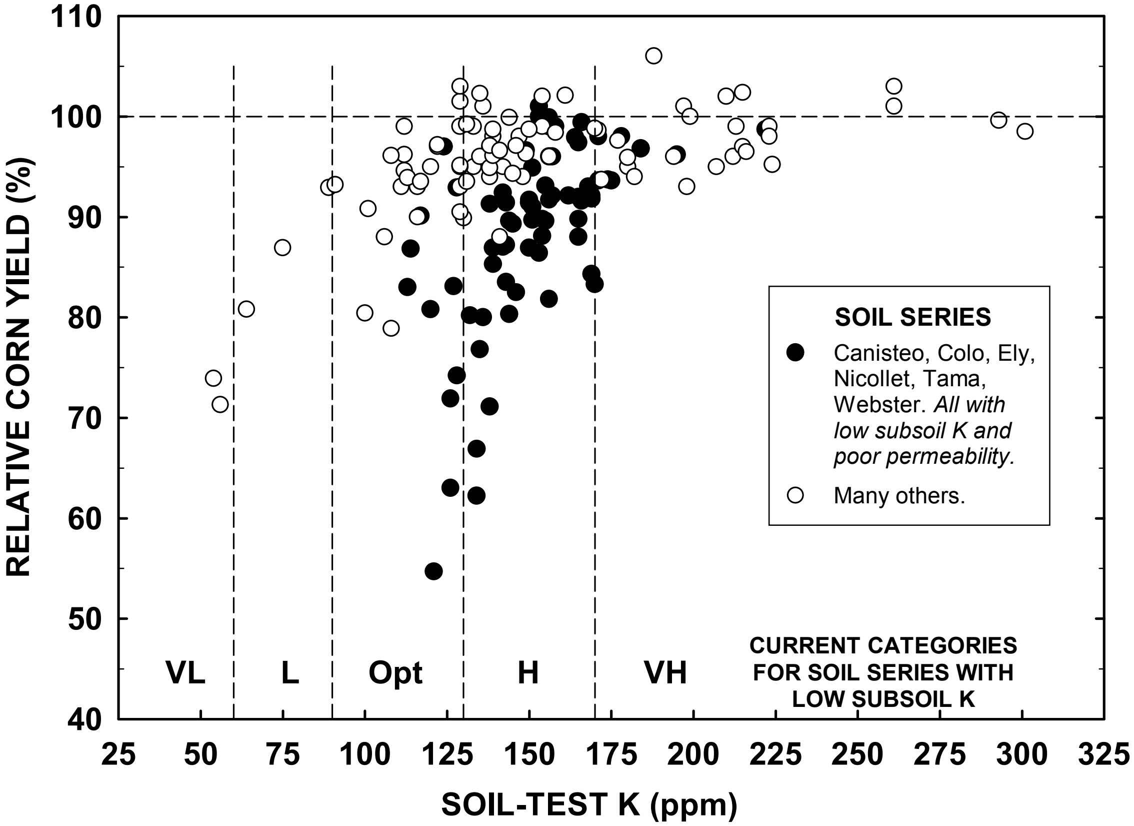

Fig. 1. Relationship between corn yield response to K fertilizer and ammonium-acetate K soil test across numerous sites and years. The interpretation classes shown are the classes used until November 2002 in Iowa.

Table 1. Current and updated Iowa soil-test K interpretation classes for the ammonium acetate and Mehlich-3 K tests and K fertilizer recommendations for corn and soybean.†

Soil-test category	Current recommendations			New recommendations		
		K fertilizer rate			K fertilizer rate	
	Soil-test K	Corn	Soybean	Soil-test K	Corn	Soybean
	--- ppm ---	---- lb K_2O/acre ----		--- ppm ---	----lb K_2O/acre ----	
Very Low	0-60	120	90	0-90	130	120
Low	61-90	90	75	91-130	90	90
Optimum ‡	91-130	40	65	131-170	45	75
High	131-170	0	0	171-200	0	0
Very High	171+	0	0	201+	0	0

† Classes are shown only for soil series with low subsoil K. ‡ The fertilizer recommendations for the Optimum class assume corn and soybean yields of 150 and 55 bu/acre.

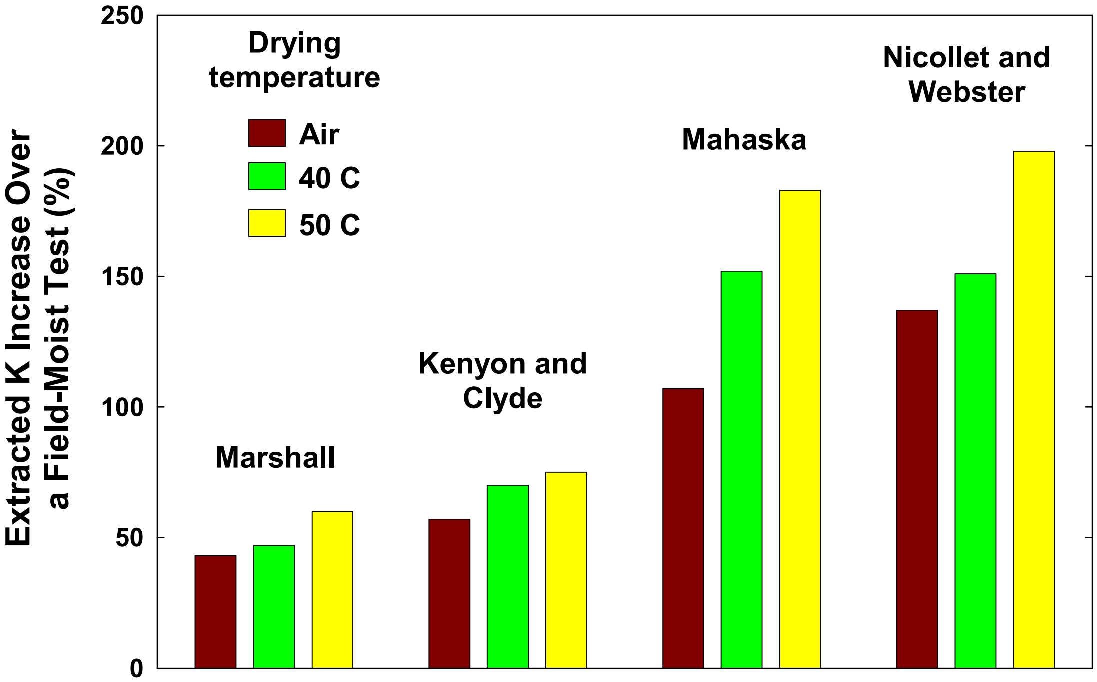

Fig. 2. Examples of the effect of soil drying temperature on ammonium-acetate soil-test K compared with a field-moist test for contrasting soil series (one year data).

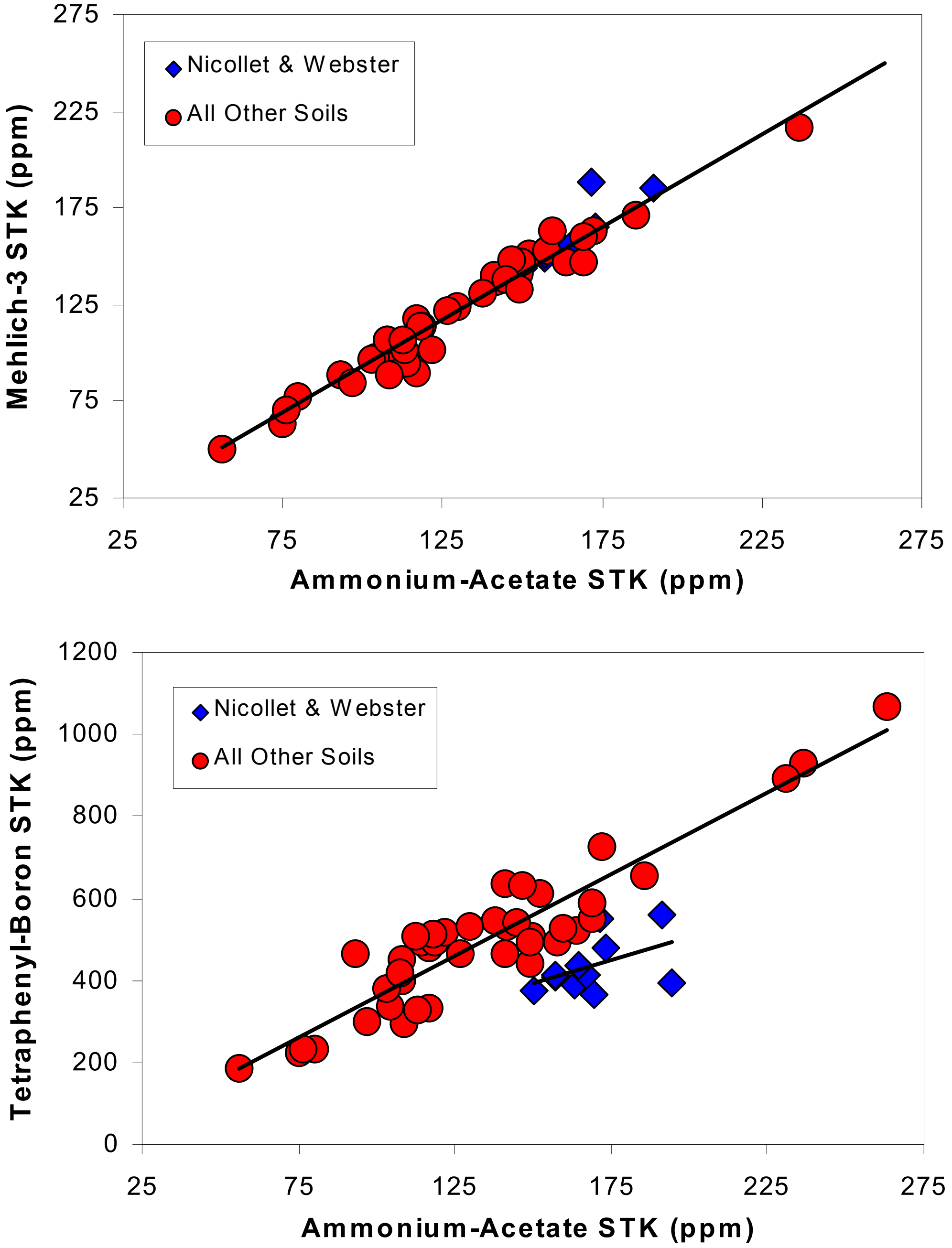

Fig. 3. Relationship between soil K measured with the ammonium-acetate, Mehlich-3, and sodium tetraphenyl-boron tests for a selected number of sites.

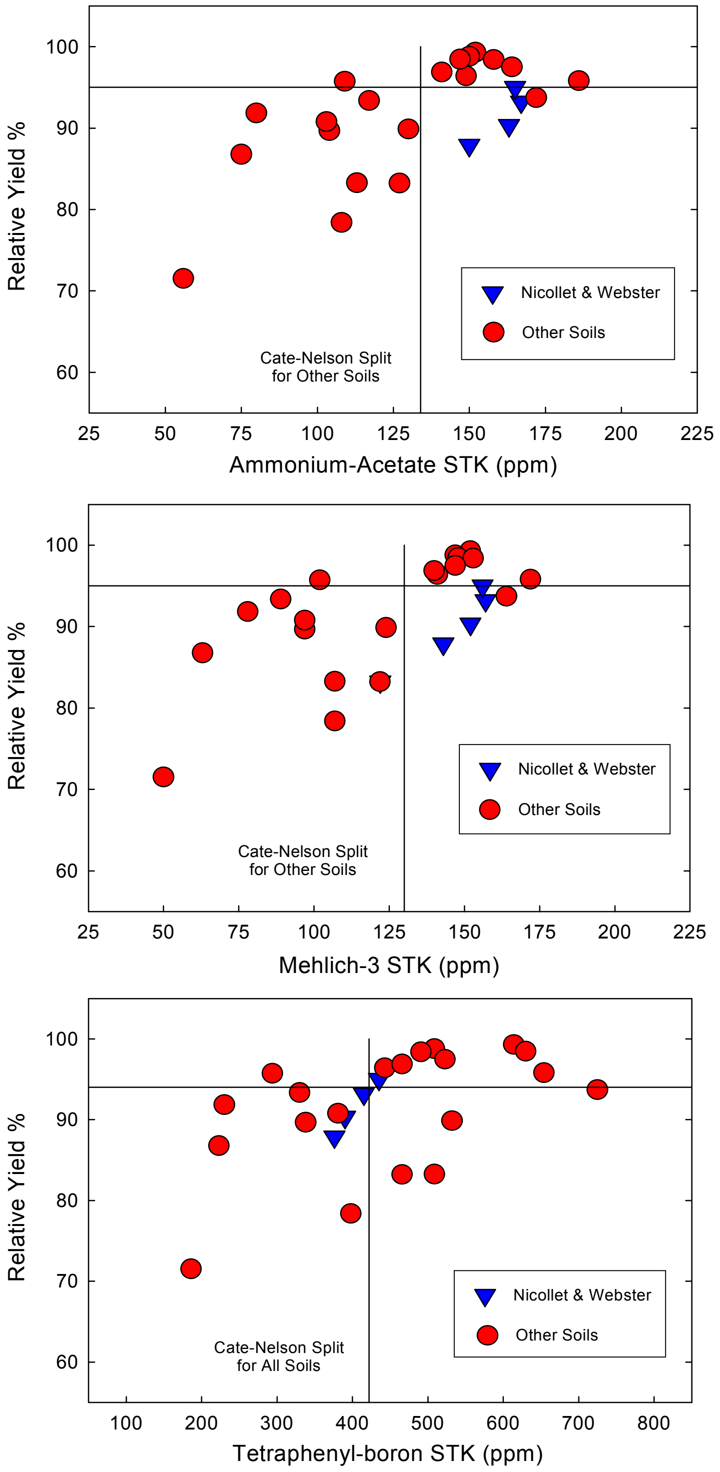

Fig. 4. Relationships between corn yield response to K fertilizer and soil K measured with the ammonium acetate, Mehlich-3, and sodium tetraphenyl-boron tests.