SOIL-TEST POTASSIUM FIELD CALIBRATIONS FOR SOYBEAN IOWA INTERPRETATIONS AND RESEARCH UPDATE

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Background

There is a long history of potassium (K) fertilization research for soybean and other crops in the North-Central Region. Sustained Iowa field research efforts focused on developing soil-test K (STK) interpretation and on studying impacts of K fertilization strategies on grain yield and STK. Because of changes in the soil-test K method used in Iowa, this information collected over time should be evaluated separately. The field crop response and STK calibration research conducted from the late 1960s until 1991 involved extracting soil K from field-moist soil samples with the commonly used ammonium-acetate extractant. Research during the 1960s showed that extracting K without drying soil samples gave more consistent results than extracting K from air-dried or oven-dried samples (Hanway et al., 1962). Evaluations of STK results from field-moist samples are different from those for dried samples because usually less K is extracted from moist samples. Therefore, published articles summarizing soil-test field correlations as recently as 1991 (Mallarino et al., 1991a and 1991b) refer to STK values in field-moist samples.

The Iowa State University Soil and Plant Analysis Laboratory ceased analyzing samples with the moist K test in 1988 based solely on practical considerations for laboratory work. Although research during the 1960s showed that correlations between K uptake or yield were better for the moist test than for the dry test, laboratory procedures were simpler dried soil samples. Moreover, although the moist test was among tests recommend for the North-Central Region by the NCR-13 soil testing committee (NCR-13, 1980) it was not adopted by other private or public soil testing laboratories. Therefore, based mainly on comparisons of amounts of soil K extracted by the two tests, the interpretation categories for STK were increased by a factor of 1.25 to account for the average increase in extracted K across Iowa soils when samples were dried (at 35 to 40 EC). The STK values for the dry test were classified into interpretive categories very low, low, medium, high, and very high (Voss and Killorn, 1988). Recommended K fertilization rates for the very low, low, and medium categories were designed to achieve maximum or near-maximum yield and to increase STK to the high category (100-150 ppm K) over a few years. The probability of crop response within the high category was very low, and an optional fertilizer recommendation was based on expected nutrient removal with harvest. The STK interpretation categories were similar for all Iowa soils, but fertilizer rates were modified according to five subsoil classes. Larger K fertilizer rates were recommended when the subsoil K concentration of the soil series (from soil survey tables) was lower.

Major interpretation changes for the K test based on dried samples were introduced in 1996 (Voss et al., 1996; Voss and Mallarino, 1996). Interpretation classes were modified to very low, low, optimum, high, and very high categories. The optimum category was considered the most profitable to maintain (91-130 K ppm) and the corresponding fertilizer recommendation was based on expected K removal. Fertilization was not recommended for the high or very high categories. Another major modification was to change the way subsoil K was considered. Instead of having a single set of soil-test interpretation categories for all soils and changing the fertilizer rate on the basis of five subsoil K classes, two distinct sets of interpretation categories were developed for soils with either "high" or "low" subsoil K concentration. These K interpretations and recommendations remained unchanged until 2002, except for adding interpretations for the Mehlich-3 (M3) K test in 1999 (Voss et al., 1999). Interpretation categories for the ammonium-acetate and M3 K tests (both based on dried samples) were made similar because Iowa research had shown small and inconsistent differences in the amounts of K extracted by these tests across soils.

Results of a field correlation research effort during the late 1990s lead to significant changes in Iowa STK interpretations in 2002 (Sawyer et al., 2002; Mallarino et al., 2002). The two most significant modifications were a change in interpretation classes to recommend higher STK for crop production and to recommend deep-placed K fertilizer for no-till and ridge-till corn and soybeans. Summarized information that justifies the placement method recommendations was published in proceedings of this conference (Mallarino et al., 2001; Mallarino et al., 2002) and in several journal articles since 1998. In this article we review the new Iowa STK interpretations effective since 2003 and summarize recent soil-test K field calibration research for soybeans.

Soil-Test Potassium Interpretations

A need to update Iowa STK interpretations implemented in 1996 was first suggested during the middle 1990s by an increasing frequency of corn K deficiency symptoms in some soils that tested optimum according to existing interpretations. Also, field experiments designed primarily to evaluate K fertilizer placement methods often showed larger than expected yield response in soils testing optimum and smaller but frequent response in soils testing high. Field soil-test correlation trials conducted until 2001 confirmed that use of the interpretations of the time sometimes would recommend too little or no K fertilization in soils with a high probability of yield response. Data in Table 1 show, as an example, the STK interpretations and fertilizer recommendations for corn and soybean in place until 2002 together with the new ones.

Data in Table 1 indicate that the new interpretation categories recommend significantly higher STK levels for crop production, although the corresponding K fertilization rates for the very low, low, and optimum categories were increased slightly. These interpretations are for soils classified as having low subsoil K, which encompass more than 80% of the row-crop production area of Iowa. The Iowa State University Extension publication Pm-1688 (Sawyer et al., 2002) includes tables for most crops grown in Iowa and interpretations for soil series with higher subsoil K together with the subsoil classification for the most relevant soil series. In the older interpretations the optimum class encompassed 91 to 130 ppm by either the ammonium-acetate or M3 K tests for dried soil samples collected to a 6-inch soil depth. The fertilization rate recommended for this category would maintain STK and was deemed enough to eliminate any minor and infrequent K deficiency in this STK range. In the updated interpretations, the STK range for the older optimum category is reclassified as low, and maintenance fertilization is recommended for the former high category, now designated optimum. Therefore, the new interpretations recommend farmers to increase and maintain a higher STK level for optimal crop production.

Soil-Test Potassium Field Correlations for Soybeans

In this section we discuss the STK field correlations for soybeans used to update the Iowa interpretations in 2002 and show additional data collected during 2002 and 2003. Results for corn were shared and published before (Mallarino et al., 2002 and 2003). Figure 1 shows the relationship between relative soybean yield and STK measured with the ammonium-acetate test. The graph mainly represents data from field trials conducted from 1998 until 2003, and each data point represents one site-year. Most data were collected from on-farm experiments, although a few correspond to long-term K experiments in which most fertilization treatments (except the highest annual rates) were discontinued so plots could be used for STK calibration. In all instances the data points represent averages of three to six field replications.

The graph shows the classic relationship between yield response and soil-test values, but also shows that there was much variation. In spite of the variation in response, the distribution of the data points indicates different relationships for two groups of soil series. The white data points represent results for soils in which STK levels ranging from approximately 130 to 145 ppm produced more than 95% relative yield. This STK range is suggested by data in the figure and by results of fitting Cate-Nelson and linear-plateau models to those data (not shown). The gray and black data points represent results for soil series in which the critical concentration range is much higher and could not be determined with certainty. Results for soils and site-years represented by the gray data points blend with the general relationship represented by the white data points. However, results for the black points obviously depart from that relationship and indicate that higher STK is needed to produce maximum soybean yield. The site-years of data represented by gray and black data points were from Nicollet, Webster, and Canisteo soil series, which predominate in central and north-central Iowa and in south-central Minnesota. These soils are deep, somewhat poorly to very poorly drained, moderately to poorly permeable, were formed in loam glacial till, and slope ranges from 0 to 5% for Nicollet and 0 to 3% for Webster and Canisteo. The top 6 to 8 inch layer of these soils is loam, clay-loam, or silty-clay-loam. The surface layer of the Canisteo series has higher pH than the other soil series and often is calcareous.

The dichotomy in the relationship between yield response and STK for the two groups of soils in this study and approximately similar STK ranges needed to produce maximum yield were also observed for corn (Mallarino et al., 2002 and 2003). However, the data for corn also showed higher STK requirements for other Iowa soil series developed on similar low-laying landscape positions, and having similar texture and moderately poor to very poor drainage. A general relationship similar to that shown in Fig. 1 was observed for both crops when the M3 K test was used (not shown). Data in Fig. 2 shows that ammonium-acetate and M3 K extractants were highly correlated for soils of these trials. Also, the data show that the observed variation between these two tests was not explained by the soils grouping.

Several reasons could explain higher STK requirements for many soils and large response variation across soils with similar STK levels. Ongoing research is addressing these issues and no firm conclusions are possible at this time. Although all soils represented by grey and black data points have low subsoil K, most soils represented by the white points also have low subsoil K. Preliminary data indicate that soil pH, texture, mineralogy, or cation exchange capacity do not completely explain response differences between the soil groups. Although soil cation exchange capacity, exchangeable Ca, and organic matter is high for the Nicollet, Webster, and Canisteo soils, levels are similar to those for many other soil series. We believe that field moisture relations (associated to physical soil properties, internal soil drainage, and landscape position) and soil sample drying are important factors. Our research suggests that the effect of sample drying (and the temperature used) on extracted soil K varies greatly across soil series, with the soil moisture content when the sample is collected, and with other unknown factors. Research in Minnesota reported to the NCR-13 soil testing committee (Roger Eliason and George Rehm, 2004, unpublished) showed similar variation across soils when other extractants were used (such as ammonium acetate, barium acetate, and magnesium acetate). Furthermore, our results (not shown) indicate that the K moist/dry extraction ratio often (but not always) is lower for soils represented by the gray and black dots in Fig. 1. These results confirm old Iowa research in showing that uniform drying temperature across labs is critical to achieve comparable results and that drying soil samples reduces the reliability of soil K testing.

We currently are conducting field calibration research for an ammonium-acetate K test based on field-moist samples. Preliminary results are not shown because data available at this time are from few site-years. The early results do indicate, however, that the dichotomy observed for relationships in Fig. 1 is not as obvious for the field-moist based K test. This result is explained by proportionally less K extracted by the moist test than the dry test from soils in which the dry test would suggest that higher STK is needed to produce a certain relative yield level.

Summary

Recent field soil-test calibration research with corn and soybeans provided the basis for an update of Iowa K interpretations and fertilizer recommendations. Results of field calibrations for the ammonium-acetate and M3 K tests based on dried soil samples showed that higher STK levels were needed for many soils and conditions. Although the results suggested that two sets of interpretations would be needed for two large groups of soils, large variation across fields due to poorly understood reasons did not allow for establishing different and reliable interpretations. The updated STK interpretations and K fertilizer recommendations should prevent K deficiency in most conditions, although they may not achieve desirable STK build-up in some conditions and result in application of more K fertilizer than needed in other conditions. Ongoing research that includes new field trials and additional soil analyses likely will provide useful information for establishing improved STK interpretations for different Iowa soil series or regions in the near future.

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Table 1. Iowa soil-test K interpretation categories for the ammonium-acetate and Mehlich-3 K tests and K fertilizer recommendations for corn and soybean.[†]

Soil-test category	Recommendations until 2002			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

† Interpretations are for Iowa soil series with low subsoil K, which are the majority.

‡ Fertilizer amounts for the Optimum category assume corn and soybean yield of 150 and 55 bu/acre.

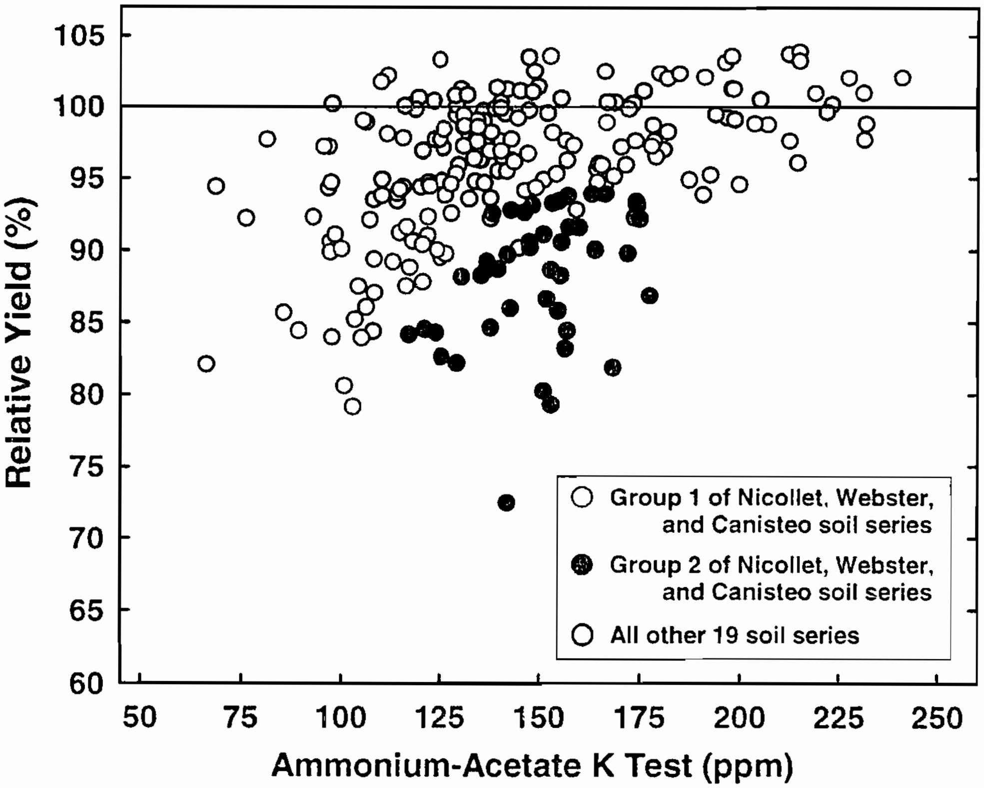

Fig. 1. Relationship between relative soybean yield and soil-test K across Iowa fields.

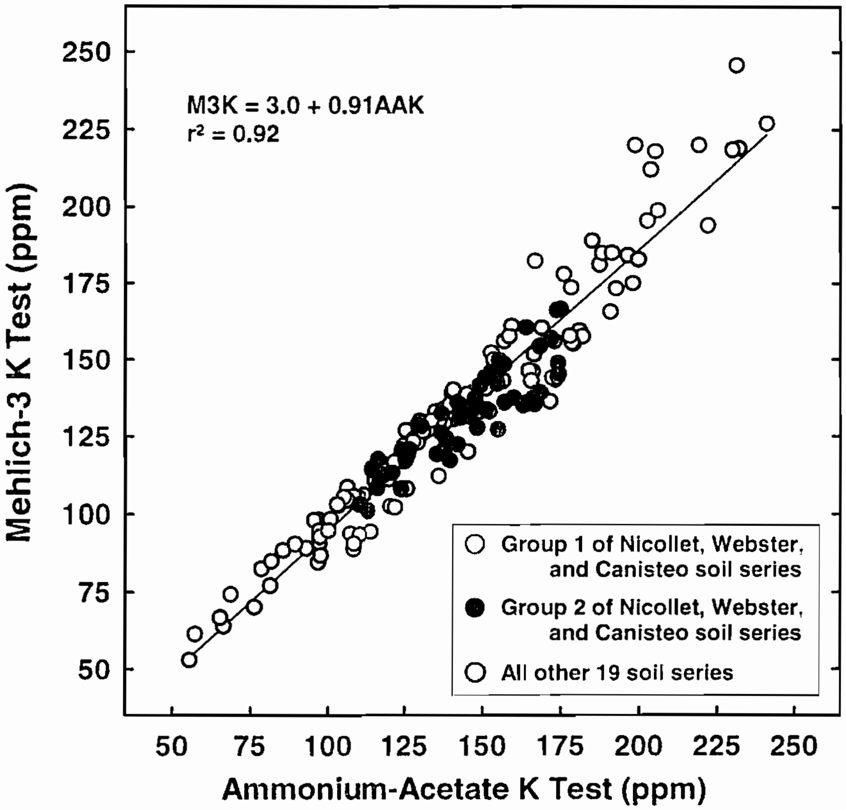

Fig. 2. Relationship between soil K extracted with ammonium-acetate and Mehlich-3 K tests from soils of the field correlation trials.

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