REVISION OF POTASSIUM SOIL-TEST INTERPRETATIONS AND FERTILIZER RECOMMENDATIONS

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Recent History of Iowa Soil-Test Potassium Interpretations

There is a long history of potassium (K) fertilization research in the North-Central Region. Sustained Iowa field research efforts have focused on developing soil-test K (STK) interpretation and studying the effect of K fertilization strategies on grain yield and STK. Because of changes in the soil-test K method used in Iowa, information published over time should be evaluated separately. Published research conducted from the 1960s until 1991 (the last publications by Mallarino et al., 1991a and 1991b) involved extracting K from field-moist soil samples using the ammonium-acetate test. Research during the 1960s and 1970s showed that extracting K from the soil without drying the samples gave more consistent results than using air-dried or oven-dried samples. Evaluations of STK results from field-moist samples are different from those for dried samples because less K is extracted from moist samples. The Iowa State University Soil and Plant Analysis Laboratory discontinued analyzing samples with the moist K test in 1988 based solely on practical considerations for laboratory work. Laboratory procedures are simpler for dried soil samples. Moreover, although the moist test was used in Iowa and was among tests recommended for the North-Central Region by the NCR-13 soil testing committee, it was not adopted by other private or public soil testing laboratories.

Therefore, based mainly on comparisons of amounts of soil K extracted using dried or moist soil samples, existing interpretation categories for STK were increased in the late 1980s by a factor of 1.25 to account for the average K increase when samples were dried (at 35 to 40 C). The STK values for the dry test were classified into the following interpretive categories: very low, low, medium, high, and very high. 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 considered low, and an optional K fertilizer recommendation was based on expected K removal with harvest. The K fertilizer rates were different according to the subsoil K content of the soil series (using soil survey tables), and higher K rates when the subsoil K concentration was lower. In practice, however, most Iowa soil series were classified in the lowest subsoil K category.

Another major change to STK interpretation categories was introduced in 1996 (Voss et al., 1996; Voss and Mallarino, 1996). The STK limits of the categories and names were modified. The names were changed to very low, low, optimum, high, and very high. The new optimum category (91-130 K ppm) was defined as the range to be maintained based on expected K removal with harvest. Fertilization was not recommended for the high or very high categories. These K interpretations and recommendations remained unchanged until 2002, except for adding interpretations for the Mehlich-3 K test (M3K) in 1999 (Voss et al., 1999). Interpretation categories for the ammonium-acetate and M3K tests (both based on dried

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samples) were made similar because Iowa research had shown small and inconsistent differences in the amounts of K extracted by these tests across soils.

The Iowa fertilizer recommendations did not specify a tillage system or a fertilizer application method until 2002. Research conducted during the 1950s to the late 1970s showed no major difference between band and broadcast placement methods for the chisel-plow/disk tillage system, and there was little or no local research for no-till or ridge-till systems. However, existing recommendations specified that application of a starter N-P-K mixture for corn could be advantageous within the high category under conditions of limited soil drainage, cool soil conditions, or with crop residues on the soil surface.

Results of field research from the middle 1990s until 2002 justified a significant change of Iowa STK interpretations and K fertilizer recommendations. The two most significant changes were to maintain higher STK levels for optimum crop production and to use deep placement of K fertilizer for crops managed with no-till and ridge-tillage. The reasons for these drastic changes are discussed in this article. Reasons for other minor changes are not discussed here because they are easily understood from the revised extension publication PM 1688 *A General Guide for Crop Nutrient and Limestone Recommendations in Iowa* (Sawyer et al., 2002) available on the Iowa State University Extension Publications Web site (http://www.extension.iastate.edu/pubs). Some other changes included adjustments to nutrient concentrations in harvested products and default yield values used to estimate maintenance fertilization.

Why Were Recommended Soil-Test Potassium Levels Increased?

A need to update STK interpretations in use since 1996 was first suggested during the mid-1990s by an increasing frequency of K deficiency symptoms in corn for some soils that tested optimum according to those interpretations. Also, field experiments designed primarily to evaluate K fertilizer placement methods for various tillage systems often showed larger than expected yield responses in soils testing optimum and smaller but frequent yield responses in soils testing high. Numerous soil-test correlation field trials conducted for corn and soybeans confirmed that existing interpretations sometimes recommend too little or no K fertilizer in fields with a high probability of response. Data in Table 1 show, as an example, the STK interpretations and K fertilizer recommendations for corn and soybean that were used until 2002 together with the new ones. More complete tables are shown in publication PM 1688.

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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 soil series with low subsoil K, which are the majority in Iowa.
‡ Fertilizer amounts for the Optimum class assume corn and soybean yield of 150 and 55 bu./acre.

Data in Table 1 indicate that the new interpretation categories recommend significantly higher STK levels for crop production and that new recommended 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 percent of the row-crop production area of Iowa. The publication PM 1688 includes tables for other crops and interpretations for soil series with higher subsoil K. In the older interpretations the optimum class encompassed 91-130 ppm by either the ammonium-acetate or M3K tests on dried soil samples collected to a six-inch depth. The K fertilization rate recommended for this category would maintain STK and was deemed enough to take care of small and infrequent K deficiency expected for this category. In the updated interpretations, the STK range for the older optimum category was reclassified as low, and maintenance K 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.

The new interpretation classes reflect results of field research conducted during many years in Iowa research farms and farmers' fields. Results of the grain yield correlation research are summarized for corn in Figure 1 and for soybeans in Figure 2. These figures show the relationship between relative grain yield and STK measured with the ammonium-acetate test on dried samples. The graph represents data from field trials conducted from 1998 until 2003, and each data point represents one site-year and averages of three to six field replications.

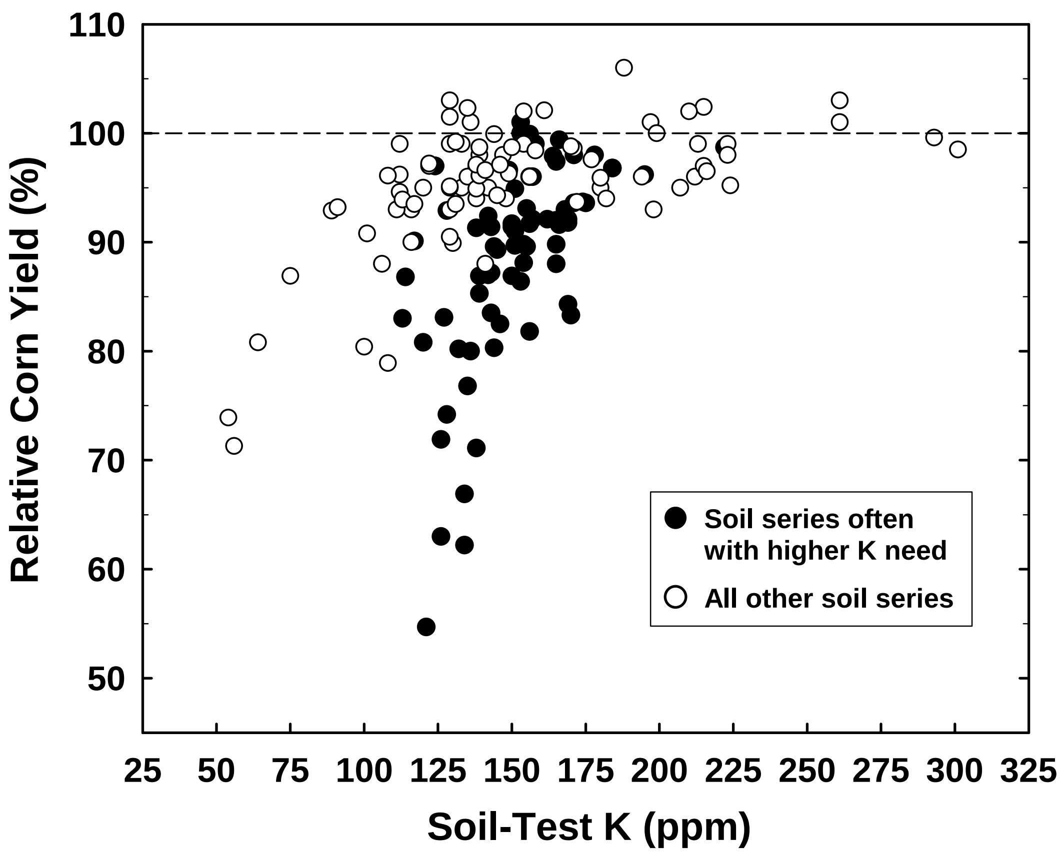

Fig. 1. Relationship between relative corn yield and soil-test K (ammonium-acetate test) across Iowa fields.

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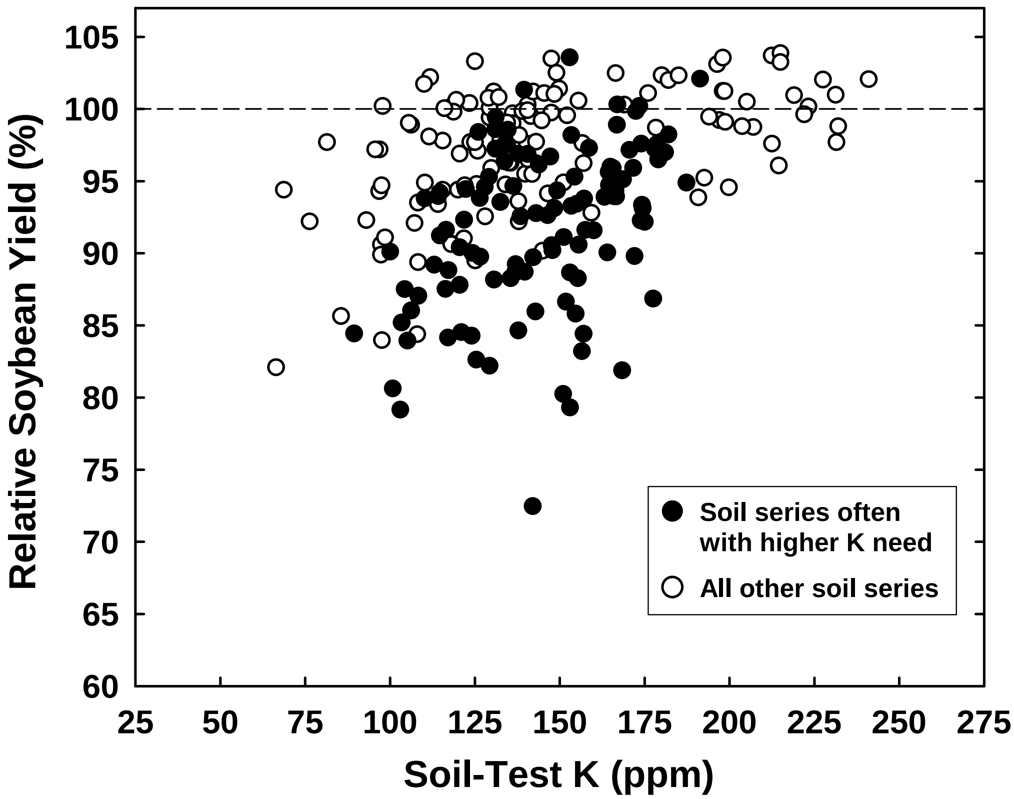

Fig. 2. Relationship between relative soybean yield and soil-test K (ammonium-acetate test) across Iowa fields.

The graphs show the classic relationship between yield response and soil-test values, but also show that there was much variation. In spite of the variation in response, the distribution of the data points suggests different relationships for two groups of soil series. The open data points represent results for soils in which STK levels ranging from approximately 130 to 145 ppm produced more than 95 percent relative yield. This STK range is suggested by data in the figures and by results of fitting various mathematical models to the data (not shown). The black data points represent results for soil series for which the critical concentration range is higher and could not be determined with certainty (at least 170 ppm). Results for some soils represented by the black data points blend with the general relationship represented by open points; but for many of these soils higher STK is needed to produce maximum crop yield. The black points mainly represent Nicollet, Webster, and Canisteo soils developed on glacial till materials, which predominate in central and north-central Iowa and south-central Minnesota, but also represent several other Iowa soil series. All these soils have in common deep profiles, somewhat poor to very poor drainage, moderate to poor permeability, slopes from 0 to 4 percent, and loam, clay-loam, or silty-clay-loam texture in the top six- to eight-inch layer, and high exchangeable calcium (Ca) compared with other Iowa soils. Very few of these soils (such as Canisteo and Harps) have high pH due to calcium carbonate.

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A general relationship similar to that shown in Figures 1 and 2 was observed for both crops when the M3K test was used (not extractants were highly correlated for soils of these trials. Also, the observed variation between these two tests was not explained by the soils grouping. Although data in Figures 1 and 2 suggest different STK requirements for different soils, because of the wide data spread below and STK value of about 170 to 180 ppm the new

shown). Data in Figure 3 show that ammonium-acetate and M3K

interpretations were made to apply across all Iowa soil series. Yield data from numerous field trials established this year that have not been analyzed and new trials should provide information useful to develop specific interpretations for different Iowa soil series or regions in future updates.

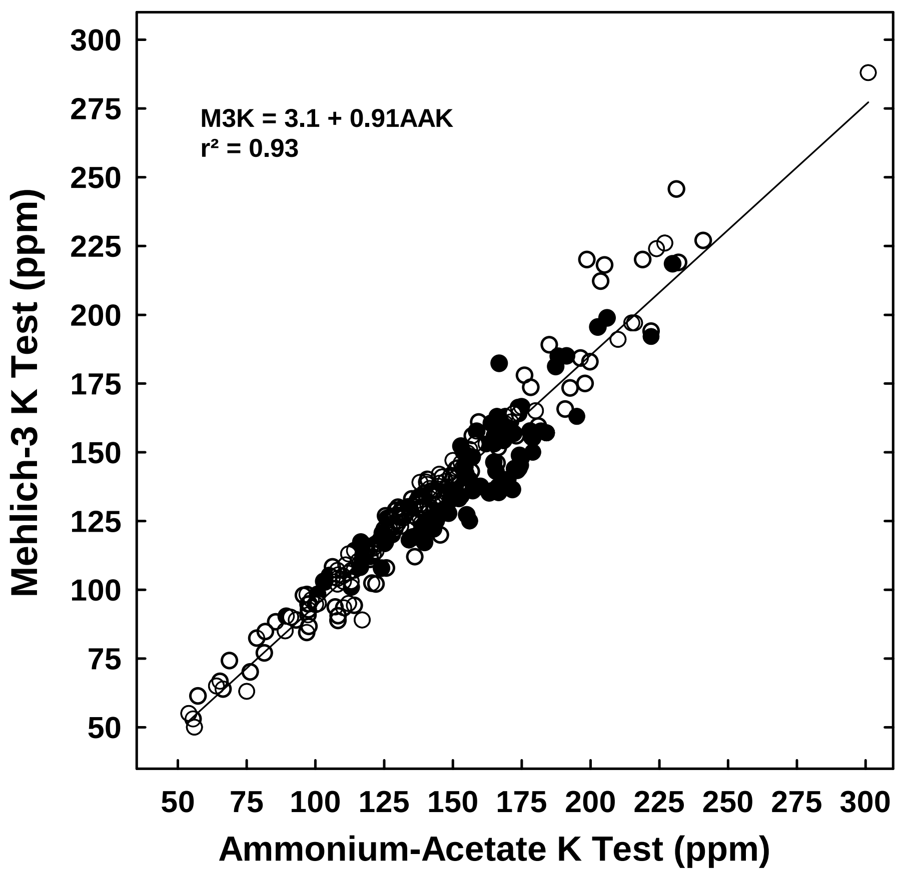

Fig. 3. Relationship between soil-test K measured with ammonium-acetate and Mehlich-3 K tests from soils of the Iowa field correlation trials.

Several reasons could explain different STK requirements across 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.

Preliminary data indicate that subsoil K, soil pH, texture, mineralogy, or cation exchange capacity (CEC) do not completely explain response differences between the soil groups. Although soil CEC, exchangeable Ca, and organic matter usually is higher for soils represented by black data points, levels are similar to those for many other soil series. We believe that field moisture relations (associated with physical soil properties, internal soil drainage, and/or landscape position) and soil sample drying in the laboratory are important factors explaining the observed variation. Ongoing research suggests that the effect of sample drying (and of 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 M3 and barium or magnesium acetate). Furthermore, our results indicate that the moist/dry K extraction ratio often (but not always) is lower for soils represented by black points in Figures 1 and 2. All these results confirm older 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 testing for K. We are conducting field calibration research for an ammonium-acetate K test based on field-moist samples. Preliminary results are not shown because data available are from few site-years, although results indicate that the dichotomy observed for relationships in Figures 1 and 2 is not as obvious for the field-moist 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 suggests that higher STK is needed to produce a certain relative yield level.

Why Were Recommendations for the Potassium Placement Method Changed?

With reduced tillage, broadcast fertilizers are not incorporated (such as in no-till) or are incorporated in ways that may not optimize early nutrient uptake (such as in ridge-till). Use of broadcast or planter-band fertilization methods and nutrient recycling with crop residues result in large P and K accumulation near the soil surface. Increased residue cover with conservation tillage improves water availability and root efficiency in shallow soil layers during dry periods but may result in cooler and wetter soils in early spring, which may reduce early crop growth and nutrient uptake. Consideration of these facts and increased adoption of no-till management has prompted extensive placement research in Iowa.

Ten long-term studies were conducted to evaluate P and K placement methods for corn-soybean rotations managed with chisel-plow/disk or no-till management from 1994 to 2001. Treatments were various rates of granulated fertilizers broadcast, deep banded, and banded with the planter. Approximately 80 additional short-term trials were established on farmers' fields managed with no-till and ridge-till systems to evaluate broadcast and deep fertilizer placement. At fields managed with no-till or chisel-plow/disk tillage, the deep bands were applied at a five-seven-inch depth and at a 30-inch spacing. This spacing coincided with row spacing used for corn, although row spacing used for soybeans varied (drilled, 15 inches, and 30 inches). Planter-applied bands were placed two inches beside and below the seeds for crops planted using a 30-inch row spacing. At ridge-till fields, the deep bands were applied through a slit opened either through the center or the shoulder of the ridges and the fertilizer was placed at least three inches below the planned seed depth.

Corn and soybean responses to P or K deep placement observed in these trials were presented with detail in other conference publications (Mallarino et al., 2001) and in several scientific papers. Therefore, only a brief summary of results for K is included here. The results for P showed small and inconsistent differences between P placement methods for any crop or tillage system. Results of the K placement studies for crops managed with chisel-plow/disk tillage also showed small and inconsistent differences between placement methods. However, the results for no-till and ridge-till corn and soybeans indicated that deep-band K application often produces higher yield than either broadcast or planter-band K application. Figure 4 show average results across many sites and years for no-till corn and ridge-till corn. Results for soybean are not shown, and responses to deep banding were smaller and less consistent than for corn. The differences between K placement methods were more consistent and larger for ridge-till corn than for no-till corn. Results of comparisons of strip tillage and deep K placement for no-till indicated that the response to deep K placement is observed in addition to any strip tillage effect on early growth or grain yield.

Based on these results, the new P fertilizer recommendations (not shown here) do not include specific guidelines for P placement methods, except for suggesting starter fertilization under a few specific conditions. However, deep-band K fertilization is recommended for no-till and ridge-till systems. It is stated, however, that no-till corn yield increase from deep K banding often is not large and may not always offset increased application costs. Large variation in the no-till corn response to deep-band K was more related to soil moisture in late spring and early summer than to STK stratification, and responses tended to be larger when rainfall was deficient. Some no-till producers are using strip tillage, and our research indicates that this practice may increase yield in some conditions (mainly on soils low in the landscape having poor drainage and large residue accumulation). Therefore, strip tillage and deep placement of K can be combined. Although we have not seen consistent yield response to deep P placement, P fertilizer also can be deep banded together with K fertilizer.

Summary

Field research has justified a major change of Iowa STK interpretations and K fertilizer recommendations. Results of field calibrations for the ammonium-acetate and M3K tests based on dried soil samples showed that higher STK was needed for many soils and cropping 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 reliable separate interpretations at this time. Research results from fertilizer placement methods indicated that deep K placement usually is superior to broadcast or planter-band methods for corn and soybeans managed with no-till and ridge-till systems, although expected benefits are larger for ridge-tillage. The updated recommendations should prevent K deficiency in most conditions, although they may not achieve desirable STK build-up in some conditions and may result in application of more K fertilizer than needed in others. Ongoing research that includes new field trials and different soil tests 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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