Project "Relationship Between Soil-Test Potassium and Crop Yield"

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Antonio P. Mallarino
Iowa State University

Introduction

The main objectives of this ongoing project were (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 new K soil tests with potential to improve the prediction of crop response to K fertilization. The research is based on evaluation of conventional, long-term trials at research farms and several on-farm, replicated strip trials harvested with yield monitors.

2004 Field Trials

Conventional plots.
Several field trials were conducted in 2004 having the same objectives and design used last year. Eight conventional long-term trials established at research farms continued to be evaluated as in the past. Three trials evaluated residual effects of annual K fertilizer rates applied since the middle 1970s until 1998. Since 1999, only the highest annual K rate continued to be applied and the plots for other treatments were used to study decline of soil-test K over time and for soil-test calibration. The other five long-term trials evaluate four broadcast K fertilizer rates and two annual band K rates applied with "2 x 2" starter attachments.

Two-year trials with different design and objectives started in 2003 were continued in 2004, and a new set of similar trials was started in 2004 to be continued in 2005. The objectives of these trials are to determine rates of K needed to maximize crop yield in different soils having soil-test K within the current Low or Optimum interpretation classes and to determine the residual response of the next year crop to these various rates. In 2003, four trials began with corn and four with soybeans, and five K fertilizer rates ranging from 0 to 180 lb K_2O/acre were applied. For 2004, the plots were subdivided into two halves, 120 lb K_2O/acre were applied to one half, and crops were switched to complete the 2-year rotations. In 2004, two new trials began with corn and two with soybeans, and the five K fertilizer rates were applied. For 2005, plots of these four trials will be subdivided into two halves to apply 0 or 120 lb K_2O/acre and crops were switched to complete the 2-year rotations.

Soil samples for K tests were collected from each plot of all trials before applying the treatments and after crop harvest in the fall. Grain from selected plots was sampled to measure grain K concentration and K removal using in-kind contributions (laboratory analyses) from a lab supporting the PPI. Because corn is always grown in rotation with soybeans, effects of direct or residual K fertilization were also measured for soybeans using complementary funds from the United Soybean Board and the Iowa Soybean Promotion Board.

On-farm strip trials managed with precision agriculture technologies. Treatments for these trials (eight with corn) consisted of a check and a K fertilizer amount of at least 180 lb K_2O/acre applied to strips 60 feet wide and as long as 1,500 feet. Treatments were replicated three to four times in each field. Initial soil-test K before applying the fertilizer treatments was measured on soil samples collected from cells approximately 0.5-acre in size. Grain was harvested with combines equipped with yield monitors and GPS receivers. After crop harvest, soil samples were collected again to study fertilizer effects on soil-test K measured with various methods (the soil sampling density multiplies by a factor of two because samples are collected from each treatment). Corn is also grown in rotation with soybeans in these trials, and effects of direct or residual K fertilization are measured for soybeans using complementary funds from the United Soybean Board and the Iowa Soybean Promotion Board.

Harvest and laboratory test results.
All field trials were conducted successfully. However, very low yields were observed at one conventional trial affected by a strong summer hailstorm, and very variable yields were observed at two strip trials because of flooding in spring or lodging because of strong winds near the silking stage. Yield results and relationships between yield and K fertilizer application or soil-test K are being analyzed at this time and no results can be shared. This is because of a very late corn harvest in most areas of Iowa and intense field work since harvest for flagging, sampling, and fertilizing new trials for 2005. The harvest was late because of late planting in some areas, giving priority to soybean harvest, record high corn yields, and because elevators were not accepting grain in many areas. The soil tests used were the routine ammonium-acetate K and Mehlich-3 K tests for all plots, the sodium tetraphneyl-boron test for selected replications of all trials (to reduce costs), and a field-moist based ammonium-acetate K test for selected replications of all trials. The samples for the field-moist test are mixed, sieved to pass a 2 mm screen, moisture is determined, and a ratio of dried-based soil to extracting solution equivalent to that for the dry test is used for the analysis. Furthermore, the aboveground part of small plants at the V5 to V6 growth stage were collected from plots of selected trials and are being analyzed for total K.

Publications and Outreach

Much effort was dedicated this year to share previous years' results at scientific meetings and meetings targeted to farmers or professional agronomists. The main thrust of this effort was on explaining the need for higher soil-test K levels for optimum crop production in many soils, results of new soil-test calibrations, and problems associated with soil sampling drying in the lab when estimating plant-available K by soil testing.

These issues were shared with Iowa farmers and professional agronomists at nine winter meetings and three field days conducted in Iowa during the year. Potassium management issues and results of this project also have been shared during many interviews by reporters of radios or farm magazines.

In addition, these issues were discussed at three major conferences, for which posters or proceedings articles were also prepared. One was at the North Central Extension-Industry Fertility Conference in Des Moines. The presentation was “Soil Test Potassium Field Calibration for Soybeans in Iowa. A Research Update”, although results for corn were also presented. This article was coauthored by Pedro Barbagelata (graduate student), David Wittry (research associate), and myself. Another conference was the Indiana CCA Convention in Indianapolis, and the presentation was “Revision of Potassium Soil-test Interpretations and Fertilizer Recommendations”. The third conference was at the ASA Annual Meetings in Seattle, where a poster was presented with the title “On-Farm Research Methods for Soil Test Potassium Calibration Using Precision Agriculture Technologies” (coauthored by Pedro Barbagelata, graduate student, and myself).

The article about soil-test K interpretations and K fertilizer recommendations written for the Indiana CCA convention and the poster presented at the Seattle ASA meetings about soil-test K calibration based on strip trials are good examples of positive outcomes of this project. Therefore, these two materials are attached at the end of this progress report.

Work Conducted in Preparation for the 2005 Season

Although the results of the project have been very useful, they also pointed to problems that need continued investigation and explanations to farmers and professionals. These include understanding extremely large crop response variation below soil-test K levels of 170 to 180 ppm (from samples taken to a 6-inch depth and measured with ammonium-acetate or Mehlich-3 tests), completing field calibrations for a K test based on field-moist samples, assessing the value of the tetraphenyl-boron test for K, and studying within-field variation of crop response to K fertilization based on strip trials.

To achieve these objectives, work was conducted late this fall for new strip trials (12 with corn or soybean), 2-year conventional trials (12 with corn or soybean, either new or second-year trials), and long-term trials (seven with corn in 2005). The work consisted on flagging plots, taking soil samples, and applying fertilizer treatments for the 2005 season. The same field and laboratory research methods used for 2004 will be used for 2005. However, the work will also emphasize study of basic soil properties that may explain the problems of the tests based on dried samples. Unfortunately, USB funding from a FAR-sponsored multi-state project for work with soybean crops was not renewed but the soybean crops will be planted hoping funds from the Iowa Soybean Promotion Board or other sources will be made available.

REVISION OF POTASSIUM SOIL-TEST INTERPRETATIONS AND FERTILIZER RECOMMENDATIONS

Antonio P. Mallarino
Department of Agronomy, Iowa State University

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 recommend 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 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 from 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 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 have not specified 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). 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 middle 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 response in soils testing optimum and smaller but frequent yield response in soils testing high. Numerous soil-test correlation field trials conducted for corn and soybeans confirmed that use of existing interpretations sometimes would 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 (Sawyer et al., 2002), which is available at the Iowa State University Extension Publications web site.

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% 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 to 130 ppm by either the ammonium-acetate or M3 K tests on dried soil samples collected to a 6-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 Fig. 1 and for soybeans in Fig. 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.

The graphs show 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 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% 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, slope from 0 to 4%, and loam, clay-loam, or silty-clay-loam texture in the top 6 to 8 inch layer, and high exchangeable Ca compared with other Iowa soils. Very few of these soils (such as Canisteo and Harps) have high pH due to calcium carbonate.

A general relationship similar to that shown in Figs. 1 and 2 was observed for both crops when the M3K test was used (not shown). Data in Fig. 3 shows that ammonium-acetate and M3K 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 Figs. 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 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.

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 to 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 Figs. 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 Figs. 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 a way 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 5-7 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 2 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 3 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 though 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 can also 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. Results of placement methods research 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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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.

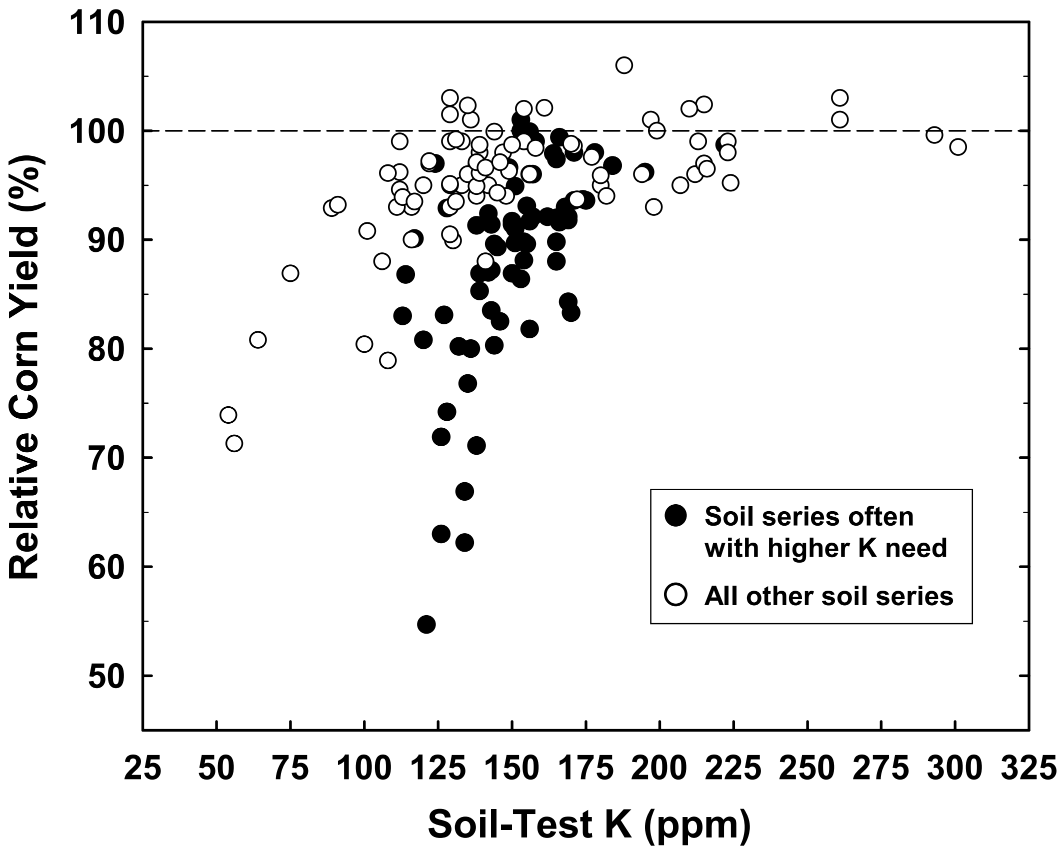


Fig. 1. Relationship between relative corn yield and soil-test K (ammonium-acetate test) across Iowa fields.

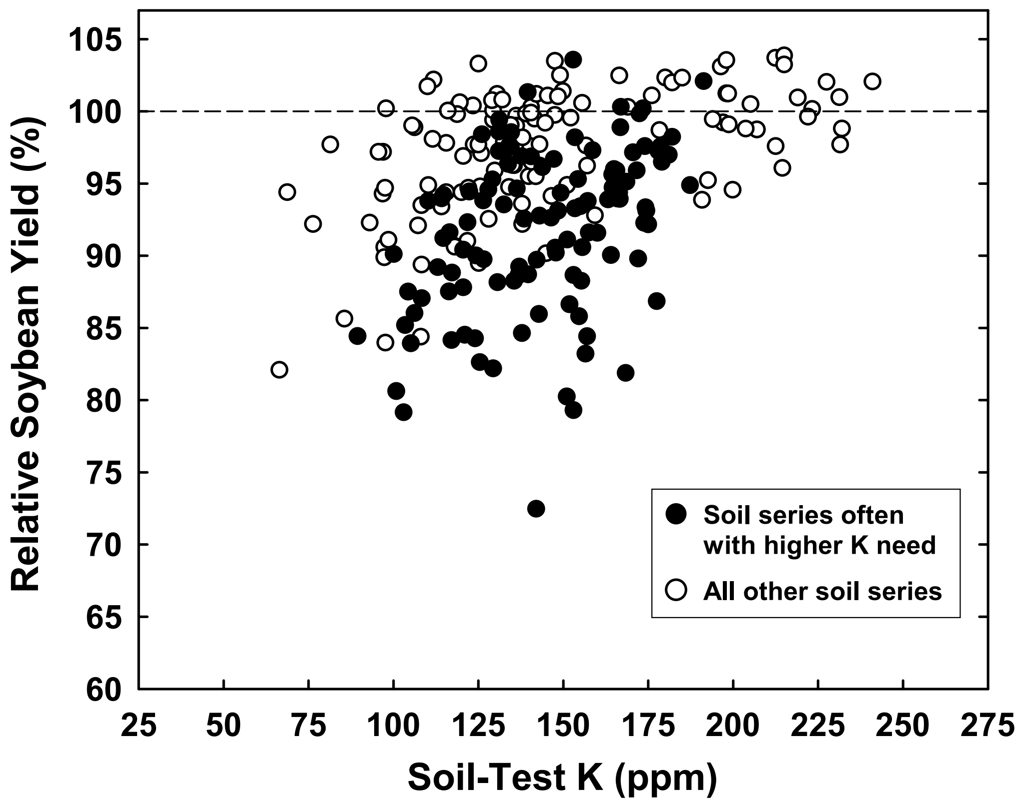


Fig. 2. Relationship between relative soybean yield and soil-test K (ammonium-acetate test) across Iowa fields.

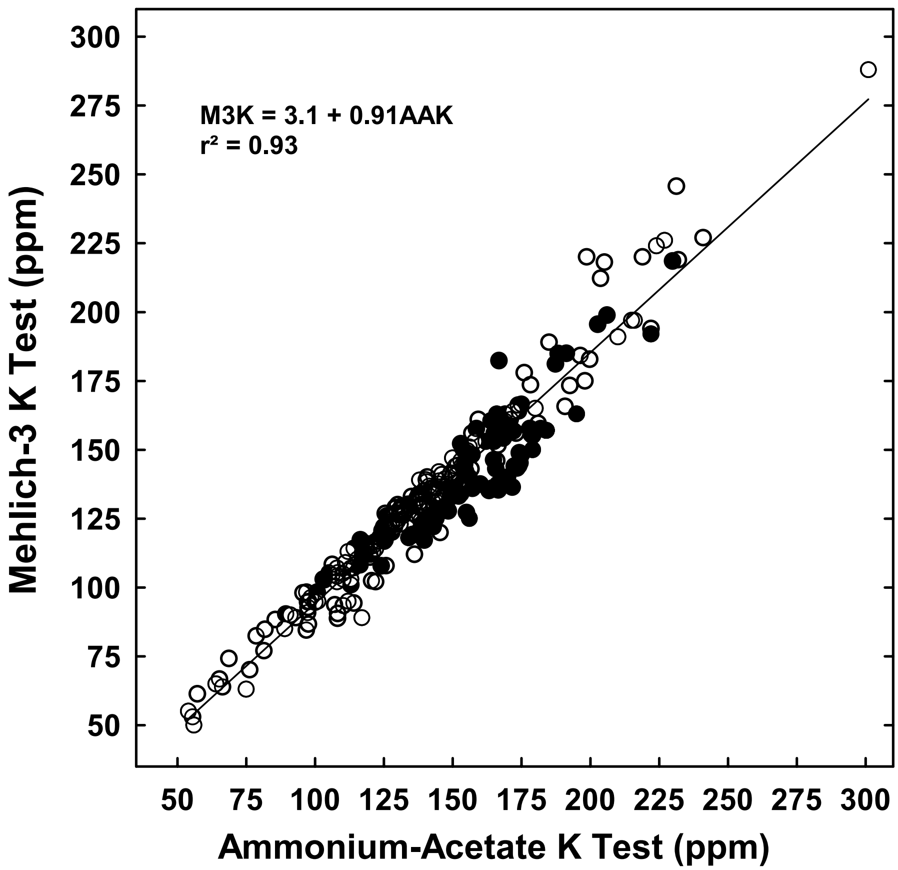


Fig. 3. Relationship between soil-test K measured with ammonium-acetate and Mehlich-3 K tests from soils of the Iowa field correlation trials.

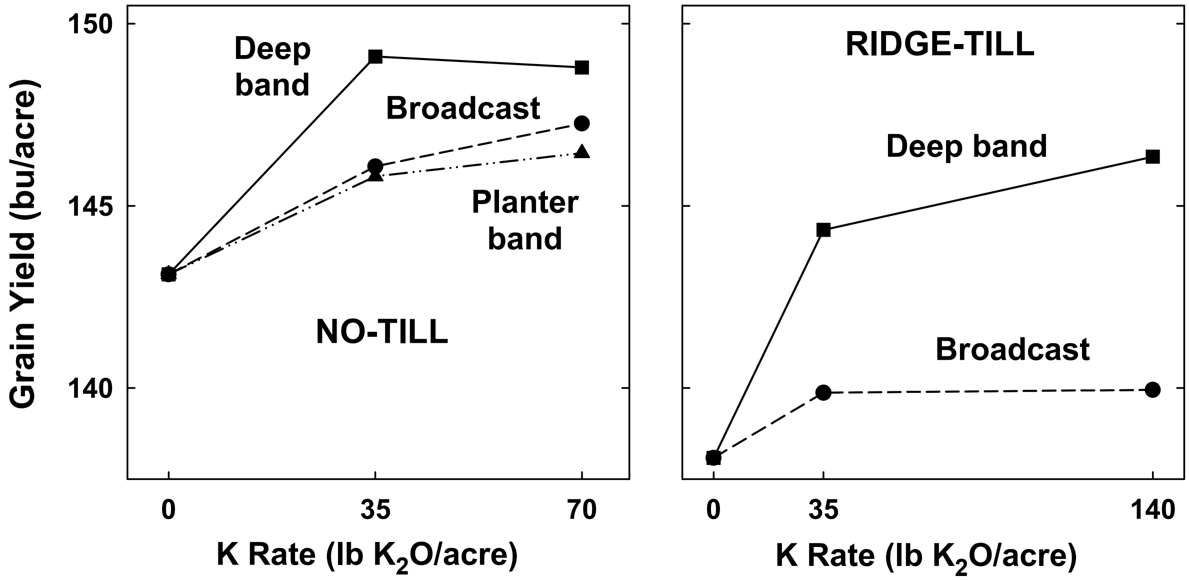


Fig. 4. Yield response of no-till and ridge-till corn to broadcast and deep-band K fertilizer placement methods in Iowa. Averages of 20 site-years for no-till and 15 site-years for ridge-till. Yields between tillage systems should not be compared because sites and years were different.

On-Farm Research Methods for Soil Test Potassium Calibration Using Precision Agriculture Technologies

Pedro A. Barbagelata and Antonio P. Mallarino
Iowa State University

Introduction

Soil testing has a key role in estimating plant-available soil K and K fertilization needs. If fertilization is needed, test results are one of the criteria used to recommend fertilizer application rates. A soil-test value of a properly calibrated soil-test method provides both a relative index of K availability and an indication of the magnitude of the yield increase resulting from fertilization. Traditionally soil-test correlation research has been based on replicated, small-plot response trials conducted over several years in several locations with different soils and soil-test values. Precision agriculture technologies can be successfully adapted to on-farm research to improve soil fertility and crop management research. Global positioning systems (GPS), yield monitors, intensive soil sampling, and new GIS (geographical information systems) software in combination with a traditional replicated strip-trial methodology allow for evaluation of treatment effects for different parts of a field. Usually there are contrastingly different soil series, topographic positions, soil-test values, and yield potential for areas within a field that could be considered as different "sites". However there is uncertainty about possible ways for collecting data and using these data for soil-test correlation.

The objective of this study was to demonstrate alternative data management techniques to correlate soil-test K methods based on a strip-trial methodology adapted to precision agriculture technologies.

Materials and Methods

Thirteen replicated field-scale strip trials (2.5-7.2 ha experimental areas) with corn (*Zea mays* L.) were established in Iowa to study yield response to K fertilizer and to correlate soil-test K methods. Treatments were a non-fertilized control and a high K rate (186 kg K ha^{-1}) applied to long strips (220-640 m long) measuring 18 m in width (the width of the fertilizer spreader) and were replicated three or four times. Adapted corn hybrids were planted by the producers using commonly recommended seeding rates, N and P fertilizers rates, and pest management practices.

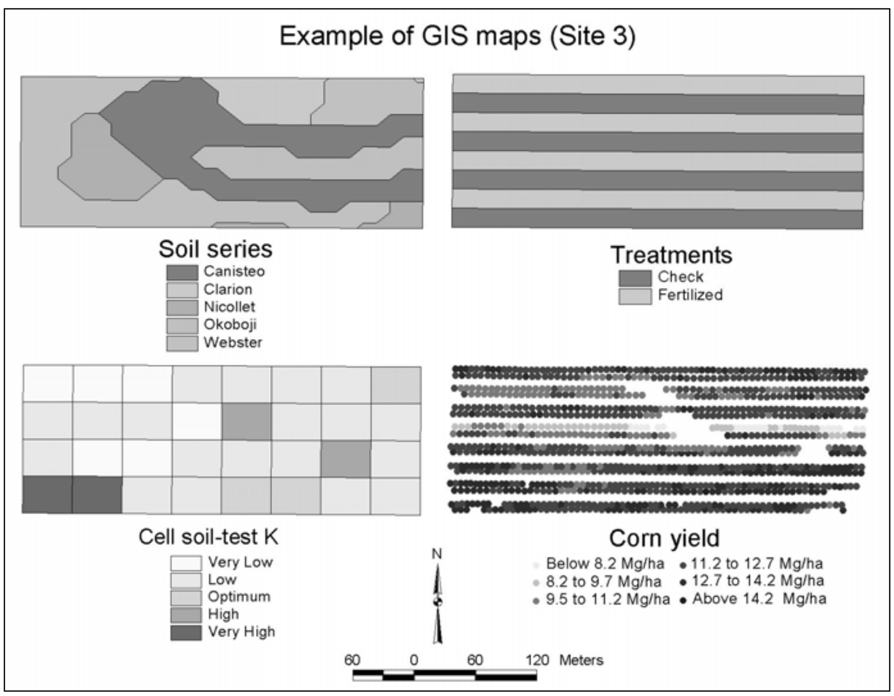
Soil samples were collected from a 0-15 cm depth before applying the treatments. Each composite sample consisted of 12 cores collected from an area about 80 m^2 in size at the center of 0.13-ha cells. Soil samples were dried at 35-40 ºC and analyzed for K with the ammonium-acetate and Mehlich-3 methods, and for other nutrients. Only results for the ammonium-acetate extractant are shown in this presentation. Grain yield was measured with combines equipped with calibrated yield monitors and GPS. The yield data were imported into ArcView GIS, and analyzed and corrected for errors that commonly occur when using yield monitors for GIS and statistical analyses. Yield maps were subdivided into small cells defined by the grid sampling cells, replications, and treatment strips. Relationships between grain relative yield (RY) and soil-test K (STK) across sites were described with the Cate-Nelson statistical procedure (Cate and Nelson, 1971), linear-plateau, and quadratic-plateau grafted polynomials (using SAS NLIN) to determine critical STK concentrations (CC). The RY was defined as the yield of the check expressed as a percentage of the yield of the fertilized treatment.

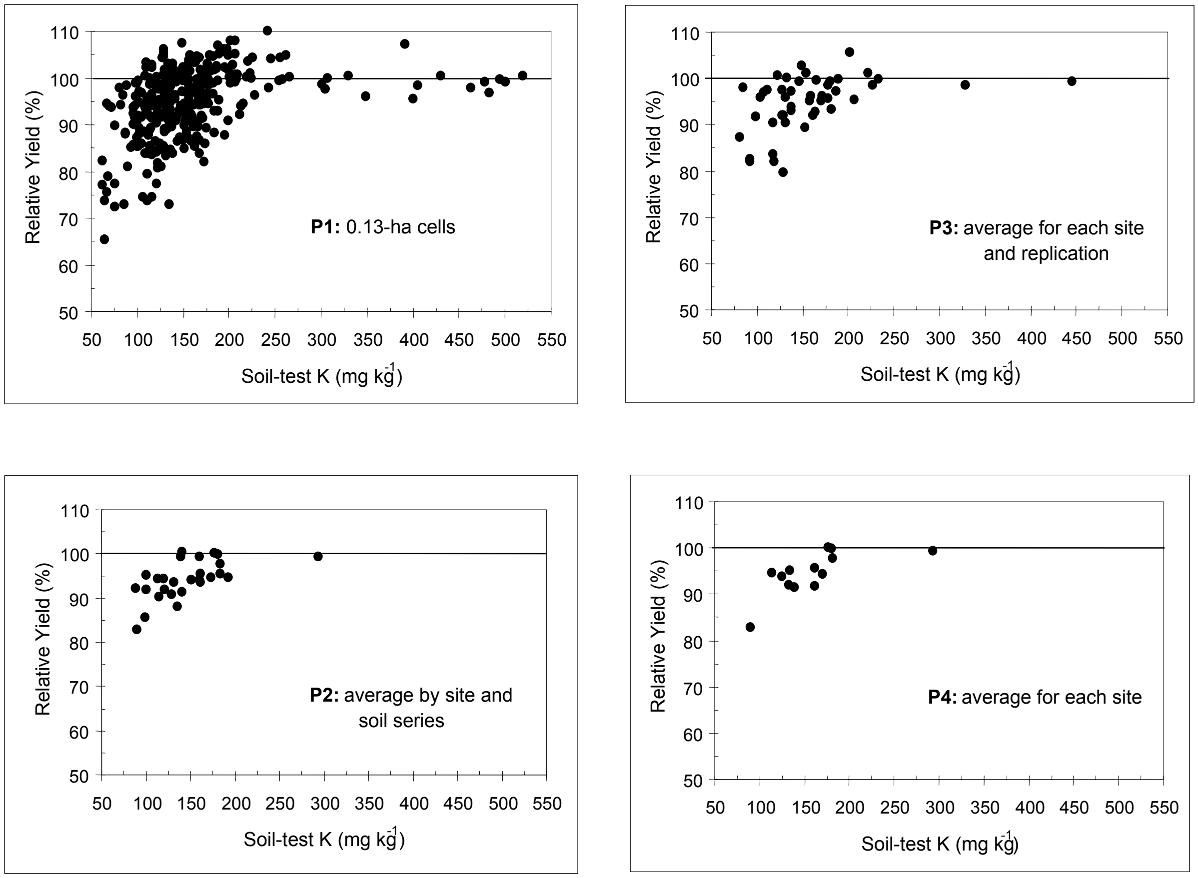
Four procedures (P1 to P4) were used to evaluate this relationship. For P1, data pairs were RY and STK values for areas defined by the width of each replication and the separation distance of the sampling grid lines along the strips (0.13 ha). For the other procedures, data pairs were averages by site and soil series (P2), considering only soils present in at least three cells; for each site and replication (P3); and for each site (P4).

Table 1. Site characteristics

Site	Soil-test K Mean	Min.	Max.	CV†	Predominant soil series Series	Classification ‡	Field area
	------------mg kg^{-1}	-----------		(%)			(%)
1	89.3	62.0	175.0	34.7	Spillville	C. Hapludoll	100
2	132.6	89.5	175.5	15.8	Nicollet	A. Hapludoll	40
					Canisteo	T. Haplaquoll	29
3	136.9	68.0	520.0	73.3	Webster	T. Haplaquoll	41
					Canisteo	T. Haplaquoll	38
4	161.5	98.0	391.5	38.0	Webster	T. Haplaquoll	41
					Canisteo	T. Haplaquoll	38
5	180.4	130.0	225.0	15.2	Tama	T. Argiudoll	100
6	161.2	133.0	216.0	13.9	Tama	T. Argiudoll	100
7	135.3	100.5	189.5	17.5	Killduff	D. Eutrochrept	63
					Colo-Ely	C. Haplaquoll	33
8	110.5	73.0	159.0	16.6	Killduff	D. Eutrochrept	78
					Tama	T. Argiudoll	22
9	124.8	95.0	150.5	11.9	Killduff	D. Eutrochrept	78
					Tama	T. Argiudoll	22
10	181.3	131.5	304.5	21.6	Tama	T. Argiudoll	94
					Colo	C. Haplaquoll	6
11	293.6	132.0	501.0	40.5	Otley	T. Argiudoll	100
12	175.7	105.9	256.4	19.8	Calco	C. Haplaquoll	100
13	170.5	132.3	207.3	10.7	Nicollet	A. Hapludoll	75
					Clarion	T. Hapludoll	25

†CV= Coefficient of Variation.
‡A= Aquic, C= Cumulic, D= Dystric, T= Typic.





Relationships between relative corn yield and soil-test K from strip-trials harvested with yield monitors using four data management techniques.

Table 2. Critical concentrations determined with three statistical models

Procedures	n†	Model‡	R^2	CC§
				mg kg^{-1}
P1	317	CN	0.17	177
		LP	0.27	202
		QP	0.27	256
P2	27	CN	0.45	138
		LP	0.44	181
		QP	0.44	246
P3	46	CN	0.31	132
		LP	0.38	199
		QP	0.37	236
P4	13	CN	0.58	102
		LP	0.64	188
		QP	0.66	224

†n = number of observations.
‡CN= Cate-Nelson, LP= linear-plateau, QP= quadratic-plateau.
§CC= critical concentration.
The fit of all models was statistically significant ($P < 0.05$).

Results

Most fields showed large variation in STK and soil series (Table 1). In all fields STK encompassed at least three of Iowa (recently updated) STK interpretation classes, and usually varied from Very Low or Low to High or Very High, except for Site 9.

Field average yield responses to K fertilizer were statistically significant in 5 site-years (Sites 1, 2, 8, 10, and 13). Field-average STK in these fields was Optimum or lower, except in Site 10 and 13, which were borderline with the High class.

The relationship between relative corn yield and STK for the four procedures are shown in the figures. Critical concentrations differed among data management procedures and models used for determining them (Table 2). Large differences in CC among models have been shown before for P or K (Mallarino and Blackmer, 1992; Mallarino and Blackmer, 1994). The CC were lower for the Cate-Nelson model and highest for the quadratic-plateau model.

Averaging field data increased R^2 of all models but reduced CC (by 14 to 75 mg kg^{-1} depending on the model). The CC determined with P1, P2, and P3 and Cate-Nelson statistical model are near CC determined with conventional small plots (not shown). They are near or within the Optimum Iowa STK interpretation class (131 to 170 mg K kg^{-1}), for which fertilization based on K removal is recommended.

The use of P1 and P2 allow assessment of differences in soil-test correlation between soil series. However this data set did not show consistent CC differences across soils.

No single criterion exists to select the procedure that provides the “best” CC or CC range. Study of yield response to K for each field indicated that only use of CC determined by P4 (data averages by site) and the Cate-Nelson model to guide fertilization would have resulted in major yield loss in responsive fields.

Conclusions

Precision agriculture technologies improve the value of replicated strip trials for soil-test correlation by providing information for field areas that traditional grain weighing methods or small plots cannot practically provide. Use of these technologies does not preclude the need for trials across several fields and years.

No single data management procedure can or should be recommended for all conditions. However, results of this study and previous research based on small plots indicate that use of both dense data and averages by site and soil series in combination with various models provide the most valuable information to develop soil-test interpretations from strip trials.

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