Relationship Between Soil-Test Potassium and Crop Yield

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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 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 research farms and several on-farm, replicated strip trials harvested with yield monitors.

Summary of Methods for 2003 Field Trials and Laboratory Tests

Field trials in 2003.

Continued trial designs from last year.
Several field trials were conducted in 2003 having the same objectives and design used last year. Three conventional long-term trials established at research farms continued to be evaluated as in the past, although one was in soybeans. Five long-term K trials established at five farmers in 1994 to evaluate K fertilizer placements were modified to assess the impact of four K fertilizer rates applied broadcast or with the planter (with 2x2-inch starter attachments) on grain yield of corn. Soil samples were collected from each plot for K tests before applying treatments and after crop harvest in the fall. Two on-farm strip trials continued evaluating uniform-rate and variable-rate fertilization for the last 2-year cycle of the corn-soybean rotation. Other similar trials were completed in 2002 and a simpler and less expensive strip-trial design was adopted for new trials to focus on describing response to uniform K fertilizer rates over the landscape. The variable-rate component had provided sufficient data. Treatments in the new strip trials (nine were conducted in 2003) consist 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 the fields and 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. Grain is harvested with combines equipped with yield monitors and GPS receivers in all strip trials. After crop harvest, the soil sampling density multiplies by a factor of three because samples are collected from each strip and cell. Corn in all conventional and strip trials is always grown in rotation with soybeans and that results for soybeans are not presented in these reports because funding form other sources are used for that part of the work.

New trial designs in 2003.
New trials with new design and objectives were started in 2003 to be continued in 2004. These trials have two main objectives that complement the other trials. One objective is to determine rates of K needed to maximize crop yield in different soil types having soil-test K within the

current Low or Optimum interpretation classes, which are the classes for which more doubts exist. The second objective is to determine the residual response of the next year crop to these various rates. Four experiments began with corn and four with soybeans managed with chisel-plow/disk tillage. Five K fertilizer rates ranging from 0 to 180 lb K_2O/acre were applied. Soil samples for K tests were collected from each plot before applying the treatments and after crop harvest in the fall.

Laboratory tests.

The work continued as before by collecting and analyzing soil and plant-tissue samples for K. Planned 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 of all trials (to reduce costs), and a field-moist based AA-K test for selected replications of all trials. The samples for the field-moist test are carefully 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. In addition, selected samples from five fields with contrasting soil series were analyzed with the AA-K test by drying the sample at different temperatures (air dried, 40 °C, and 50 °C). The plant tissue samples collected were the above-ground part of small plants at the V5 to V6 growth stage from all trials and the leaf blade of ear leaves at the silking growth stage from selected trials. All these tissue samples were analyzed for total K.

Summary of Progress

All field trials were conducted successfully. Drought in some parts of the state greatly affected soybean yields but not corn yields. The 2003 yield data has been processed for all plots trials but not for the strip trials. The yield monitor maps involve careful study and GIS work before results can be trusted, and this work has not been completed at this time. Thus, data from strip trials conducted in 2001 and 2002 are summarized in this report.

Highlights of the results for most components of this large project are summarized in this report, mainly by showing corn responses and relationships between response and soil-test values across sites. Some issues will not be addressed because work is still being conducted at this time an available data would not add much to results discussed in last year progress report. This include additional results for the tetraphenyl-boron test over those presented in last year progress report and relationships between yield or soil-test K with plant-tissue K concentrations. Five major results are discussed in this report.

Relationships across sites between yield response soil K extracted by the ammonium acetate and the Mehlich-3 tests from dried soil samples.

Figures 1 and 2 show the relationship across all fields between corn relative yield response and soil-test K measured with the commonly used AA-K and M3-K tests on dried (35 to 40 °C) soil samples. The results show a very poor correlation between yield response and soil-test K measured n this way, which confirms the need for this research. The calibrations are similar for both tests. Figure 3 shows that the AA-K and M3-K tests have a correlation almost 1.0 and that the M3-K test measures a bit less K but the difference is insignificant. The data shown correspond to soil-test results in Figs. 1 and 2, which are averages across field treatment replications. Data for the much more numerous individual samples collected from each plot showed more variation but a similar relationship.

The soil-test calibration results for these tests agree with previous data that were used to update the Iowa interpretations for this test (in 2002) in that no corn response to K is expected above about 170 ppm. However, results clearly show that there is much variation below that soil-test K level. Analyses of soil properties such as pH, cation exchange capacity, K base saturation, tetraphenyl-boron extractable K, and field-moist extractable K are being conducted to understand reasons for differences across soils. Preliminary study of soil texture, CEC, K saturation, pH, and percentage organic matter for the soils did not explain the variation.

Relationship across sites between yield response and ammonium-acetate soil-test K measured on field-moist soil samples.

Figure 4 shows the relationship across all fields between corn relative yield response and soil-test K measured by the AA-K test on field-moist soil samples (not dried). The results show that much less K is extracted from field-moist samples and that the calibration curve has a more distinct critical concentration than for the dried samples. Although a few soils with low extractable K have relative yields at or near 100% (which is possible but not desirable), the general correlation is better than for dried samples. Figure 5 shows a poor correlation between the field-moist and dried AA-K tests, and these preliminary results show that the difference between tests is larger at low K availability values. The results shows that no simple factor can be used to express results of one test based on the other. Moreover, the difference between measured K varied greatly across soils and growing conditions. For example, Figure 6 shows differences of extracted K at various drying temperatures for various typical Iowa soils series. As was said before, analyses are under way to be able to explain the results. Inclusion of the 2003 strip trials and numerous new trials already flagged and fertilized for the 2004 season will provide more information.

Potassium extracted with the tetraphenyl-boron test and relationships with other tests or corn yield response.

No results are shown for relationships between the tetraphenyl-boron K test and other soil tests or corn yield responses because work to correlate the 2003 yield data continues at this time. Priority has been given to work with the moist lab tests. Preliminary results for the tetraphenyl-boron test were presented in last year report. Briefly, the results have been showing that, as expected, the tetraphenyl-boron test measured much more K than the two routine tests. The relationship between corn yield response and tetraphenyl-boron K test tests across all sites has been disappointedly poor, and almost as poor as relationships for the AA-K or M3-K tests based on dried samples. However, results of few fields were included in the correlations, and no definite conclusion can be drawn until the results for 2003 and the new trials established for the 2004 season are available.

Distribution of the response to K fertilization for field areas testing within different soil-test K interpretation classes.

Analyses of soil samples collected before applying the K treatments to the strip trials showed large variation in soil-test K within and across fields, which was also shown in previous years. Use of yield monitor maps are useful to study yield responses for different parts of the fields having different soil series or soil-test values within the different interpretation classes. The data in Fig. 7 show the yield response for areas testing within various current soil-test K interpretation classes within each trial conducted in 2001 and 2002. As was explained above, results for 2003 are still being processed at this time. The bars represent response to uniform-rate or variable-rate methods or their average as appropriate. Differences between these methods are discussed in the next session.

The results show very large differences in corn responses across a field and that the response is larger for the low-testing interpretation classes. The results shows that the change in the Iowa K interpretations introduced for 2003 (the result of work during the early years in this project) improved the prediction of response because in the past a similar study showed much higher responses for the older Optimum and High classes. For example, the limit between the old Optimum and High classes was 130 ppm while it is 170 ppm for the new classes. Although these results are reasonably good, there is still much error in the prediction of degree of response in the low-testing classes that does not show well in this figure but is observed well in Figs. 1 and 2.

Comparison of uniform-rate and variable-rate methods of K fertilizer application.

Data in Fig. 8 shows that the methods of fertilizer application differed slightly only in a few fields and the differences were not consistent across the eight fields. Because of these inconsistencies, averages across fields showed no difference between uniform-rate and variable rate K fertilization. These results could be explained by several reasons. One possible reason is that fertilization rates applied to low-testing areas with both application methods often were sufficient to produce maximum crop yield. The K fertilizer recommendations used in Iowa and the Corn Belt for low-testing soils often include a build-up component or recognize that application of recommended rates will result in significant build-up. Sufficient K fertilization to maximize yield is even more likely for the first crop of the rotation when the 2-yr needs are applied once, as was the case in this study because this is commonly done in production agriculture.

Another reason could involve insufficient precision of commercially available variable-rate technology, including controller's response. This could explain lack of differences when low-testing areas were not large and in isolated spots across a field but not when areas testing low or high are large. Lack of yield differences between methods could also be explained by high small-scale soil-test variability. Previous research based on denser sampling methods showed very high small-scale variability of soil-test K in Iowa fields. However, it must be remembered that the soil sampling density of the grid sampling used for these trials was about 0.5-acre grids, which is much more dense than the density used or could be afforded by farmers.

The variable-rate method had two advantages, although data are not shown or discussed at length here because work is in process at this time and data are available for few fields. One advantage is that the variable-rate method usually applied less K fertilizer than the uniform-rate methods. However, the average difference across fields was small (about 15 lb K_2O/acre less) and the economic impact of savings is small. The other advantage is that K fertilizer was applied better with the variable rate method and soil-test K variability was greatly reduced in the few fields for which analyses were completed. Presentation and discussion of these results will be expanded in the next report.

Publications and Outreach

Publications. No student thesis or journal papers have been published yet because the project has not been completed. However, the results have been summarized in the following extension publications or conference proceedings.

Mallarino, A.P., D.J. Wittry, and P.A. Barbagelata. 2003. New soil test interpretation classes for potassium. Better Crops Plant Food 87:12-14.

Mallarino, A.P. 2003. Phosphorus and potassium management for corn and soybean in humid regions. Proceedings. 10th No-till Production Conference. August 25-29. Rosario. Argentina.

Mallarino, A.P. 2003. Use new potassium soil test and fertilizer recommendations. The Integrated Crop Management Newsletter. IC-490 (23). Iowa State Univ. Extension.

Mallarino, A.P. 2002. Revised Iowa P and K recommendations: New soil-test K interpretations and support for a new soil P test. In Proceedings. 14th Annual Integrated Crop Management Conference. December 4-5, 2002. Ames, IA. Iowa State Univ. Extension.

Mallarino, A.P., D.J. Wittry, and P.A. Barbagelata. 2002. Iowa soil-test field calibration research update: Potassium and the Mehlich-3 ICP phosphorus test. p. 29-39. *In* North-Central Extension-Industry Soil Fertility Conf. Proceedings. Vol. 17. Des Moines, IA.

Presentations. Results of this project, the need for maintaining higher soil-test K values for profitable crop production, and general discussions of K management and deficiencies have been presented at 35 extension field days or other meetings since 2000. Some of these meetings were of a regional or national scope.

Popular press coverage. Potassium management issues and results of this project have been shared during numerous interviews by reporters of radios or farm magazines that cannot possibly be listed in this summary report.

Year 2004 Research Plans

Although the Iowa K recommendations were changed based mainly on the results of early years of this project, the results obviously show that this was 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 corn responses across all soils and conditions, the predictive value of the tests below that value was very poor. Both tests perform very poorly at identifying both the magnitude and probability of response below that level.

To better understand this problem, new strip trials and conventional small-plot trials were already flagged and fertilized last fall for the 2004 season. Plots were laid out and fertilizer treatments were applied for six strip trials and 14 conventional small-plot trials. The same field and laboratory research methods used in 2003 will be used in 2004. However, next year work will emphasize study of basic soil properties that may explain the problems of the tests based on dried samples, fine-tuning calibrations for the field-moist based test, and possibly establishing regions or soils in Iowa with different interpretations for tests based on dried samples.

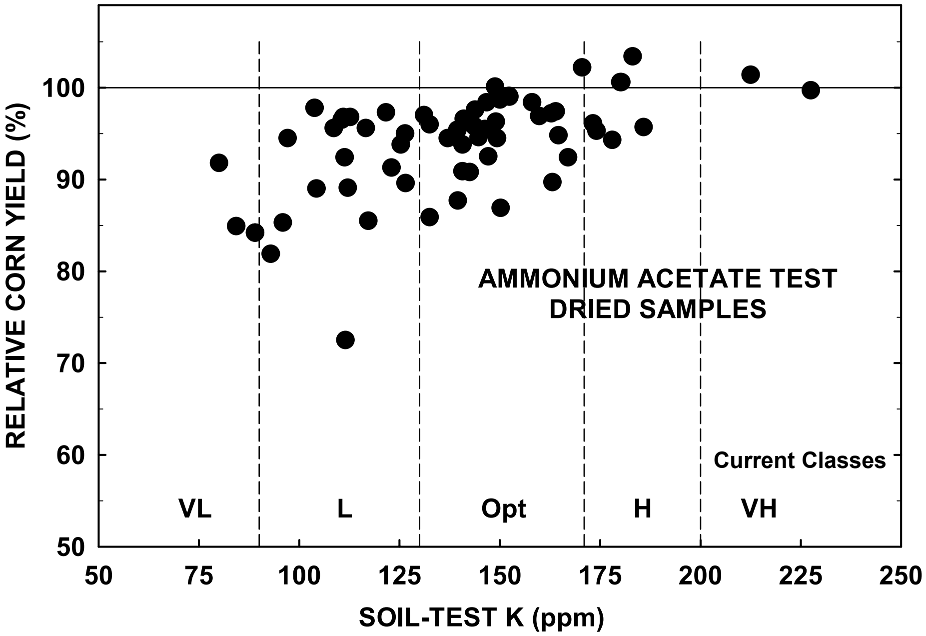

Fig. 1. Relationship between corn response to K fertilizer and the commonly used ammonium-acetate K test based on dried soil samples across sites. The interpretation classes shown are the classes used in Iowa since 2003.

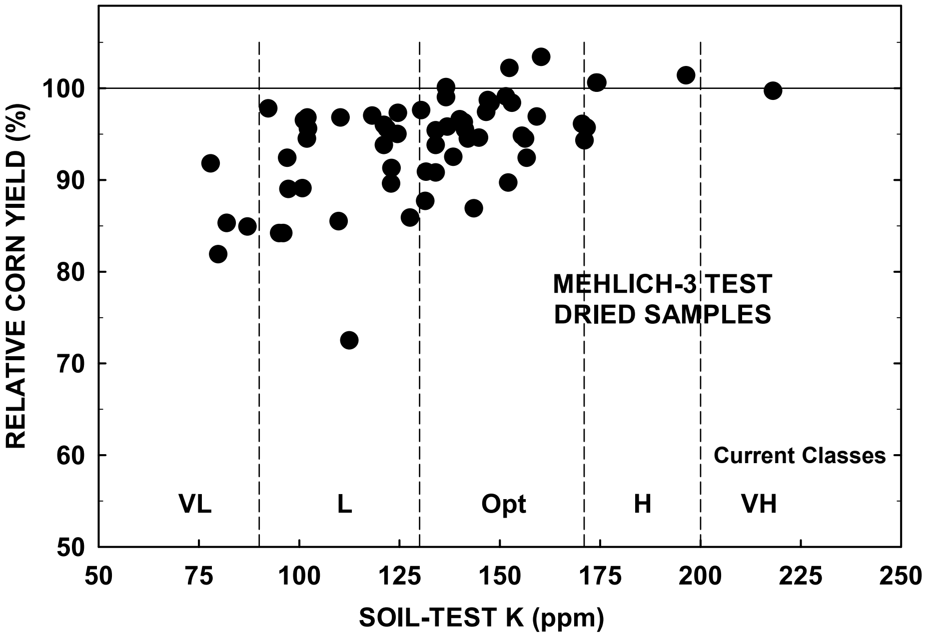

Fig. 2. Relationship between corn response to K fertilizer and Mehlich-3 soil-test K based on dried soil samples across sites. The interpretation classes shown are the classes used in Iowa since 2003.

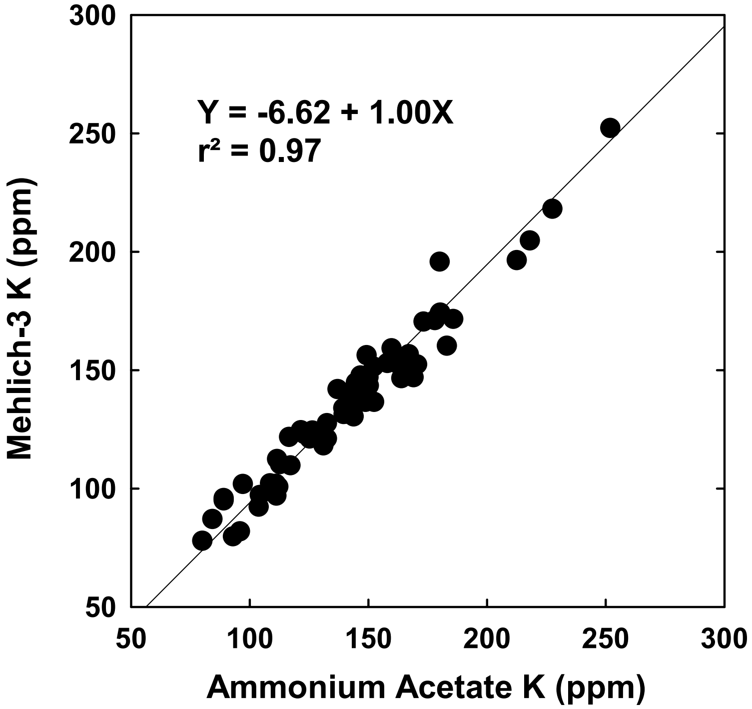

Fig. 3. Relationship between soil K measured with the ammonium-acetate and Mehlich-3 tests based on dried samples (data corresponding to soil-test values shown in Figs. 1 and 2).

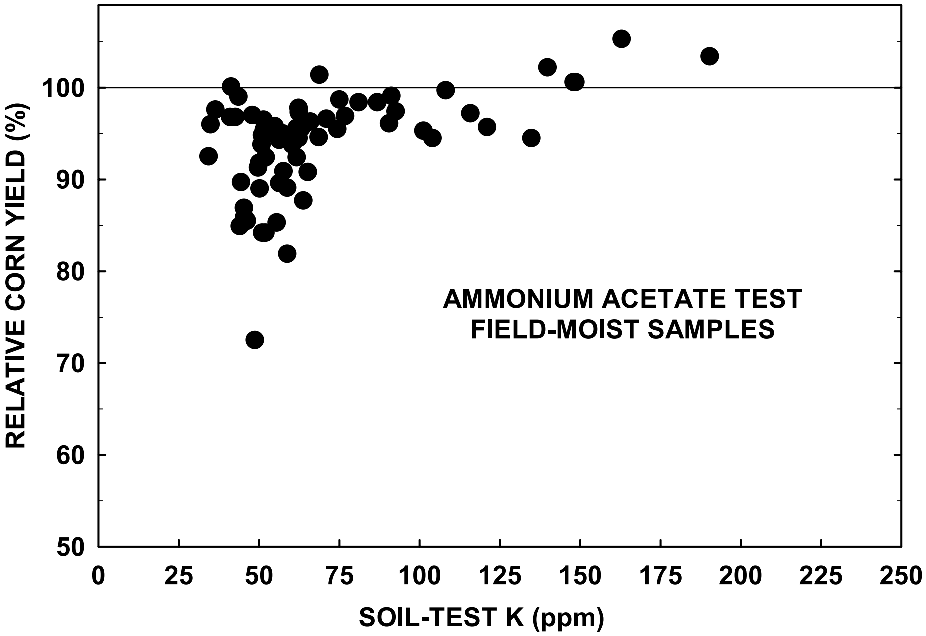

Fig. 4. Relationship between corn response to K fertilizer and soil K measured with the ammonium acetate extractant on field-moist soil samples across sites.

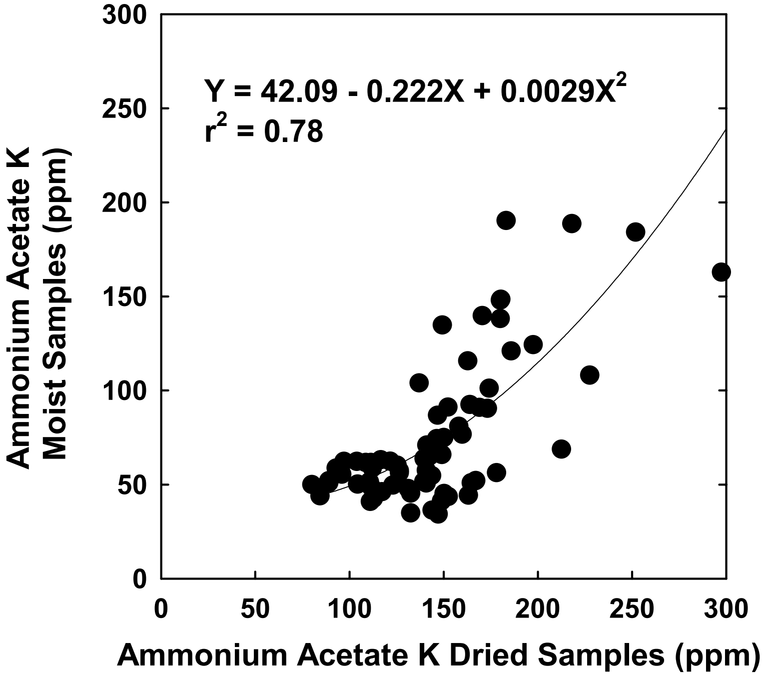

Fig. 5. Relationship between soil K measured with the ammonium acetate extractant from field-moist soil samples and the common ammonium-acetate K test based on dried samples.

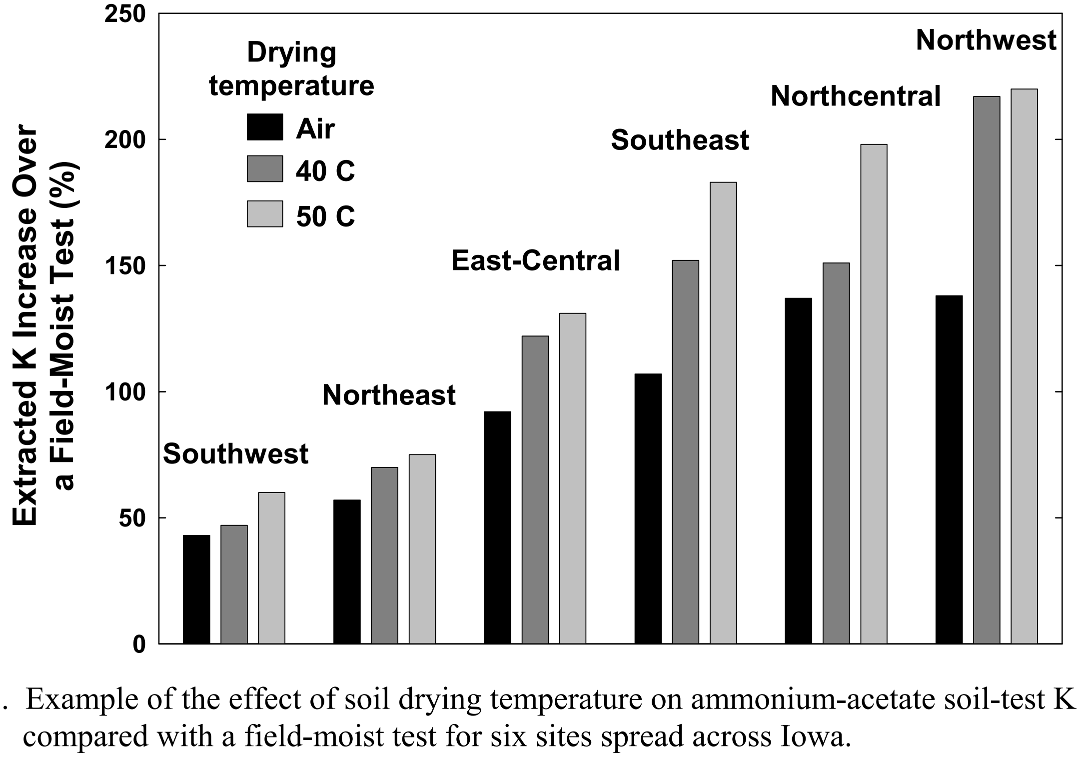

Fig. 6. Example of the effect of soil drying temperature on ammonium-acetate soil-test K compared with a field-moist test for six sites spread across Iowa.

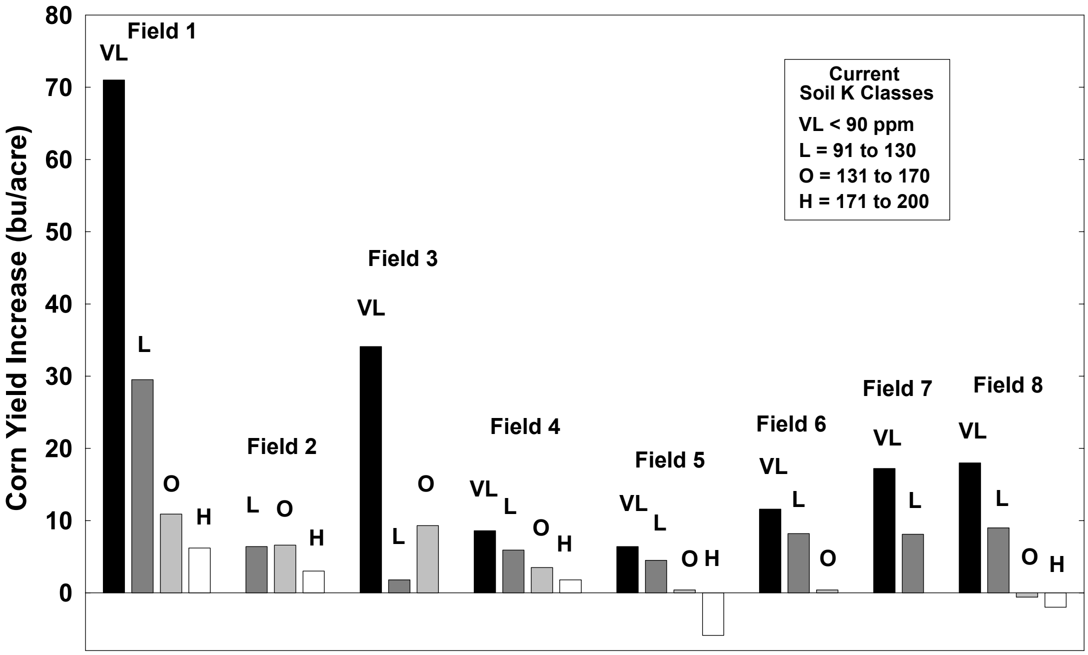

Fig. 7. Corn grain yield response to K fertilization for areas within fields testing within the current soil-test K interpretation classes.

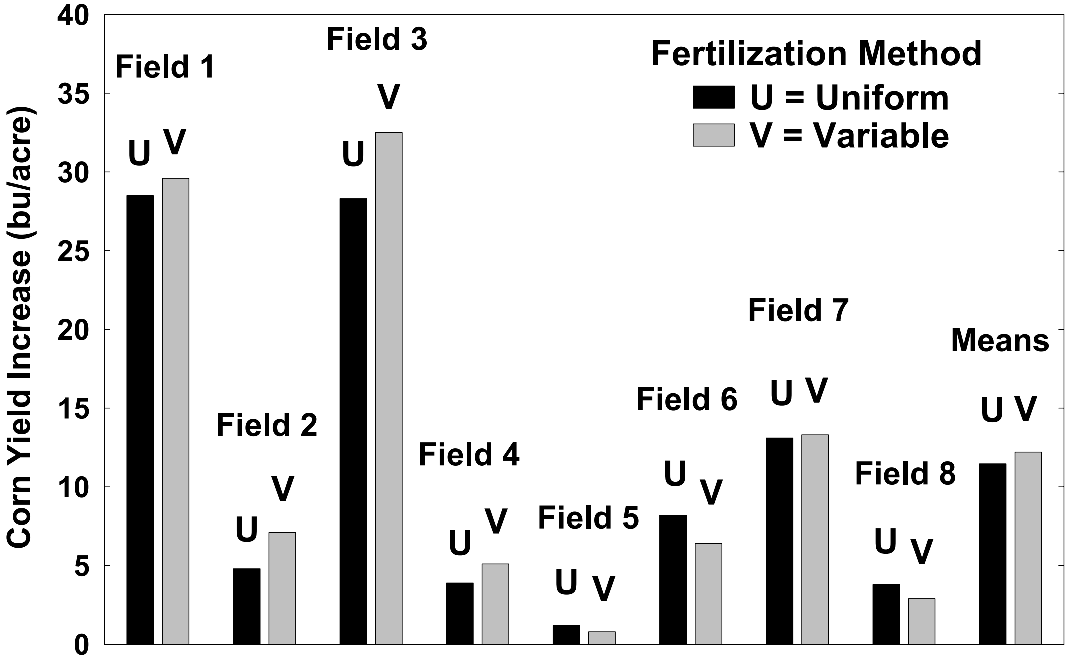

Fig. 8. Whole-field grain yield response of corn to K fertilization using uniform-rate or variable-rate methods for eight Iowa fields.