Reimplementation of Moist Soil Testing to Improve the Assessment of Crop-Available Potassium in Iowa Soils

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Potassium Soil Testing Issues

Since 1989 and until the summer of 2012 all soil testing laboratories in Iowa and the USA dried soil samples at 35 to 40 ºC (95 to 104 ºF) before soil analysis for potassium (K), phosphorus (P), and other nutrients. Since last fall, however, a laboratory that began operations in Iowa is using testing procedures that involve no soil sample drying, and another laboratory is offering moist soil testing in addition to the commonly used test based on dried samples. These laboratories are using a moist soil sample handling procedure that the Iowa State University (ISU) Soil and Plant Analysis Laboratory used from 1963 to 1988, and which was among methods recommended by the North-Central Regional Committee for Soil Testing and Plant Analysis (NCERA-13) committee during the 1980s (Eik et al., 1980; Eik and Gelderman, 1988). The re-implementation of the moist test by these laboratories and last fall update of the NCERA-13 sample preparation chapter to again include the moist sample handling procedure (Gelderman and Mallarino, 2012) have generated many questions.

Most soil-test K (STK) methods used in the USA estimate crop-available soil K by measuring exchangeable K and K in the soil solution because these forms are readily available or quickly become available. The ammonium-acetate and Mehlich-3 methods are the two K tests used in Iowa and most other states. They provide comparable results, and are suggested methods by ISU (Sawyer et al., 2002) and the NCERA-13 committee (Warncke and Brown, 1998). In spite of extensive field K research in Iowa and the north-central region, predicting crop-available K by soil testing has proven to be a difficult task, and the reliability of soil testing for K has been shown to be much less than for P or pH. This is due to complex and largely unpredictable reactions between several soil K pools, interactions with many site factors that influence crop-available K levels, and plant K uptake.

Research with soils of the north-central region during the 1960s, mainly in the greenhouse, showed that K extracted from undried soil samples was better correlated with crop K uptake and yield than from dried samples. Therefore, a procedure for extracting K from homogenized moist samples or from a soil-water slurry was implemented by the ISU laboratory in 1963. Comparisons at the time comparing these two versions of the moist test gave similar results (unpublished), but for fine-textured soils the slurry facilitated sample handling and improved the repeatability of the analysis. Detailed sample handling procedures for both versions of the moist test were included among procedures suggested by the NCERA-13 committee during the 1980s.

In spite of demonstrated better performance of K testing of undried soil samples, no other laboratory adopted the test, citing impractical handling procedures. Therefore, in 1988 the ISU laboratory discontinued its use. As a consequence, in 1998 the NCERA-13 committee also dropped this procedure from its sample preparation chapter of the updated recommended methods publication (Gelderman and Mallarino, 1998).

Iowa field calibration with the dry K test with both corn and soybean conducted from the middle 1990s to 2001, which were to update interpretations and recommendations in 2002 (Sawyer et al., 2002), continued showing a poor prediction of crop response to K fertilization. Therefore, new research began in 2001 to re-evaluate the moist K test as a way of improving the assessment of soil K availability for crops.

Comparison of Nutrient Amounts Extracted by Dry and Moist Tests

Soil samples (6-inch depth) were collected from many field K trials from 2001 through 2006 were sieved, mixed, and divided in two sub-samples. One subsample was prepared for K analysis with the oven-dried sample handling procedure (35 to 40 ºC) and the other with the direct version of the field-moist K analysis (no soil/water slurry preparation). Soil moisture was determined immediately after sieving by drying a small subsample to constant weight, which ranged from 6 to 31% across samples (20% on average). The K extraction and measurement procedures by the ammonium-acetate and Mehlich-3 methods were similar for the dry and moist sample handling procedures. Grain yield data was expressed as relative responses to K fertilization by dividing the average yield of non-fertilized soil across replications at each site by the average of the highest K rate and multiplying the result by 100.

In 2011 soil samples again were collected from many Iowa field trials, and this time were analyzed by P, K, calcium (Ca), and magnesium (Mg) in either moist or dried samples. The sample handling for the dry testing was similar to that described for the earlier study. For the moist test, however, this time the soil-water slurry version of the method was used. Moist soil was sieved through a 1/4-inch screen and an amount of soil equivalent to 100 g of oven-dry soil was mixed with 200 mL water and stirred to prepare an homogenous slurry. A subsample of the slurry was extracted with the same ammonium-acetate and Mehlich-3 procedures as used for the dry and direct-sieving moist tests, being careful to use the same dry soil/solution ratio and molarity recommended for the dry tests. The P in the extracts was measured colorimetrically, whereas K, Ca, and Mg were measured by inductively-coupled plasma (ICP).

Comparisons for potassium

The amount of K extracted from dried soil usually was much higher than for moist soil for most samples collected and analyzed. The relative difference between dry and moist K tests decreased with increasing STK levels, however, and varied greatly among years. Only results for the ammonium-acetate test are shown because results for the Mehlich-3 K method showed similar differences between dry and moist tests.

Figure 1 shows K test results for the study conducted in the 2000s. The dry K test results averaged 145 ppm and ranged from 56 to 388 ppm. Results for the moist test (using the direct version of the method) averaged 76 ppm and ranged from 30 to 356 ppm. Therefore, on average the dry K was 1.92 times higher than the moist test. The difference and ratio between dry and moist K values decreased with increasing STK levels, although the relationship was very weak for the difference but strong for the ratio. The amounts of K extracted from dried and moist samples tended to be the same for the few values greater than about 200 ppm by the moist test (only six samples tested between 200 and 360 ppm, the highest observed value).

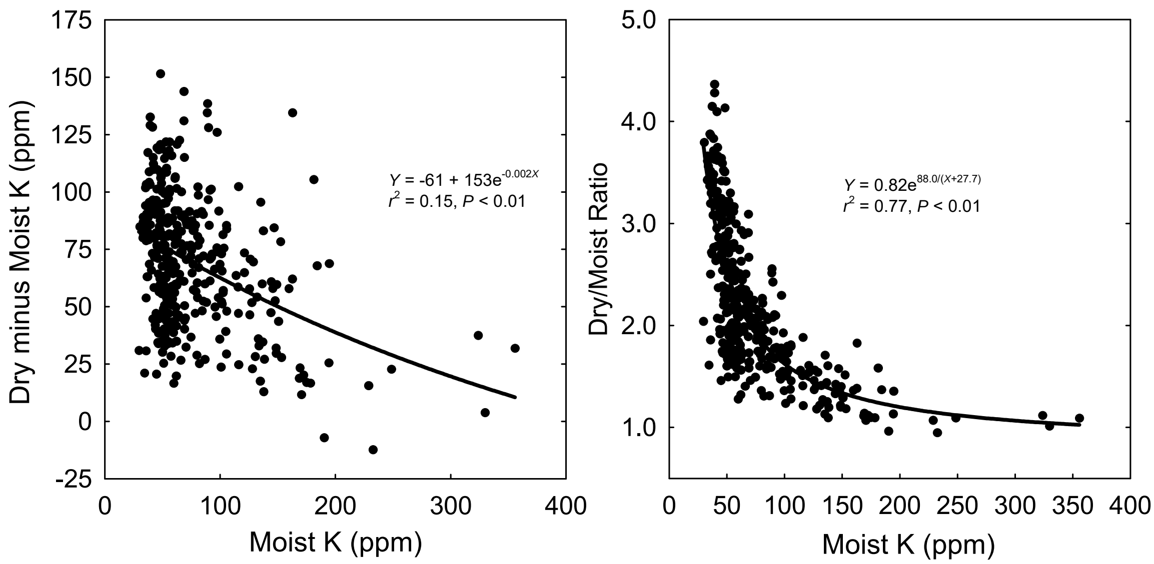

Fig. 1. Relationship between the difference or the ratio of K extracted from dried or field-moist soil samples collected and analyzed from 2001 through 2006.

Figure 2 shows comparisons for soil samples collected in 2011, for which the slurry version of the moist test was used. Potassium for the dry test averaged 161 ppm and ranged from 73 to 373 ppm and results for the moist test averaged 112 ppm and ranged from 25 to 567 ppm. Therefore, on average the dry K test was 1.44 times higher than the moist K. As with the 2000s data, the difference and ratio between dry and moist K values decreased with increasing STK levels.

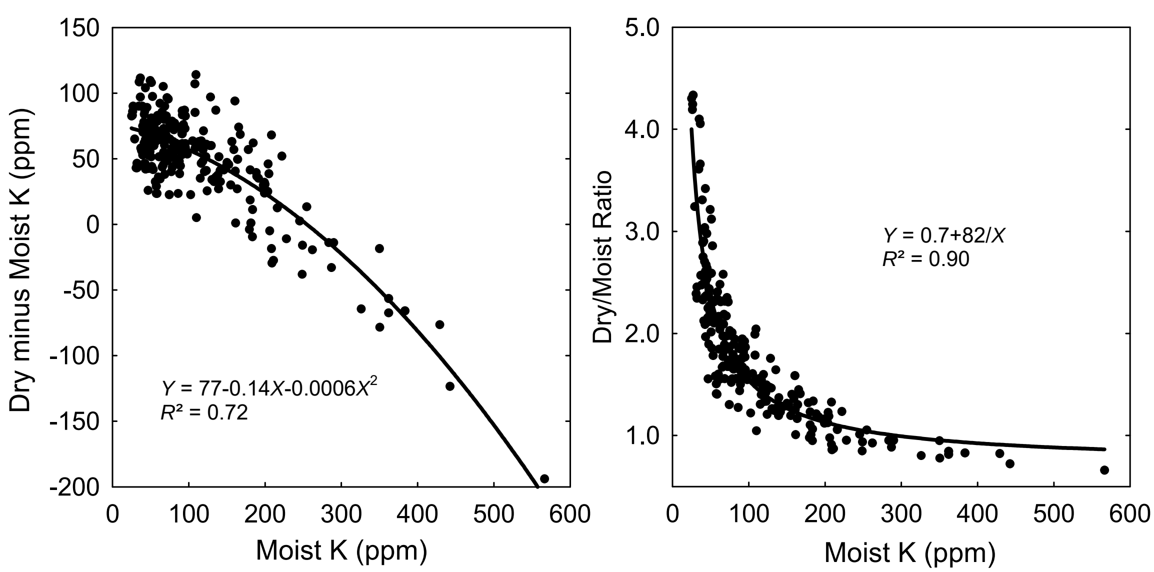

Fig. 2. Relationship between the difference or the ratio of K extracted from dried or field-moist soil samples collected and analyzed in 2011.

The highest STK levels observed for this sample set were much higher than for the sample set from the 2000s, however. Therefore, this data set showed that for values higher than about 350 ppm by the moist test the difference between dry and moist tests reversed, and K extracted from dried samples was less than for moist samples. This inverse relationship at extremely high STK values also was observed in studies conducted during the 1960s.

Therefore, the amounts of K extracted from dried and moist samples indicate that no simple factor can be used to relate or "correct" dry and moist K test results. Furthermore, laboratory studies during the 1960s with soils from several states of the north-central region showed that the difference between dry and moist K tests tended to be larger for the western states of the region than for the eastern states. It is relevant to note that the ratio of dry/moist K tests for both sets of samples increased linearly (not shown) with soil clay, organic matter, cation exchange capacity (CEC), and (Ca+Mg)/K ratio, but the strength of the relationships was poor ($r^2 < 0.35$). The ratio of dry/moist K increased with increasing sample moisture content for both sets, but the relationship was very poor ($r^2 < 0.10$). This research and other NCERA-13 committee research (not shown) have demonstrated that the effect of soil drying on STK increases with increasing temperature, but the effect can vary greatly across soil series.

Comparisons for phosphorus, calcium, and magnesium

Unpublished results of laboratory research in Iowa during the 1960s showed no significant differences for soil P measured by the Bray-1 method on dried or field-moist samples, as long as the ratio of the extracting solutions to equivalent dry soil was kept the same. Data from samples collected in 2011 (shown in Fig. 3) confirm this result, and show a similar result for the Mehlich-3 method. Small deviations from an intercept of zero and a slope of 1.0 were not statistically significant or important given the usual variability due to soil sampling or analytical error.

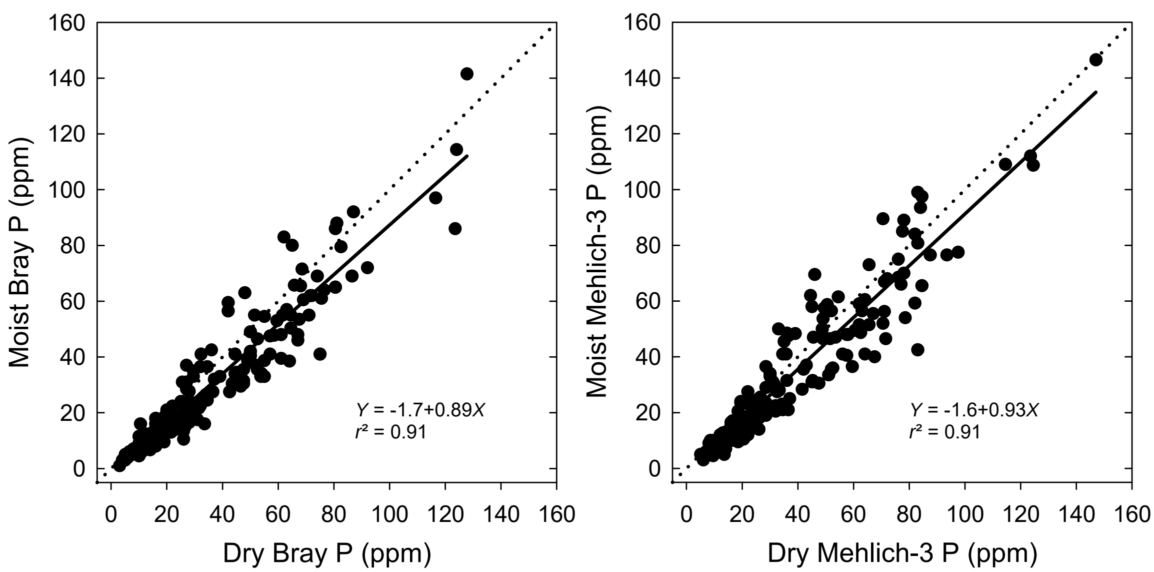

Fig. 3. Relationship between P measured on moist or dried samples using the Bray-1 and Mehlich-3 methods (extracted P was measured colorimetrically for both methods).

Relationships between Ca and Mg measured from dried and moist soil samples by the ammonium-acetate or Mehlich-3 methods did not deviate from a 1:1 ratio (not shown). There were small deviations, but the slopes of the regressions between dry and moist tests for both the ammonium-acetate and Mehlich-3 methods were statistically similar to 1.0. The relationships had more random variability than for P and K, however, and the variability for the difference between dry and moist tests was higher for the ammonium-acetate method than for the Mehlich-3 method. The reasons for a higher variation for the ammonium-acetate method are not clear.

Field Correlation between Crop Response to Potassium Fertilizer and Dry or Moist Tests

Iowa field correlations for the moist K test during the 1980s

Iowa interpretations for the moist K test were last published by Voss (1982). As an example, Fig. 4 shows correlations between moist K test results and yield response of corn and soybean published by Mallarino et al., (1991), which summarized data from two Iowa long-term experiments conducted from 1976 until 1989. At the time there was no comparison with the dry K test, and the slurry version of the moist test was used by the ISU soil testing laboratory following the standard handling procedures used by the lab and which were included among recommended procedures by the NCERA-13 committee during the 1980s. The categories very low, low, optimum, high, and very high shown in the figure for the moist test were the ones recommended in Iowa at the time. The interpretation classes border values were 0-36, 37-67, 68-100, 101-149, and > 150 ppm, respectively.

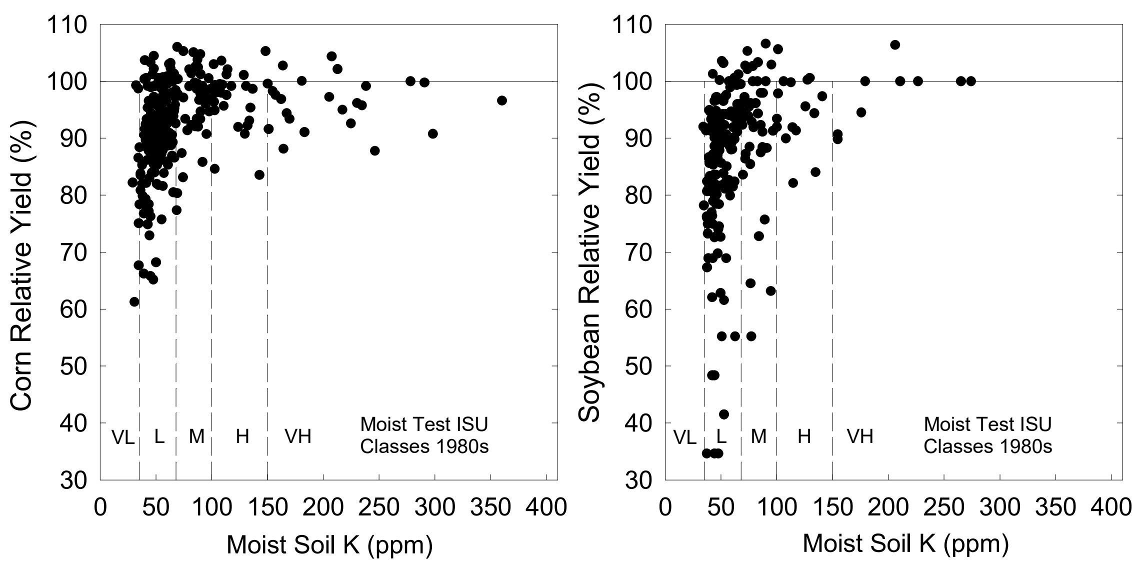

Fig. 4. Relationship between relative corn and soybean yield response to K and soil-test K measured on moist samples for data collected from 1976 until 1989 (Mallarino et al., 1991). VL, L, M, H, and VH identify the 1982 ISU very low, low, medium, high, and very high interpretation classes for the moist test.

New field correlations shown here are from a field study that was conducted in Iowa from 2001 through 2006 with corn and soybean to compare K testing of dried and moist soil samples by the ammonium-acetate and Mehlich-3 methods. Field response trials with either crop were conducted across 20 counties and 32 soil series. There were 200 corn site-years and 162 soybean site-years. Crops and soils were managed with chisel-plow/disk tillage for 120 trials and with no-till for 42 trials. Each trial included several K fertilizer rates (granulated 0-62-0) applied in the fall. The fertilizer was broadcast at most sites, except 30 trials where broadcast and planter-band K placement methods were evaluated. Averages across K placement methods were used for the correlations since they seldom differed. The soil samples were analyzed as described above for this study, by the dry K test following recommended NCERA-13 procedures and by the moist testing using the direct testing of moist soil as recommended until the late 1980s and again since 2012 by the NCERA-13 committee.

Figure 5 shows relationships between relative corn and soybean yield response to K fertilizer and dry K test results using the ammonium-acetate extractant for the field response trials conducted from 2001 until 2006. Results for the Mehlich-3 method were similar to that with ammonium acetate, and are not shown. The graphs also show the current ISU STK interpretations for the dry K test (Sawyer et al., 2002). Only fertilization based on crop K removal is recommended for the Optimum class. When applying the boundaries of the optimum category, then the optimum category encompasses mean relative yields of 93% for corn and 95% for soybean. The different symbol colors indicate the drainage class for each soil series. The graphs for both crops show that according to the dry test, crops grown on the best drained soils needed a lower STK level than crops grown on soils with poor drainage, and crops grown on soils with moderate drainage were distributed between these two extremes. The different STK values for the different groups of soils and the number of site-years for each group do not allow for determining reasonable separate relationships by drainage group. A classification of soil samples based on clay, CEC, K saturation, cation ratios, and other properties (not shown) did not indicate as clear of a grouping as that shown for soil drainage. Several, but not all, soils with poor drainage also had deep profiles and higher CEC, extractable Ca, and organic matter compared with the other soils.

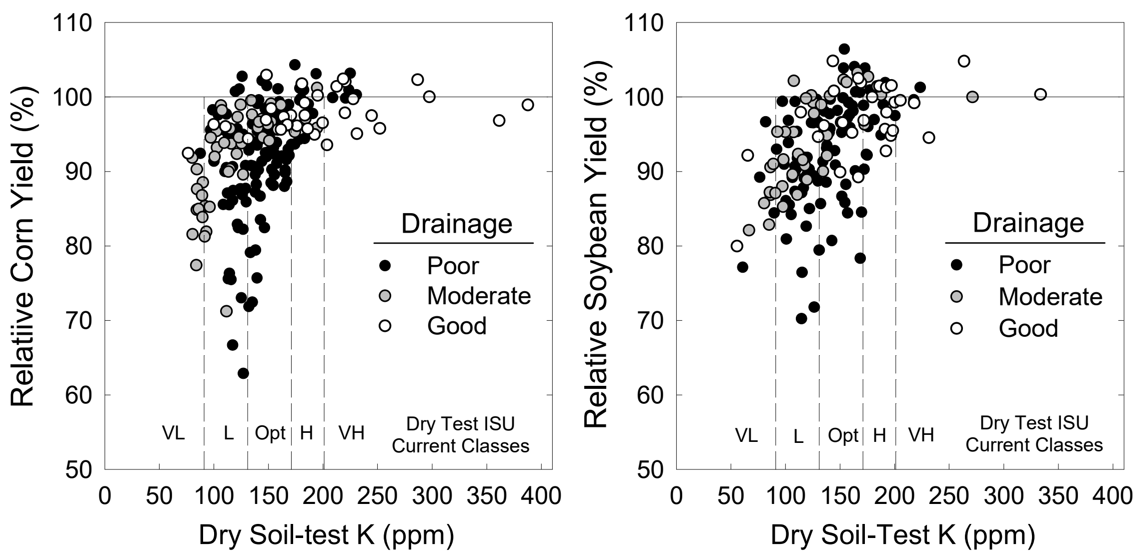

Fig. 5. Relationship between relative corn and soybean yield response to K and soil-test K measured on dried samples. Symbols identify data for soil series with different drainage. VL, L, Opt, H, and VH identify current ISU very low, low, optimum, high, and very high interpretation classes for the dry test.

Figure 6 shows relationships between relative corn and soybean yield responses to K fertilizer and the moist K test results, using the ammonium-acetate extractant. There was a much better relationship for the moist test than for the dry test. This result indicates a better capacity to identify different soil K sufficiency levels for corn and soybean than the dry test, and better prediction of yield response to K fertilization. Moreover, with few exceptions, the data points representing contrasting soil drainage blend into the same general trend for the moist test without the obvious differences shown for the dry test.

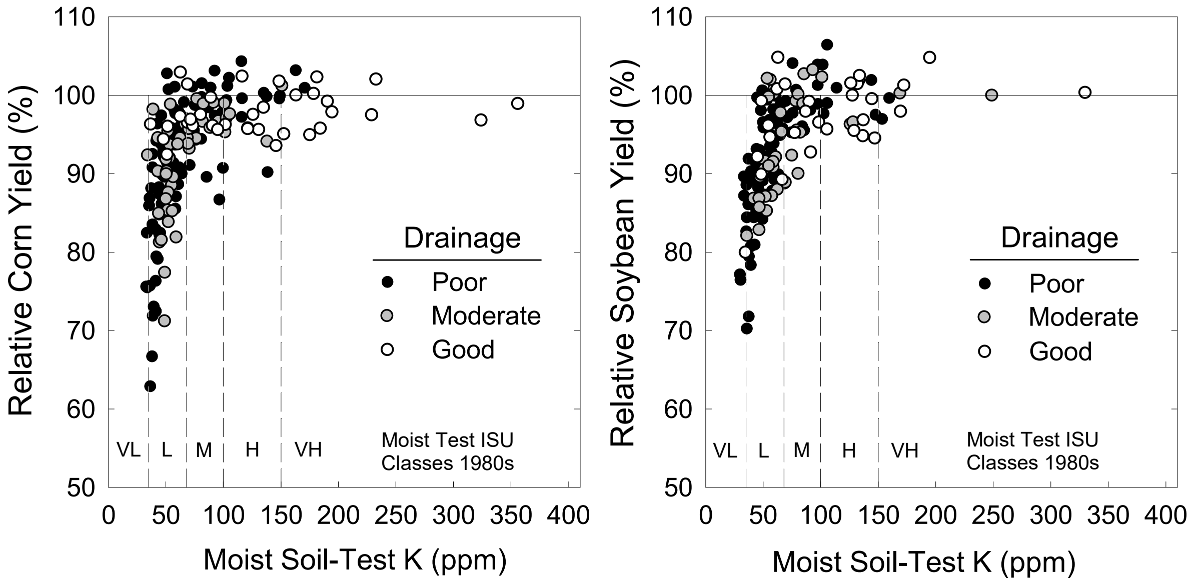

Fig. 6. Relationship between relative corn and soybean yield response to K and soil-test K measured on moist samples. Symbols identify data for soil series with different drainage. VL, L, M, H, and VH identify the 1982 ISU very low, low, medium, high, and very high interpretation classes for the moist test.

The Iowa interpretation category for the moist K test used until 1988 for which maintenance fertilization was recommended (named medium at the time) was 68 to 100 ppm for both corn and soybean. For the old moist K and yield correlation data set (Fig. 4), the boundaries of the old medium category encompass mean relative yields of 96% for corn and 92% for soybean. For the new data set (Fig. 6), the boundaries of the old medium category encompass mean relative yields of 97% for corn and 98% for soybean. The approximately similar fit of the old ISU moist test interpretation classes to both the old dataset and the new dataset is remarkable, since in the 1970s and 1980s crop yields were much lower (especially for corn), hybrids or varieties were different, and only two soil series were included in the old research (many years of two long-term experiments), however, 32 soil series and six years were included in the new research.

Therefore, if criteria for establishing the moist test interpretation categories were the same as in the 1980s, approximately similar interpretations could be used today. New field calibration research for the moist test with corn and soybean are being conducted since 2011 using the slurry version of the moist test. Therefore, results summarized in this study together with results of the ongoing research will be merged during 2013 to establish updated interpretations for the moist K test and fertilizer recommendations.

Summary

Results of the summarized studies strongly suggest that re-implementation of the moist K test in Iowa would significantly improve the assessment of crop-available K and the prediction of crop yield response to K fertilization. Based on old and new research results, and because at least two private laboratories already are offering the moist test for P, K, and other nutrients, in the fall of 2012 the NCERA-13 regional committee re-introduced the moist sample handling procedure to the Sample Preparation chapter of its publication with recommended soil testing procedures.

New ISU interpretations for the moist test will be developed during 2013, as results of ongoing field and laboratory research become available and can be merged with results of previous research summarized in this article. The interpretations for the moist test for K may be approximately similar to those suggested by ISU in the 1980s. Moist test interpretations for P using Bray, Olsen, and Mehlich-3 methods (using colorimetric or ICP procedures) should be similar to those for the dry tests, since data already showed similar test results.

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