Value of tissue testing to improve phosphorus, potassium, and micronutrients management for corn and soybean

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Background

Soil testing is a useful and commonly used diagnostic tool for making phosphorus (P) and potassium (K) fertilization decisions. Soil testing for micronutrients also is useful, but its value is more uncertain because of more complex and less understood soil processes that affect their availability for crops. Also, micronutrients deficiencies other than of iron (Fe) for soybean in soils with very high pH and calcareous seldom are observed in Iowa and neighboring states, so test methods field calibration research with yield response is difficult and usually inconclusive. Tissue testing has been suggested for decades as another diagnostic tool to help make fertilization decisions for these and other nutrients. Iowa State University (ISU) has not developed guidelines or implemented tissue test interpretations for crops such as corn, soybean, and forages because of inconclusive results about its value from old and limited field calibration research with crop yield response. Only a few states in the North Central Region recommend tissue testing as a diagnostic tool to decide fertilization, but are based on decades old research and may not apply to Iowa soils and hybrids or varieties used. Therefore, a large research program was developed to evaluate the value of tissue testing for P and K and the micronutrients boron (B), copper (Cu), manganese (Mn), and zinc (Zn) in corn and soybean. Iron (Fe) deficiency is common in soybean in Iowa soils with very high calcareous content (not in corn, however), but the study did not evaluate tissue tests for this nutrient because Fe fertilization seldom is effective.

Summary of procedures

P and K field trials

For corn, several P or K fertilizer application rates were applied in 73 field response trials in 2013 and 2014, and these data were combined with data from 20 K trials and 6 P trials that had been conducted previously since 2003. Therefore, the study included 99 corn site-years, 32 for P and at 67. For soybean, several P or K rates were applied to 66 response trials in 2013 and 2014, and these data were combined with data from 20 K trials that had been conducted from 2003 until 2006. Therefore, the study included 86 soybean site-years, 34 for P and at 52 for K. The trials were distributed across several ISU research farms located in central, northern, northeast, northwest, southern, southeast, and southwest Iowa. The study encompassed 17 different soil series. Some fields were managed with chisel-plow/disk tillage and others with no-tillage. All trials used a conventional plot methodology and treatments were replicated three to six times. Granulated fertilizers were applied before planting the crops. Soil-test values in samples taken before fertilization and planting ranged from very low to very high.

Micronutrients field trials

Foliar fertilization trials with B, Cu, Mn, and Zn were conducted at 46 soybean fields and 10 corn fields from 2012 to 2014; 35 of them were at farmers' fields and the others were at several ISU research farms. Treatments applied replicated four times were a control, each micronutrient applied separately, and a mixture of all four of them. The treatments were sprayed at the V6 growth stage of both crops, and again at the soybean R2/R3 stage or corn R1 (silking) stage. Commercially available fluid fertilizers based on boric acid for B and EDTA for the other nutrients were sprayed using a hand-held CO_2 sprayer with a 5-foot spraying width and 15 gal/acre of water. The total amount applied of B, Cu, Mn, and Zn was 0.16, 0.08, 0.33, and 0.50 lb element/acre, respectively.

Trials with B, Mn, and/or Zn application to the soil for corn-soybean rotations were established in spring 2012 at fields of eight research farms and were evaluated until 2014. Therefore, there were twelve trials with each crop. The farms were in central, northern, northeast, northwest, southern, southeast, and southwest Iowa. Four trials began with corn and four with soybean. Treatments replicated three times that were a control, separate applications of B, Mn, or Zn banded with the planter, their mixture banded with the planter, and their mixture broadcast and incorporated into the soil by light disking. Granulated fertilizers were used, and the nutrient sources and application rates were for B NuBor 10, 10% B, at 0.5 lb B/acre for planter-band and at 2 lb B/acre for broadcast application; for Mn Broadman20, 20% Mn, at 5 lb Mn/acre both for planter-banded and broadcast placement methods; and for Zn EZ20, 20% Zn, at 5 lb Zn/acre both for planter-banded and broadcast placement methods. All planter-banded micronutrients were mixed with MAP fertilizer at a rate of 4 lb N/acre and 21 lb P_2O_5/acre, and the same banded MAP rate was applied to plots of the control and the broadcast mixture.

The micronutrient trials encompassed 25 soil series. The soil pH ranged from 4.9 to 7.4, organic matter was 2.5 to 8.0, and texture ranged from sandy to silty-clay-loam. About two-thirds of the trials were managed with no-till and others were managed with chisel-pow/disk tillage.

Plant tissues sampled, analyses, and data management

The corn tissue tests evaluated were the P and K concentrations in aboveground corn plants at the V6 growth stage and in ear-leaf blades opposite and below the main ear at the R1 stage (silking). The soybean tissue tests evaluated were the P and K concentrations in aboveground soybean plants at the V6 growth stage and upper fully mature trifoliate leaves (including the petioles) at the R2-R3 stage. To be able to relate crop yield responses with the tissue-test values across fields and years, grain yield at each trial was expressed as relative yield response by dividing the yield for each treatment as a percentage of the statistically maximum observed yield and multiplying by 100. The plant tissue samples were analyzed for the total concentration of the nutrients by recommend methods. Critical nutrient concentrations in soil or plant tissue distinguish between conditions of nutrient deficiency with likely crop response to fertilization from conditions with adequate levels or high and unlikely response. A critical concentration range was determined for each nutrient and tissue sampled by using two response models (linear-plateau and quadratic-plateau) that are commonly used for this purpose.

Results for P and K in corn and soybean

The trials encompassed a wide variety of growing conditions, which included fields with low to high yield potential and years with favorable to unfavorable weather. Corn grain yield across treatments and trials ranged from 78 to 238 bu/acre. There were statistically significant yield increases in 27 of the 32 P site-years (up to 77 bu/acre) and in 37 of the 67 K site-years (up to 111 bu/acre). No yield response to P or K fertilization was expected in several fields because soil-test P or K was in the high or very high interpretation categories. Figures 1 and 2 show that the corn yield response to P and K decreased (so the percent relative yield increased) with increasing tissue concentrations of both nutrients.

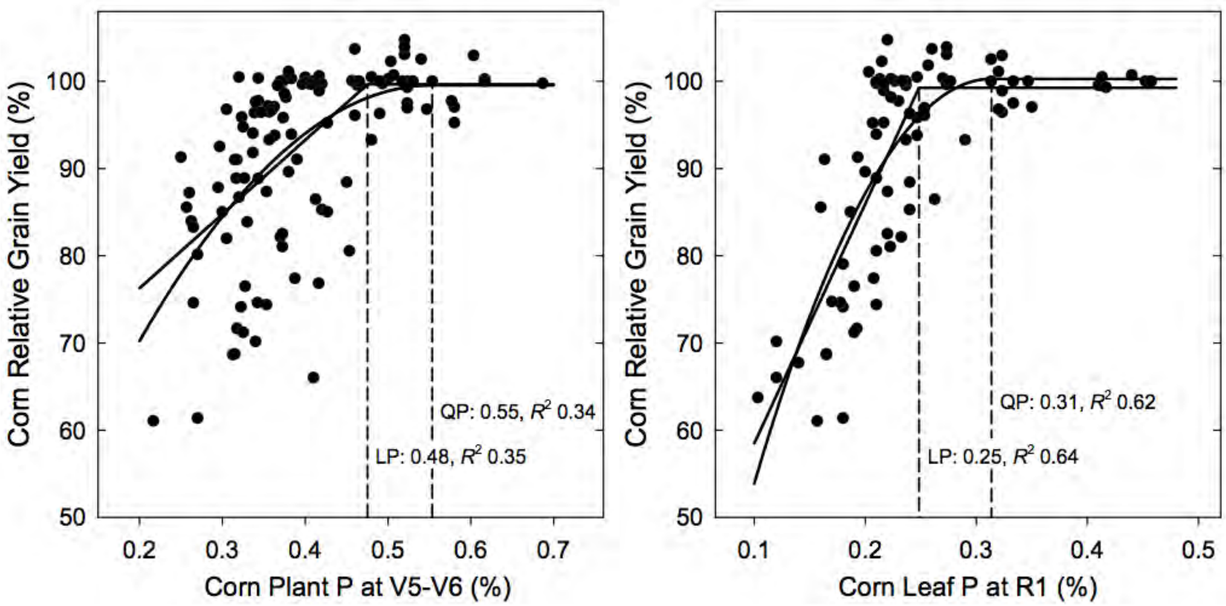

Figure 1. Relationship between corn yield response and tissue P concentrations in plants at the V6 stage and in ear leaves at the R1 stage. Critical concentrations and models R2 are shown.

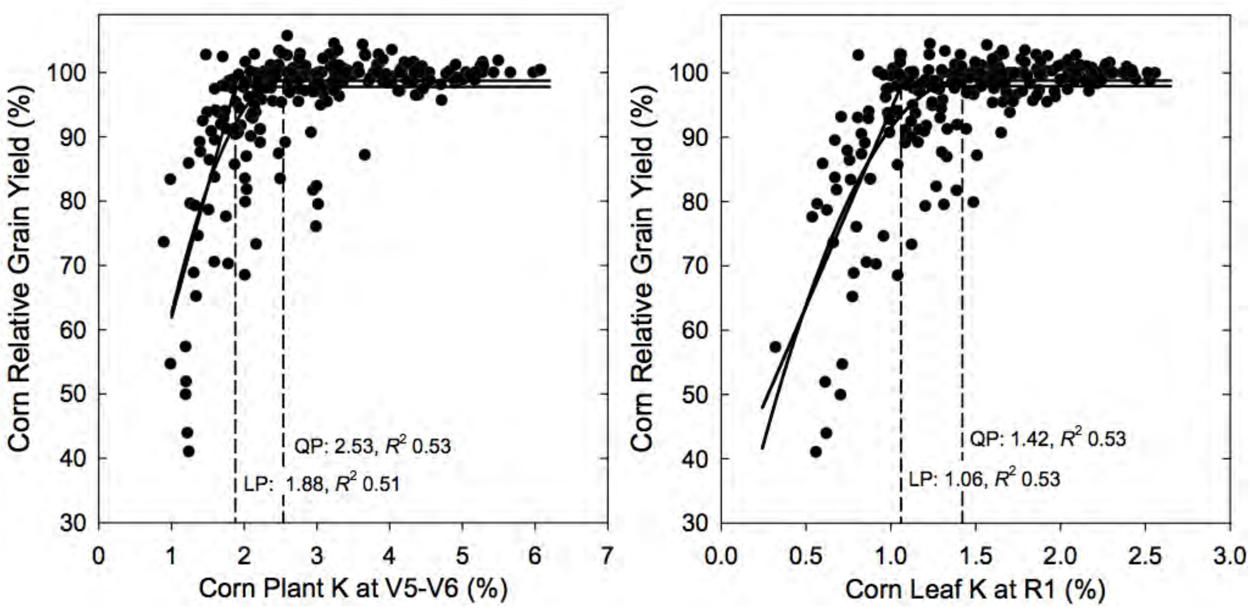

Figure 2. Relationship between corn yield response and tissue K concentrations in plants at the V6 stage and in ear leaves at the R1 stage. Critical K concentrations and models R2 are shown.

The P critical concentration ranges in corn tissue (Figure 1) were 0.48 to 0.55% P for young plants and 0.25 to 0.31% P for leaves. The models R2 values indicate the proportion of the variation explained, were very similar for both models, but were higher for leaf tissue test than for the young plant tissue test. Also, the capacity of the tissue test values to predict the magnitude of the yield response when the test result was below the critical concentration range was poorer for young plants than for leaves at silking. Figure 2 shows that the critical K concentration ranges in corn tissue were 1.88 to 2.53% K for young plants and 1.06 to 1.42% K for leaves. The R2 values of the relationships were approximately similar for both response models and both tissue tests. Therefore, a P tissue test for leaves at silking was better than for young plants, whereas K tests based on young plants or leaves showed similar performance.

Soybean grain yield across treatments and trials ranged from 22 to 73 bu/acre. As for corn, the soybean trials encompassed a wide variety of soils and weather conditions. There were statistically significant yield increases in 22 of the 34 P site-years and in 22 of the 52 K site-years (up to 18 bu/acre). No yield response to P or K fertilization was expected in several fields because soil-test P or K was in the high or very high interpretation categories.

Figure 3 shows that the soybean yield response to P and K decreased (so the relative yield increased) with increasing tissue P concentrations. The P critical concentration range for young plants defined by the two models was 0.33 to 0.41% P. For the leaves, the linear-plateau model estimated a critical concentration of 0.35% P but the quadratic-plateau model is not shown because it estimated a value higher than the highest observed concentration (0.42% P). Therefore, the critical concentration range for leaves was defined from 0.35 to 0.42% P. The model R2 values were slightly higher for the young plants than for the leaves, but both were much higher than for P tissue testing in corn. The P tissue testing has a poorer capacity in soybean than in corn to predict the yield response near and below the critical range.

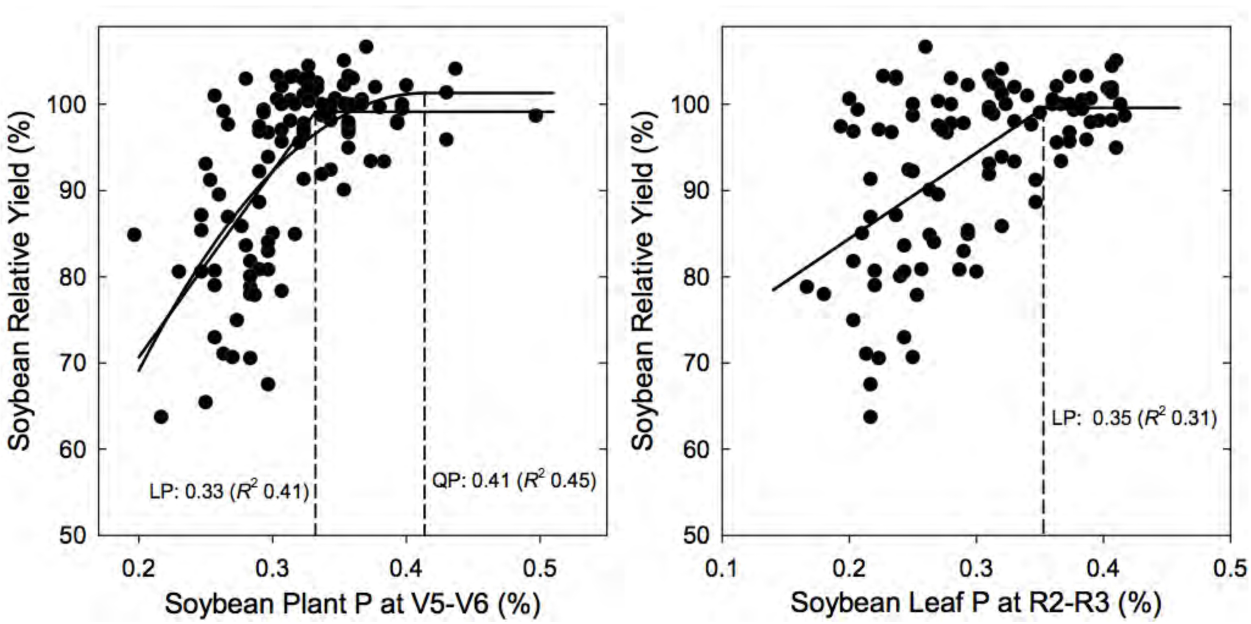

Figure 3. Relationship between soybean yield response and tissue P concentrations in plants at the V6 stage and in leaves at the R2-R3 stage. Critical concentrations and models R2 are shown. The quadratic-plateau model for leaves is not shown because it estimated a critical value higher than the highest observed concentration (0.42%).

Figure 4 shows that the soybean K critical concentration ranges were 1.89 to 2.26% K for young plants and 1.56 to 1.99% K for leaves later in the season. The R2 values of the relationships between tissue test K values and yield response were approximately similar for the response models fit for each tissue but, in contrast to results for P, the relationship was stronger for leaves than for young plants and also stronger than for P (R2 0.51). The unexplained variation in the relationships was greater for young plants than for leaves later in the season, and is explained by a poorer prediction of the magnitude of response within and below the critical range. Therefore, a K test for leaves at the R2-R3 growth stage was better than for young plants.

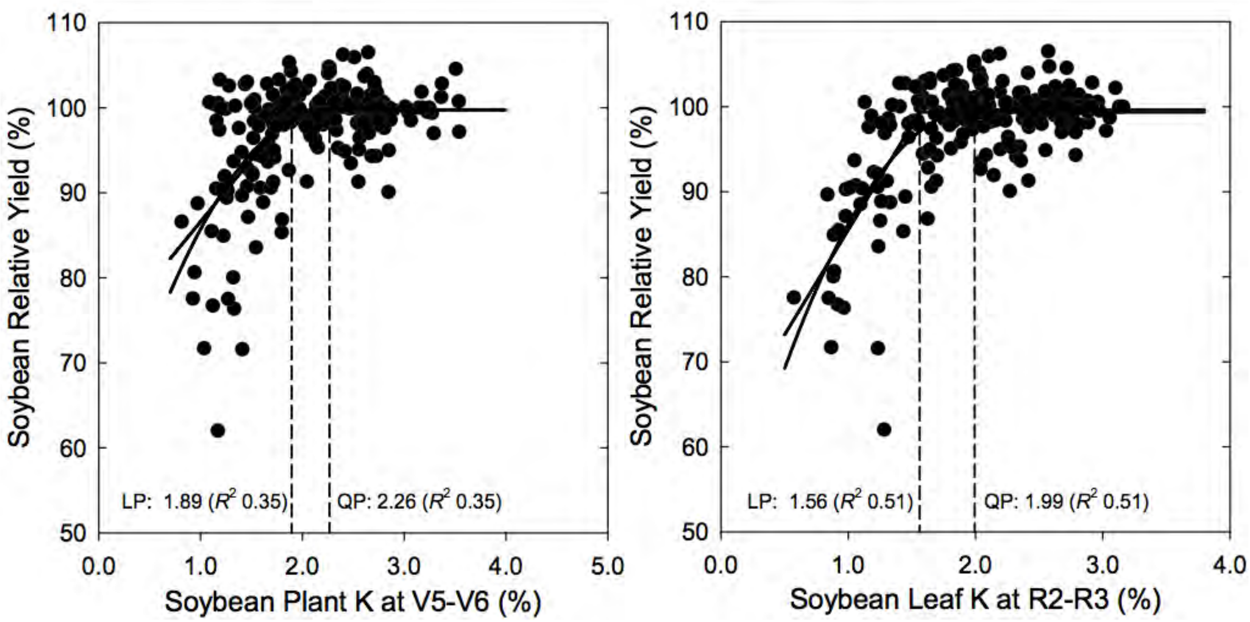

Figure 4. Relationship between soybean yield response and tissue K concentrations in plants at the V6 stage and in leaves at the R2-R3 stage. Critical concentrations and models R2 are shown.

Results for micronutrients in corn and soybean

There were no statistically significant grain corn or soybean yield increases from the application of micronutrients to the soil or foliage at any trial in any year. At one soybean foliar fertilization trial, which was in the highest yielding field, there were yield decreases from applying Cu alone or the mixture. However, at many trials application of micronutrients increased the concentrations in plant vegetative tissue during the season or in harvested grain. Soybean grain yield across trials ranged from 20 to 74 bu/acre, whereas corn yield ranged from 144 to 255 bu/acre. The lowest yields were observed in 2012, when severe drought affected some Iowa regions.

Interpretations for micronutrients plant-tissue tests are not available in Iowa and most states of the north-central region. Most include information for leaves at reproductive stages but there is little or no information for plants at early growth stages (such as at V6). Indiana, Illinois, Michigan, and Ohio, for example, have interpretations for corn leaves at the silking stage and soybean leaves at the "middle to late bloom" growth stages. Interpretations also have been published in a recently updated Plant Analysis Handbook, which indicated no geographic applicability to different regions of the USA (Plant Analysis Handbook III, Micro-Macro Publishing, Inc., 2014). These publications surprisingly agree at suggesting very broad sufficiency ranges for the different micronutrients, which is an indication of the existing uncertainty. In soybean leaves, supply is deemed adequate if concentrations for B, Cu, Mn, and Zn are 21 to 55, 10 to 30, 21 to 100 and 21 to 50 ppm, respectively. In corn leaves, the sufficiency ranges for B, Cu, Mn, and Zn are 4 to 25, 5 to 20, 15 to 15, and 15 to 70 ppm, respectively.

The corn and soybean tissue test results varied greatly across the 80 trials because encompassed many fields and three years with a large variety of soils, soil properties, hybrids or varieties and climate conditions. Table 1 shows the ranges of observed values across all trials.

Table 1. Observed concentrations of micronutrients B, Cu, Mn, and Zn in plant tissue at two growth stages across 22 corn trials and 58 soybean trials.

Crop	Micronutrient	Minimum	Maximum	Minimum	Maximum
		Plants at V6 stage		Leaves at R1 stage	
		-------------------------- ppm --------------------------			
Corn	B	4	16	3	14
	Cu	8	21	7	16
	Mn	18	131	13	116
	Zn	26	54	11	45
		Plants at V6 stage		Leaves at R2/R3 stage	
		-------------------------- ppm --------------------------			
Soybean	B	24	85	23	62
	Cu	5	15	4	11
	Mn	29	202	24	88
	Zn	25	49	18	47

Use of the published tissue-test sufficiency ranges would have wrongly predicted corn or soybean yield increases at several fields of this study. The lower value of ranges for Cu predicted a yield increase only at one corn trial but the higher value predicted a yield increase of both crops at all trials. The sufficiency ranges for Cu predicted soybean yield increases at 39 trials by using the lower value of the range or at all trials using the higher value, but for corn predicted increases at no trial by using the lower value or at all trials by using the higher value. The interpretation range for Mn predicted a soybean yield increase at no trial by using the lower value of the range or at all trials by using the higher value, but for corn predicted increases at one trial or at all trials. For Zn, the interpretation range predicted soybean yield increases at two trials by using the lower value of the range or at all trials by using the higher value, but for corn predicted increases at six trials or at all trials.

Conclusions and possible recommendations

Tissue testing for P and K

The study demonstrated that tissue tests for P and K can be used as in-season tools to assess the P and K sufficiency in corn and soybean. The estimated critical concentration ranges were lower or in the lower portion of sufficiency levels suggested in the literature, which were developed mostly from older research or for other regions. Although these results will be used to develop the first tissue-test guidelines for P and K in Iowa, the value of tissue testing for these nutrients is not better than soil testing, and is of doubtful value to correct deficiencies for the crop that is sampled. Therefore, tissue testing should be used to complement and not substitute widespread use of soil P and K testing for making fertilization decisions.

Tissue testing for micronutrients

The value of tissue testing for micronutrients could not be evaluated with accuracy because there were no grain yield increases across the 58 soybean trials and 22 corn trials conducted during three years. The measured tissue-test levels and the lack of yield increases showed, however, that use in Iowa of mainly the higher values of published sufficiency ranges from other regions would encourage unneeded micronutrients fertilization in many fields. Only the lowest value of published sufficiency ranges correctly predicted a general lack of soybean response to B, Mn, and Zn; and a general lack of corn response to B, Cu, and Mn. Even the lowest value of the ranges grossly over-estimated the frequency of soybean response to Cu and the frequency of corn response to Zn.

Acknowledgements

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