Interpretation of Plant Tissue Test Results for Phosphorus and Potassium in Corn and Soybean

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Introduction

Crop producers often ask questions about plant tissue testing to assess phosphorus (P) and potassium (K) sufficiency in corn and soybean and if it is useful to help make decisions for in-season foliar fertilization. Since adequate P and K supplies are needed early for crop growth most fertilizer recommendations recommend pre-plant P and K application, and this is the practice most producers use. In some cases this pre-plant fertilization may have not been sufficient to meet crop needs due to error in management or soil sampling and testing, however. Farmers and crop consultants have used soil sampling and testing of visually affected and seemingly unaffected field areas to help determine if there is a nutrient deficiency. Tissue testing is a diagnostic tool that could be used as the basis for remedial action for the current crop or future crops.

Interpretation of Tissue Test Results

Early research for a corn ear-leaf test for K reviewed by Jones et al. (1990) suggested a sufficiency range of 1.3 to 3.0% K. More recently suggested ranges were 1.7 to 3.0% K by Mills and Jones (1996) and 1.8 to 3.0% K by Campbell and Plank (2011) for the southern region. Based on 28 Iowa field trials with corn conducted during 1989 and 1990, Mallarino and Higashi (2009) reported an ear-leaf critical concentration (CC) of 1.23% K. Early research for a K test based on mature trifoliate soybean leaves sampled before pod set was summarized by Small and Ohlrogge (1973), who suggested a sufficiency range of 1.7 to 2.5% K. More recently, Mills and Jones (1996) suggested a sufficiency range of 1.7 to 2.5% K, and Sabbe et al. (2011) suggested a range 1.5 to 2.25% K for soybean in the southern region of the USA.

Research with tissue P testing conducted mainly before the 1980s suggested a sufficiency range from 0.25 to 0.40% P for the corn ear-leaf P test and 0.26 to 0.50% P for mature soybean leaves sampled prior to pod set (Small and Ohlrogge, 1973; Jones et al., 1990). These sufficiency ranges continued to be suggested until the middle 1990s (Mills and Jones, 1996). Iowa field correlations for the corn ear-leaf P test conducted during the 1970s and 1980s (Mallarino, 1995) showed that this test identified severe P deficiencies but did not evaluate appropriately near-optimum and above-optimum supplies. The coefficient of determination was low (R^2 0.32), but a CC range of 0.23 to 0.25% P was identified, which was in the lower portion of values reported earlier. In a study conducted during 1989 and 1990 in Iowa (Mallarino, 1996) the CC reported for corn ear leaves was 0.24% P, but the coefficient of determination was very low (R^2 0.14).

Studies in the north-central region during the early 1970s suggested that the P and K concentration of whole young corn plants (about the V5 or V6 stage) also is a good indicator of P and K supply. Although many published studies have analyzed the P or K concentration of young soybean plants at the V5 to V6 growth stage, no generally accepted sufficiency ranges have been suggested. Sufficiency ranges suggested for young corn plants from the 1970s to the middle 1990s were 2.5 to 4.0% K and 0.30 to 0.50% P (Jones et al., 1990; Mills and Jones, 1996). In their study for data collected during 1989 and 1990, however, Mallarino and Higashi (2009) did not find a significant correlation between the K concentrations of corn young plants and yield response, even though the K concentrations ranged from 0.76 to 4.6% K. In an Iowa study conducted during 1989 and 1990 (Mallarino, 1996), the CC reported for corn small plants (V6 growth stage) was 0.34% P but there was a very low R^2 of 0.18.

New Field Correlations of Tissue Tests for Corn and Soybean

Numerous tissue samples were collected during the last decade from many Iowa field trials that evaluated the corn and soybean response to P and K fertilization. The tissues samples collected were the aboveground plant portions at the V5 to V6 growth stage, corn ear leaf blades at the R1 stage (silking), and top mature trifoliate soybean leaves at the R2 to R3 stage. Therefore, we sampled tissue at two growth stages for corn and soybean. It is important to note, however, that not always both small plant and mature leaves were collected in all trials for either the P or K trials. Therefore, direct comparisons of nutrient concentrations in small plants and leaves, if made, should be interpreted with caution. Data presented are the relationships (means of replications) between relative grain yield response and the P or K concentrations in the tissues. The relative yield values give a good idea of the frequency and magnitude of the observed yield responses to P and K fertilization. The criterion for establishing CC ranges was to use the CC values identified by the two best-fitting models. Depending on the crop, nutrient, and tissue, these values were those determining a 95% of the maximum estimated relative yield for asymptotic models and values corresponding to the intersection of the two portions of linear-plateau or quadratic-plateau models.

Figures 1 and 2 show that there was a relationship between the P or K concentration in corn or soybean plant tissue and grain yield response, but the strength of the relationship always was very poor. Given the obvious poor relationships and very low correlations shown by the figures, no reliable CC ranges could be established for the P concentration of soybean small plants, soybean mature leaves, and corn ear leaves (R^2 0.02 to 0.11). For the same reason, no reliable K CC range could be established for the K concentration of soybean small plants (R^2 0.09), although the distribution of points (Fig. 2) suggest it would be lower than about 1.2% K. The strength of the other relationships (R^2 0.21 to 0.34), although still poor, allowed for tentative determination of CC ranges.

The P CC range identified for corn small plants was 0.35 to 0.40% P, and the curve for the best fitting model (asymptotic) is shown in Fig. 1. This P concentration range coincides almost exactly with CCs determined before for corn small plants by Mallarino (1996) for data collected during 1989 and 1990, and is in the middle of the sufficiency range suggested by Mills and Jones (1996).

The K CC range identified for soybean mature leaves was 1.99 to 2.22% K, and the fit line for the best model (quadratic-plateau) is shown in Fig. 2. This range is in the middle of sufficiency ranges suggested many years ago by Small and Ohlrogge (1973) and more recently by Mills and Jones (1996) and Sabbe et al. (2011). The K CC range identified for corn young plants was 2.49 to 2.99% K (Fig. 2 shows the fit by an asymptotic model). This range is in the lower portion of sufficiency ranges suggested by Jones et al. (1990) and Mills and Jones, 1996). It is noteworthy that in an Iowa study with data collected during 1989 and 1990, Mallarino and Higashi (2009) did not find a significant correlation between the K concentrations of corn young plants and yield response.

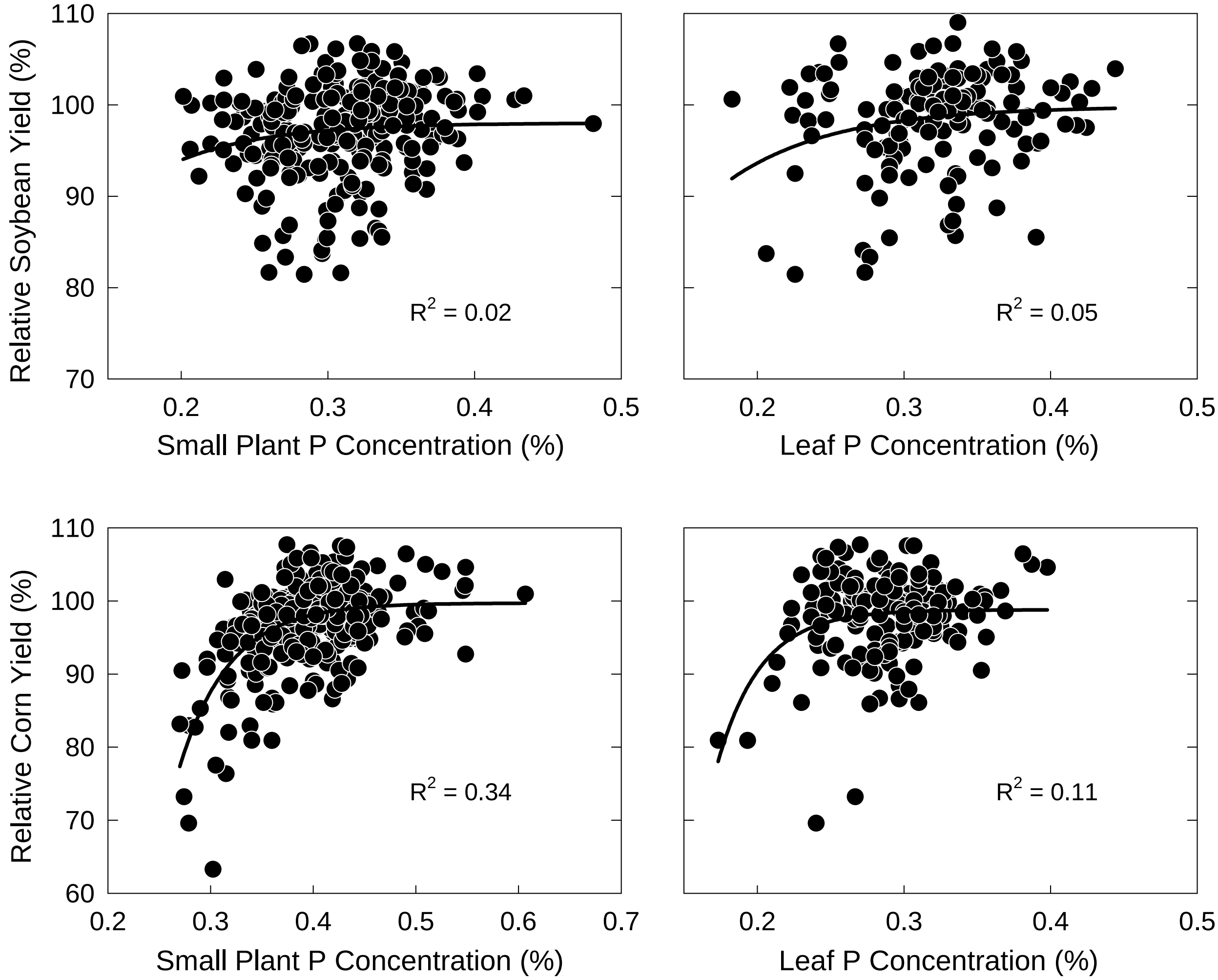

Figure 1. Relationship between the relative yield response of corn and soybean to P fertilization and the P concentration of small plants or mature leaves (V5-V6, and R1 or R2-R3 for corn or soybean) across several trials and years. All relationships were statistically significant at $P \leq 0.05$.

For corn ear leaves, the identified K CC range was 0.89 to 1.02% K (Fig. 2 shows the fit of a quadratic-plateau model, which was he one which fit the data best. This range is much lower than sufficiency ranges suggested by Jones et al. (1990) and Mills and Jones (1996) or by Campbell and Plank (2011) for the southern region. On the other hand, the upper value of the range is slightly lower than the ear-leaf K CC reported by Mallarino and Higashi (2009) for Iowa field trials conducted during 1989 and 1990.

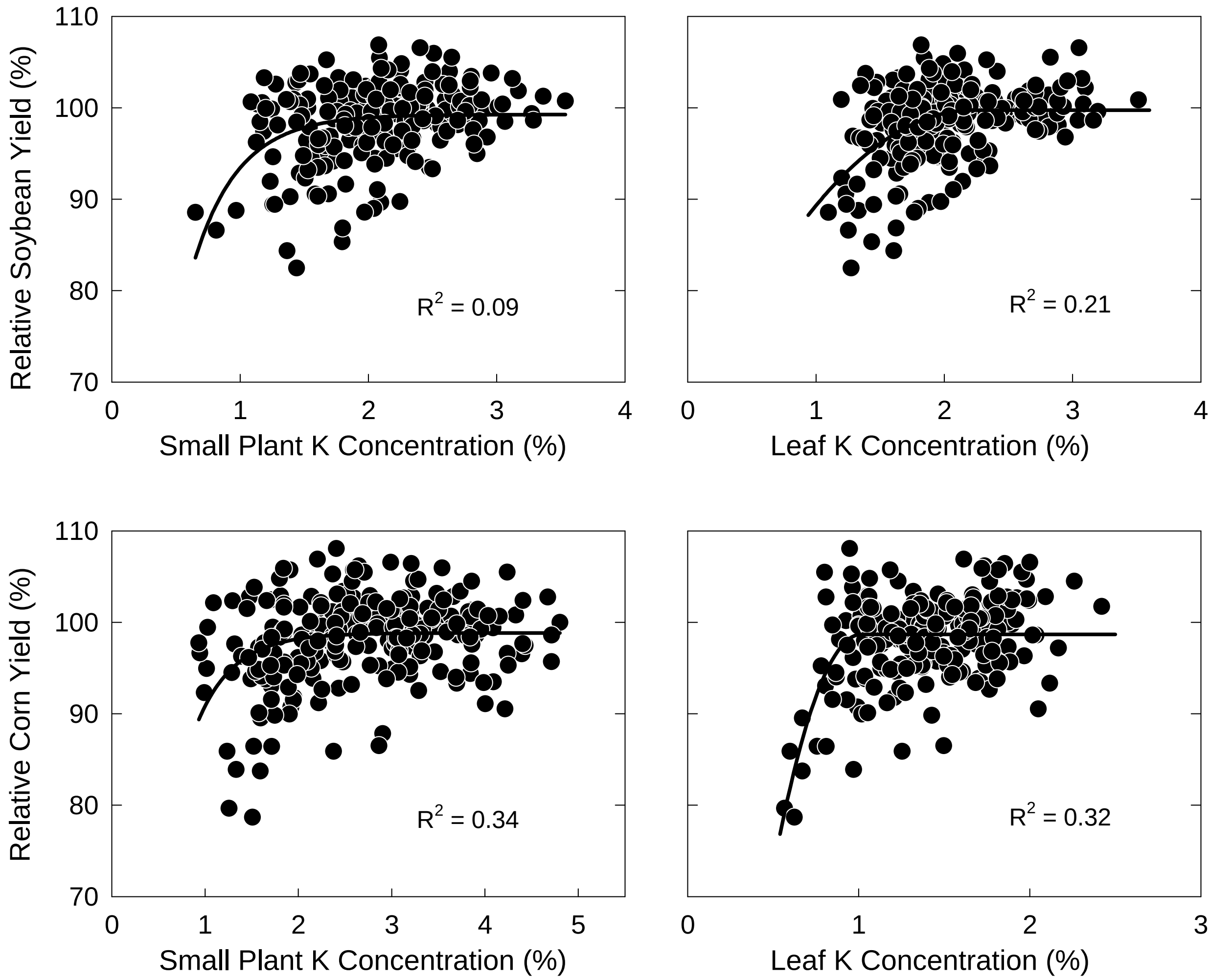

Figure 2. Relationship between the relative yield response of corn and soybean to P fertilization and the P concentration of small plants or mature leaves (V5-V6, and R1 or R2-R3 for corn or soybean) across several trials and years. All relationships were statistically significant at $P \leq 0.05$.

The tissue P and K concentrations reflected better nutrient supply and P or K fertilization treatments in a specific site and year (not shown). However, results showed that tissue testing is a poor diagnostic tool across fields and years. The reason is that many factors other than nutrient supply affect plant growth and the tissue nutrient concentrations due to nutrient uptake and dilution or concentration of nutrients in the dry matter. Attempts to overcome this problem by using systems based nutrient ratios (such a DRIS) have not been successful and often suggest higher fertilizer rates than needed.

Summary and Conclusions

Relationships between crop yield response to P and K fertilization and the concentration of P and K in plant tissue were statistically significant, but the strength of the relationships was very poor. Very poor relationships for P concentration of soybean small plants and leaves and of corn small plant did not allow for establishing CC ranges, but a range of 0.34 to 0.40% P was identified for corn small plants. The relationship between soybean yield response and small plants K concentration also was very poor, and no reliable CC range could be identified. The K CCs identified for soybean mature leaves, corn small plants, and corn ear leaves were 1.99 to 2.22, 2.49 to 2.99, and 0.89 to 1.02% K, respectively. All these ranges were in the middle of published sufficiency ranges or lower.

The observed poor relationships between yield response and the nutrient concentration in plant tissue are not surprising, and similar results abound in the literature. Use of the CCs identified in this study or sufficiency ranges suggested in the literature to make decisions about P and K status of corn and soybean in production agriculture could result in serious error. In addition to the uncertainty arising from poor relationships, no tissue test evaluated appropriately near-optimum and above-optimum nutrient supply. An appropriate evaluation of near-optimum and above-optimum nutrient supply is justified, because use of safe (high enough) tissue concentrations would lead to application of unneeded fertilizer.

Use of soil testing and fertilization before planting is the most effective way of assuring adequate P and K supply for corn and soybean. A practical and useful way of using tissue testing is to use it in conjunction with pre-plant or in-season soil testing to compare field areas with apparent deficiency symptoms or poor growth with nearby seemingly unaffected areas. This strategy may not solve the problem for this years' crop, but will provide clues to improve fertilizer or soil management for next year.

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