8. Plant tissue testing for micronutrient deficiencies and toxicities

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Summary

The relationship between nutrient concentration and yield, when properly used, is a powerful tool for diagnosing the nutritional status of annual crops for B, Cu, Mn, Mo, Zn and occasionally Fe. Imbalance between P and Zn may affect interpretation of plant Zn data at high levels of P. Also, lack of adequate field calibration, especially that involving recently matured leaves, within geographical regions at various yield levels makes the interpretation of data for some crop-element situations difficult. Mobility of elements in plants during growth should be considered when selecting tissues for analysis. Although there undoubtedly will be exceptions, fertilization of most annual crops in the year of diagnosis is unlikely to be based on plant analysis. Successful use of plant analysis for diagnosing the micronutrient status of plants demands careful attention to plant sampling, processing of samples, and laboratory techniques. These aspects and problems with calibration and interpretation of data are discussed in detail. Sap tests would appear to have only a small role to play in diagnosis of field micronutrient problems, but they may be of assistance in studying Mn toxicity and deficiency.

Introduction

Plant analysis is a procedure by which the nutritional requirement or status of an element, an inorganic fraction of the element, or some related organic of an element, an inorganic fraction of the element, or some related organic compound or enzyme activity that is associated with the metabolism of the plant. Plant analysis involving the micronutrients B, Cu, Fe, Mn, Mo and Zn is generally believed to be more useful for orchard or perennial crops than for annual crops [89].

In this review general principles and methodology will be discussed, but the agronomic emphasis will be placed on micronutrient analyses for B, Cu,
Fe, Mn, Mo and Zn and the production of annual crops. Analytical data for micronutrients are usually expressed in terms of ppm or micrograms of element per gram of oven-dried tissue (μg/g).

Traditionally, plant analysis is used: (1) to make fertilizer recommendations for the current crop; (2) to identify causes of poor growth, due to either deficiencies or toxicities, under field conditions; (3) to identify possible problems associated with introduction of new crops into an area; (4) to evaluate the effectiveness of fertilizer programs; (5) to survey the nutrient status of a crop within a region; (6) to complement soil test programs; and (7) to gain an understanding of interactions among elements. Plant analysis also has an important role to play in comparing nutrient utilization by different cultivars and species. Siddiqi and Glass [94] proposed that a utilization quotient, defined as biomass per unit amount of nutrient present in biomass, should be used in such comparisons.

Because of the shortness of the growing season for annual crops, the value of plant-analysis programs for fertilizing the current crop is often questioned. However, several successful uses of the technique with micronutrients have been reported [28, 29, 32].

Goodall and Gregory’s classical treatise [33] on plant analysis and a number of other general reviews provide useful background reading about this technique for evaluating plant health [2, 9, 17, 18, 20, 44, 48, 55, 56, 62, 89, 98, 105, 106, 107, 112, 113].

Theory of plant analysis

The underlying assumption behind the use of plant analysis as a diagnostic tool is that there is some relationship between levels of chemical constituents in the plant and the health of plants. The literature is not always unequivocal as to the desirable constituent to determine, the plant part and time to sample, and the meaning of the analytical data obtained. This uncertainty reflects partly the complexity of the problem and partly, for many plant species, the lack of data from suitable designed experiments.

Relevant chemical constituents

Total concentrations of B, Cu, Fe, Mn, Mo and Zn in plant tissue are normally used for diagnostic purposes. However, "active" Fe fractions, enzyme activities associated with an element, and ratios of elements are also used.

The concept and literature concerning an “active” Fe fraction and the uncertainty about the effectiveness of using total Fe for diagnostic purposes were discussed by Goodall and Gregory [33] over 35 years ago, but the issues are not yet resolved [81, 111]. A new technique (see Table 1) based on the quantity of Fe2⁺ which reacts with O-phenanthroline was found, unlike total Fe, to differentiate between the chlorotic and green leaves of rice and