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Diagnosis and recommendation integrated system: Concepts and applications on nutritional diagnosis of plants

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INTRODUCTION

The perennial fruit crops are distinct from seasonal crops in their nutritional requirement due to their plant size, density, root spread, growth pattern, phenomenon of bud differentiation and their relationship with the yield during the bearing and off season. Major objectives of proper nutrient management in fruit orchards are to increase the net income through efficient fertilization. This requires a precise determination of the yield limiting impact of a given nutrient. Determination of the nutritional needs of fruit crops must be made prior to the determination of potential yield. The best diagnostic tool is the one that recommends nutrient application based on the direct economic response of crops. Suitable diagnostic tools were designed to avoid nutrient shortage or excess and with proper usage, there should not be any decrease in fruit production and quality. In addition to this, leaf analysis helps in the accurate identification of the need for nutrient fertilization. Leaf analysis, is based on the assumption of a positive relationship between the doses of nutrient supplied, leaf nutrient content and the yield. Leaf analysis is useful as it helps to prevent deficiency rather than correcting them after their development. Foliar analysis can be a useful tool for assessing plant nutrient status if adequate procedures are available for diagnosis from the analytical data. The foliar diagnosis is a complex exercise because of the dynamic nature of foliar composition, which is strongly influenced by leaf age and other interactions affecting nutrient uptake and distribution. Among several approaches adopted for the interpretation of leaf analysis data, the diagnosis and recommendation integrated system (DRIS) is considered the best as it utilizes nutrient ratios and simultaneously identifies imbalances, deficiencies and excesses in crop nutrients, and, ranking them in the order of importance (Beaufils, 1973). The DRIS norms should be developed for specific conditions, in which all other factors to be correlated with yield or quality are known like cultivar, climate, soil, crop management and productivity for attaining the specific objectives.

Theoretical basis

The DRIS method expresses the results of plant nutritional diagnosis through indices, which represent the effect of each nutrient on the nutritional balance of the plant. These indices are expressed by positive or negative values, which indicate that the referred nutrient is in excess or deficiency, respectively. The closer to zero are the indices for all the nutrients, the closer the plant will be to an adequate nutritional balance. The working premises for DRIS are based on

(a) The ratios among nutrients are frequently better indicators of nutrient deficiencies than isolated concentration values
(b) Some nutrient ratios are more significant than others
(c) Maximum yields are only reached when important nutrient ratios are near the ideal or optimum values, which are obtained from high yielding selected populations
(d) The variance of an important nutrient ratio is smaller in a high yielding (reference population) than in a low yielding population, and to the relations between the variances of high and low yielding populations can be used in the selection of significant nutrient ratios
(e) The DRIS indices can be calculated individually, for each nutrient, using the average nutrient ratio deviation obtained from the comparison with the optimum value of a given nutrient ratio, hence, as pointed out by Nguyen (2024), the ideal value of the DRIS index for each nutrient should be zero.

In general, the DRIS has some advantages over other diagnosis methods, presents a continuous scale and easy interpretation, allows nutrient classification (from the most deficient up to the most excessive), can detect cases of yield limiting due to nutrient unbalance, even when none of the nutrients is below the critical level, and finally allows to diagnose the total plant nutritional balance, through an imbalance index. An additional advantage of DRIS, acknowledged by some authors but rebutted by others, is overall, it is less sensitive to tissue aging in comparison to others. Tissue aging influences the nutrient concentration, several examples are reported in the literature, including studies in alfalfa, potato, corn, peach, and many other agricultural and horticultural crop species. Although some exceptions may occur, concentrations of nitrogen, phosphorus, potassium and sulphur tend to decrease with tissue aging. On the other hand, calcium and magnesium concentrations tend to increase in older tissues (low mobility), in spite of the opposite being reported in the very early or later stages for some crops. The dynamic nature of the plant tissue mineral composition tends to restrict the use of leaf analysis for nutritional diagnosis. As already stated, the criteria of critical levels or sufficiency ranges generally depend on norms for diagnosis derived from a specific plant tissue part and age, and classify the plants based solely in the leaf nutrient concentration. Thus, the plant growth stage for leaf sampling is an essential factor for the application of both methods, and therefore, the diagnoses based on these criteria are usually applied in leaf samples obtained from a well defined growth stage. An important limitation of these methods is that, especially in some annual crops, the established standard sampling period many times occurs too late in the growing season, so that fertilizer application will not be effective to correct a nutritional problem, or may not match the sudden symptoms of a nutritional disorder, when the producer mostly need the information. To overcome this problem, it would be necessary to get nutritional reference values for several maturation stages and, as a matter of fact, some of these standards have already been established for a few crops. Although simple in theory, this procedure is of difficult application. First, there is a need for a precise definition, at the sampling time, of plant maturation stages in the field. Later, the sampler should communicate this information to the analyst or person taking care of the diagnosis, so that appropriate norms can be selected and used. Finally, factors that affect the tissue aging rate might also influence the relation between nutrient concentration and maturation.

An option for these diagnosis methods was proposed through the DRIS (Beaufils, 1973), which defined that, in general, nitrogen, phosphorus and potassium concentrations decrease with tissue maturation. Therefore, the ratios N/P, N/K, and P/K (or reciprocal ratios) should be kept constant. In the same way, because of the concentrations of Ca and Mg generally increase with maturation, quotients between these nutrients (Ca/Mg or Mg/Ca) should result in constant values. Moreover, the product of two nutrients, with concentrations running in opposite directions with time, should also remain constant. Such constancy in the nutrient ratios and their products cannot be applied in all cases. Several nutrient concentration rates can change very fast in young plants, and the nutrient ratios and their products can also vary in these cases. Even so, these expression forms are less affected by the maturation processes, therefore presenting great potential to expand the usefulness and exactness of the leaf tissue diagnosis. Nevertheless, DRIS advantages have already been contested, because for some crops, it is sensitive as a sufficiency range approach to plant tissue maturation and plant age. Moreover, additional limitations to the method can be pointed out, such as the need for extensive and advanced computational calculations and equipment, results expressed in non-independent indices, and the frequent occurrence of false diagnoses for some nutrient excesses (Khuong, 2024). Due to recent developments in both hardware and software resources, the difficulty in running the method turned out to be of little importance. The non independent indices are perhaps an advantage, because this might be the greater DRIS contribution in relation to the sufficiency range approach.

Norms of DRIS

The first step for the implementation of any nutritional diagnosis method is the establishment of standards or norms, and the same applies to the DRIS method. The DRIS norms are always obtained in a high yielding population, named the reference population, which is selected from a larger population. The databases for definition of norms might have variable size in function of premises to be adopted in the method and should be uniform, regarding the crop characteristics. Norms obtained from a large database derived from different soil types, climates and cultivars, usually cannot be generalized, and they will be considered representative just if they include all the population variability. Therefore, these attributes should be previously well defined, and thus, be gathered to form the database. DRIS norms originate after the reference population definition, in other words, the relation between all the nutrient pairs and their respective standard deviations or coefficient of variation are obtained. The ratio between a pair of nutrients can be direct or inverse. The concentrations of nitrogen and phosphorus, for instance, can be related either as N/P or P/N ratio.

After the norms definition, sample analysis results are ready to be submitted to the DRIS indices calculation, which are composed of each nutrient individual index, calculated in two steps, first, the functions for each nutrient pair ratio, and second, the sum of functions involving each nutrient. DRIS can also be expanded for expressions including non-essential elements, such as Si or Na, or even non nutritional variables, like plant population or planting date, although such variables were not included in calibrations in already published diagnoses. Theoretically, nutrients such as nitrate and ammonium can be considered separately and treated as individual nutritional factors, in expressions within the method. The absolute sum values of the nutrient indices generate an additional index denominated the nutritional balance index (NBI). This index can be useful for the plant nutritional status, without, however, hinting at their causes. The higher the sum value, the larger will be the indication of plant nutritional imbalance and, therefore, the lower will be the yield (Villamil, 2021).

To develop a DRIS for a crop, the following requirements must be met

1. All factors suspected of affecting crop yield must be defined
2. The relationship between these factors and yield must be described
3. Calibrated norms must be established
4. Recommendations suited to particular sets of conditions and based on correct and judicious use of these norms must be continually refined.

Several advantages of this method over the conventional critical level approach

1. Identification of not only the most limiting element, but also the order in which the other elements would likely become limiting.
2. The ability to diagnose the plant nutrient needs to be much earlier in the life span of the crop than the critical level approach thus, allowing one to take remedial measures earlier.
3. DRIS provides greater accuracy in diagnosis and offers relatively more freedom from the effect of some of the sampling variables such as the age of the plant part and geographical location.

The DRIS approach was designed to provide a valid diagnostic irrespective of plant age, tissue origin (**Sumner, 1977, Meldal-Johnsen and Sumner 1980, Bailey et al., 1997, Jones, 199**3) cultivar, local conditions (**Payne** et al., 1990), or changes in the method of tissue sampling or the time of sampling (**Moreno** et al., 1996). The DRIS is sometimes less sensitive than the sufficiency range approach particularly in terms of differences caused by leaf position, tissue age, climate, soil conditions, and cultivar affect because it uses nutrient ratios (**Sanchez** et al., 1991). Once DRIS norms have been established and validated from a large population of randomly distributed observations, they should be universally applicable to that crop (**Sumner** 1977a & 1979) because for a given species, there has to be specific nutrient ratios for the maximum crop performance that transcend local conditions, such soil, climate and cultivars (**Synder** and Kretschmer, 1988). The DRIS norms developed from data banks of observations of a particular cropping system, consisting of minimum tissue nutrient content and associated yields. The norms, which are used as reference standards against which samples are compared, can be calculated as the means of the various forms expressing the nutrients (N/P, N/K, and K/P etc.) for high yielding population of plants. The DRIS indices measure the deviations of various forms of expressions in the tissue under diagnosis from their respective norm values.

A comparison of DRIS and other diagnostic systems

Sumner (1979) critically evaluated the precision and flexibility of different foliar diagnostic techniques in making a valid diagnosis of nutrient imbalances in crops. A comparison of diagnostic precision between the critical level and DRIS approach was made using data from various field crop experiments with corn, soybean sugarcane, and potatoes and it was opined that DRIS was superior to the critical value approach. In most comparisons of diagnostic capabilities of critical value or sufficiency range systems and DRIS, the tissue sampling had been done at a specific stage of growth. Even under these conditions, DRIS usually maintains a slightly higher diagnostic precision.

CONCLUSION

A comprehensive review of scientific literature reveals that DRIS is a promising, effective auxiliary tool for the nutritional diagnosis of fruit crops. Except for a few studies, most of the developed research works amply clarify that DRIS is more efficient than conventional methods of nutritional diagnosis (critical values and sufficiency range) with the additional advantage of establishing a nutrient deficiency or excess ranking, according to their importance and quantifying the plant nutrient balance. The cutting edge advantage

of this approach lies in its ability to minimize the effect of tissue age on diagnosis, thus enabling interested researchers to sample over a wider range of tissue age than permissible under the conventional critical value approach. A myriad of scientific groups have opined that once DRIS norms based on foliar composition have been developed for a given crop, they are universal and applicable to that particular crop grown at any place and at any stage of its development. Therefore, the DRIS approach is holistic in nature, helps in the identification of nutrient imbalance in crops and formulation of nutrient management strategies for achieving higher crop yields. The DRIS approach represents a step forward to strengthen our abilities to diagnose the nutritional status of crops and has significant implications on nutrient management practices in horticultural and field crops.

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