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OPTIMAL SAMPLE SIZE FOR DRIS MODEL PARAMETERISATION TO DIAGNOSIS NUTRIENTS STATUS IN FRUIT CROPS

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ABSTRACT

Diagnosis and Recommendation Integrated System (DRIS) is an approach to nutrient diagnosis of crops, holistically through the relationship between nutrient balance of plants and soil. The objective of this study was to investigate the influence of sample size in DRIS model parameterisation, to diagnose nutrients status in fruit crops. Published data were resampled to obtain different sample sizes, ranging from 40 to 1000, with steps of 30. For each sample size, 1000 replications were generated to determine the mean value of the desired parameter (nutrient indices and Nutrient Balance Index). All nutrient indices decreased rapidly as sample size increased from 40 to 200. For each nutrient considered, indices varied slightly from 200 to 1000. This study has revealed that the size of sample used to establish DRIS norms, determines the accuracy of nutrient diagnoses in pineapple (*Ananas comosus* (L.) Merr.). The optimal data bank for nutrient diagnosis in the crop (pineapple) used in this study is 200.

Key Words: *Ananas comosus,* Nutrient Balance Index, nutrient indices

RÉSUMÉ

Le système intégré de diagnostic et de recommandation (DRIS) est une approche de diagnostic des nutriments des cultures, de manière holistique à travers la relation entre l'équilibre nutritif des plantes et du sol. L'objectif de cette étude était d'étudier l'influence de la taille de l'échantillon dans la paramétrisation du modèle DRIS, pour diagnostiquer l'état nutritionnel des cultures fruitières. Les données publiées ont été rééchantillonnées pour obtenir différentes tailles d'échantillon, allant de 40 à 1000, avec des pas de 30. Pour chaque taille d'échantillon, 1000 réplications ont été générées pour déterminer la valeur moyenne du paramètre souhaité (indices nutritionnels et indice d'équilibre nutritif). Tous les indices nutritionnels ont diminué rapidement à mesure que la taille de l'échantillon augmentait

de 40 à 200. Pour chaque nutriment considéré, les indices variaient légèrement de 200 à 1000. Cette étude a révélé que la taille de l'échantillon utilisé pour établir les normes DRIS détermine la précision des diagnostics nutritionnels chez l'ananas (*Ananas comosus* (L.) Merr.). La banque de données optimale pour le diagnostic des nutriments dans la plante (ananas) utilisée dans cette étude est de 200.

Mots Clés : *Ananas comosus*, indice d'équilibre nutritif, indices nutritifs

INTRODUCTION

Plant analysis is a strategy for detecting nutrient status in the field so as to plan for appropriate soil-plant nutrition management. Tools using foliar analysis are increasingly common, since they are helpful for assessing plant nutrient status. These tools are only valuable when adequate procedures are used for making diagnoses from analytical data (Walworth and Sumner, 1986).

Critical leaf nutrient concentrations are frequently used to diagnose the nutritional status of plants (Sumner, 1979). This approach is limited by the fact that accurate interpretation of foliar values, can only be obtained when sampling is restricted to the same growth stage at which the standard reference values for nutrients were established (Dagbenonbakin, 2005). Although it can be used to make accurate diagnoses, the procedure is limitated by critical nutrient values which vary with the concentration of other nutrients, plant age and among varieties (Bailey *et al*., 1997).

The Diagnostic and Recommendation Integrated System (DRIS) model, is the alternative method which uses ratios of nutrient concentrations to establish nutrient indices, and helps to identify the nutrients from the most to the least deficient (Beaufils, 1973). The DRIS approach was designed to provide valid diagnostics, irrespective of plant age, tissue origin (Jones, 1991), cultivar and local conditions (Payne *et al*., 1990); changes in the method of tissue sampling and the time of sampling (Moreno *et al*., 1996). It is designed to assess relative nutrient imbalances or deficiencies or both, in plant tissues (Beaufils, 1973; Sumner, 1981). The DRIS approach also provides the relative order of plant nutrient needs.

Since the level of one nutrient is compared with those of all other nutrients, nutrient balance is an inherent part of the system (Marschner, 2012). Furthermore, the overall status of nutrient balance in the plant is shown by the absolute sum of all of the individual DRIS indices. DRIS has been parameterised successfully, to interpret the results of foliar analyses for a wide range of crops (Agbangba *et al*., 2010; Dagbenonbakin *et al*., 2010; 2011).

DRIS norms are usually developed and validated from a large population of randomly distributed observations, leading to resource consumption. Elwali *et al.* (1985), using a small data set, concluded that local calibration is necessary to improve the accuracy of DRIS diagnosis. The sample size used to compute DRIS norms for nutrient status diagnosis in plant in literature, varies from 24 observations (Leite, 1992), to more than 2800 (Sumner, 1977).

On the other hand, DRIS norms derived from 10 observations were more representative and efficient for nutrient diagnosis, than those from larger observations (Walworth *et al*., 1988). Inappropriate sample size can lead to incorrect nutrient diagnosis in plants. Although it is well documented that DRIS is regarded by some researchers to be capable of providing nutrient diagnoses *via* foliar analyses, regardless of the origin or age of the plant, the effect of sample size on the efficiency of nutrient diagnoses is not fully understood. It is largely presumed that small sample size, leads to inadequate research findings; in contrast, over-sized datasets could waste valuable time and resources. In this

work, we hypothesize that the size of sample used to establish DRIS norms determines the accuracy of nutrient diagnoses in crop production.

MATERIALS AND METHODS

Data source and field conditions. Data used in this investigation were extracted from those used in Dagbenonbakin *et al*. (2010), which had recorded pineapple fruit yield cv-smooth cayenne and composition of leaves. Sixty plots of 16 m^2 (4 m x 4 m) each were installed using a string rope in the farm fields. At flowering stage, leaf samples per plot were taken for nutrient diagnosis in the laboratory.

Fruit yield was evaluated at production. This allowed to constitute a data matrix of content of six nutrients (N, P, K, Ca, Mg and Zn) and yields, recorded in the 60 plots sampled.

This study was conducted in the district of Allada, located at latitude 6°34' and 6°47' north, longitude 1°59' and 2°15' east, in the southern part of République du Bénin (West Africa). The climate is sub-equatorial, with two rainy seasons (March to June and September to November) and two dry seasons (July to September and November to March). The major soil type covering most of the studied area are Acrisols

Model development and simulation design. The data matrix was divided into high and low yielding subpopulations, using the mean interval of confidence as criterion for cut-off. The nutrient ratio was calculated for both the high and low yielding subsamples, so that each of the nutrients determined in the tissue appeared in the denomination and in the numerator in ratios with each of the other nutrient (for example N/P and P/N). For each form of expression, the variance for both of the high and low yielding subsamples was calculated.

A variance ratio for each nutrient ratio was also determined by dividing the variance of the low yielding subsample by the variance of the high yielding subsample (Elwali *et al.*, 1985; Amundson, 1987; Payne, 1990). For each pair of nutrients, the form of expression, which gave the highest variance ratio, was selected as the parameter to be used for DRIS-evaluation. The mean of the selected parameters for the high yielding subsample became the foliar diagnostic norms then used, along with the standard deviation, to calculate DRIS indices for diagnostic purposes.

Means and standard deviations of DRIS reference parameters in the high yielding subsample were then programmed for diagnostic purposes, using the following general calibration formula (Rathfon and Burger, 1991; Bailey *et al.*, 1997).

X indices =

$$\left[f\left(\frac{X}{A}\right) + f\left(\frac{X}{B}\right) + \cdots - f\left(\frac{M}{X}\right) - f\left(\frac{N}{X}\right) - \cdots \right]$$

where:

$$- f\left(\frac{X}{A}\right) = 100\left[\left(\frac{X}{A}\right)/\left(\frac{x}{a}\right) - 1\right]/CV$$

when $\frac{X}{A} > \frac{x}{a} + SD$

$$- \quad f\left(\frac{X}{A}\right) = 100\left(1 - \left(\frac{x}{a}\right)/\left(\frac{X}{A}\right)\right)/CV$$

when $\frac{X}{A} < \frac{x}{a} - SD$

..... Equation 1

X/A = the ratio of concentrations of nutrients X and A in the sample; while *x/a*, *CV*, *SD* = the mean, coefficient of variation, and standard deviation for the parameter *X/A* in the high-yielding subsample, respectively. Similarly, other nutrient ratios, *X/B, M/x, N/x*, etc., are calibrated against the corresponding DRIS reference parameters, *x/b, m/b, n/x,* etc., respectively.

Nutrient indices calculated by this formula ranged from negative to positive values, depending on whether a nutrient was rated insufficiently or excessively, with respect to all other nutrients considered. The more negative the index value is for a nutrient, the more limiting that nutrient tends to be.

A measure of Nutritional Balance Index (NBI) among any group of nutrient was obtained by adding the values of DRIS indices for that group of nutrients, irrespective of sign. The closer the value of this index to zero, the better was the balance among those nutrients. Means and coefficients of variation (CVs) for DRIS reference parameters in high-yielding subsamples, were used in a special calibration formula as described by Beaufils (1973).

A bootstrap resampling method (Efron and Tibshirani, 1993) was applied using data from Dagbenonbakin *et al*. (2011) to obtain different sample sizes, from 40 to 1000 with steps of 30.

For each sample size, 1000 replications were generated to determine the mean value of parameters of interest (nutrient indices and NBI). Evolution trend curves and boxplots of nutrient indices and NBI were drawn according to sample sizes. The optimal size identified at the point where the curve begins no longer varied significantly with size.

RESULTS AND DISCUSSION

Nutrient indices and balance. Evolution trend curves of nutrients indices were globally similar for all nutrients (Fig. 1a). Nitrogen indices ranged from 0.07 for 40 samples, to -0.03 for 200 samples. Phosphorus indices decreased from 0.11 (40 samples) to 0.06 (200 samples); while K indices dropped from 0.10 to 0.09, for 40 and 200 samples, respectively. The trend for Mg indices was close to that of N. Calcium indices decreased from 0.12 to 0.04; while sample size increased from 40 to 200. A weak variation of Zn indices from -0.12 to -0.13 was observed.

Whichever the nutrient considered, indices values varied slightly from 200 to 1000 samples, meaning that they reached their optima (maximum or minimum). The similar trend among all nutrients is attributed to the interdependence in influence on yield between nutrients. Indeed, the DRIS approach uses ratios of elemental concentrations to establish a series of values to identify the elements from the most to the least deficient (Beaufils, 1971). DRIS is based on nutrient balance (ratios), capturing the natural interdependence between nutrients (Beaufils, 1973).

The Nutritional Balance Index (NBI), which is useful to the plant nutritional status diagnosis (Wadt, 1996), decreased from 0.125 to 0.08, when sample size increased from 40 to 200 (Fig. 1b). Thus, sampling appeared to improve the diagnosis efficiency; beyond 200 samples, the diagnosis efficiency failed to change significantly. Indeed, NBI ranged from 0.080 to 0.079, where that it levelled off.

The trends in Figure 1b are consistent with those in Figure 1a, according to the effect of sampling size. Therefore, sampling more than 200 should be considered a waste of time and resources due to the slight gain of diagnosis efficiency. Existing literature, reports a large variation in the database size for DRIS norms definition, from just 24 observations (Leite, 1992), up to >2,800 (Sumner, 1977). This observation implies the need for a rigorous study to guide technicians on the appropriate choice of sample size in order to reduce diagnostic costs.

Previous sample size used for diagnosis of nutrient status in pineapple, varied from 60 (Agbangba *et al.*, 2010; Dagbenonbakin *et al.*, 2010) or 104 (Teixeira *et al.*, 2009) to 1185 (Angeles *et al.*, 1990). The optimal sample size from the present study is not consistent with that of Letzsch and Sumner (1984) for maize, who concluded that the best size banks were several thousands, random and had a substantial number of high yield observations. The reason for the differences in optimum

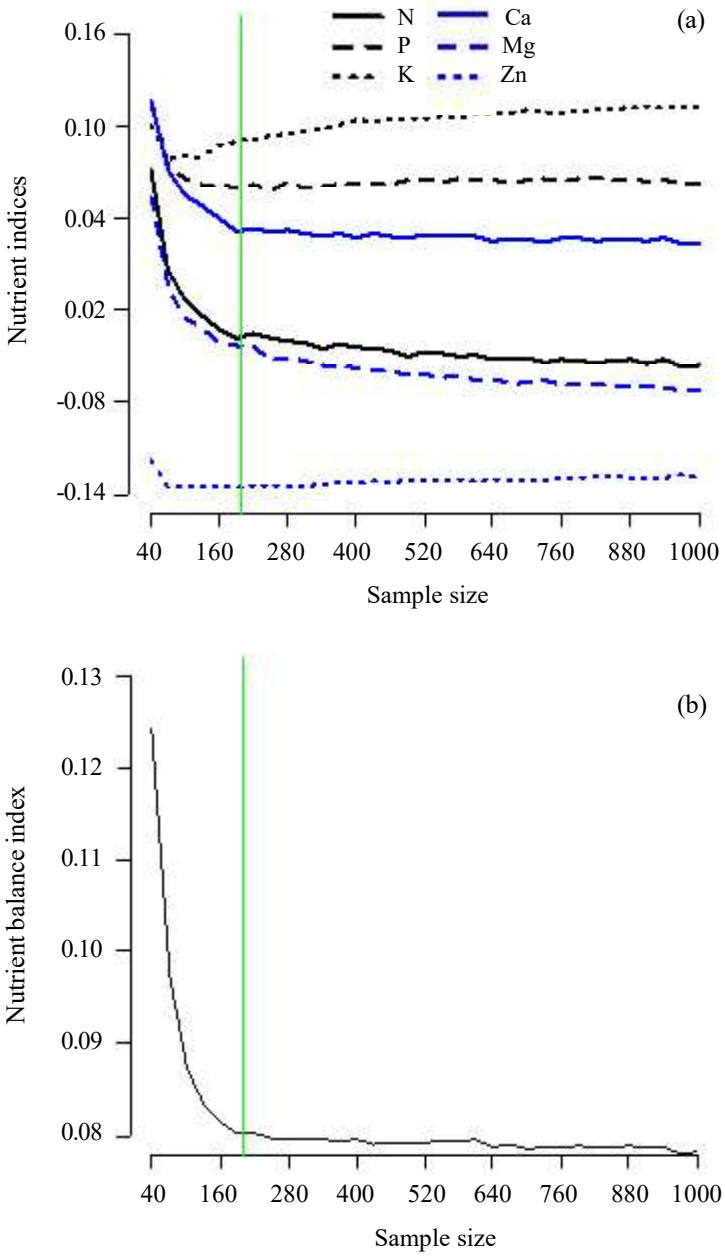

Figure 1. Evolution trend of (a) nutrient indices and (b) nutrient balance index according to the sample size.

sample size for nutrient diagnosis in pineapple and maize could be attributed to plants' different growth characteristics and nutrient requirements.

Dispersion and median values. Results showed that, irrespective of nutrient, there was similarity in performance of sample size response (Fig. 2). The dispersion and median values of the nutrient indices tended to diminish, with the increase in the sample size; and to stabilise at 200 samples. Pineapple plants exhibit variability in growth and nutrient uptake across different parts of the field, due to

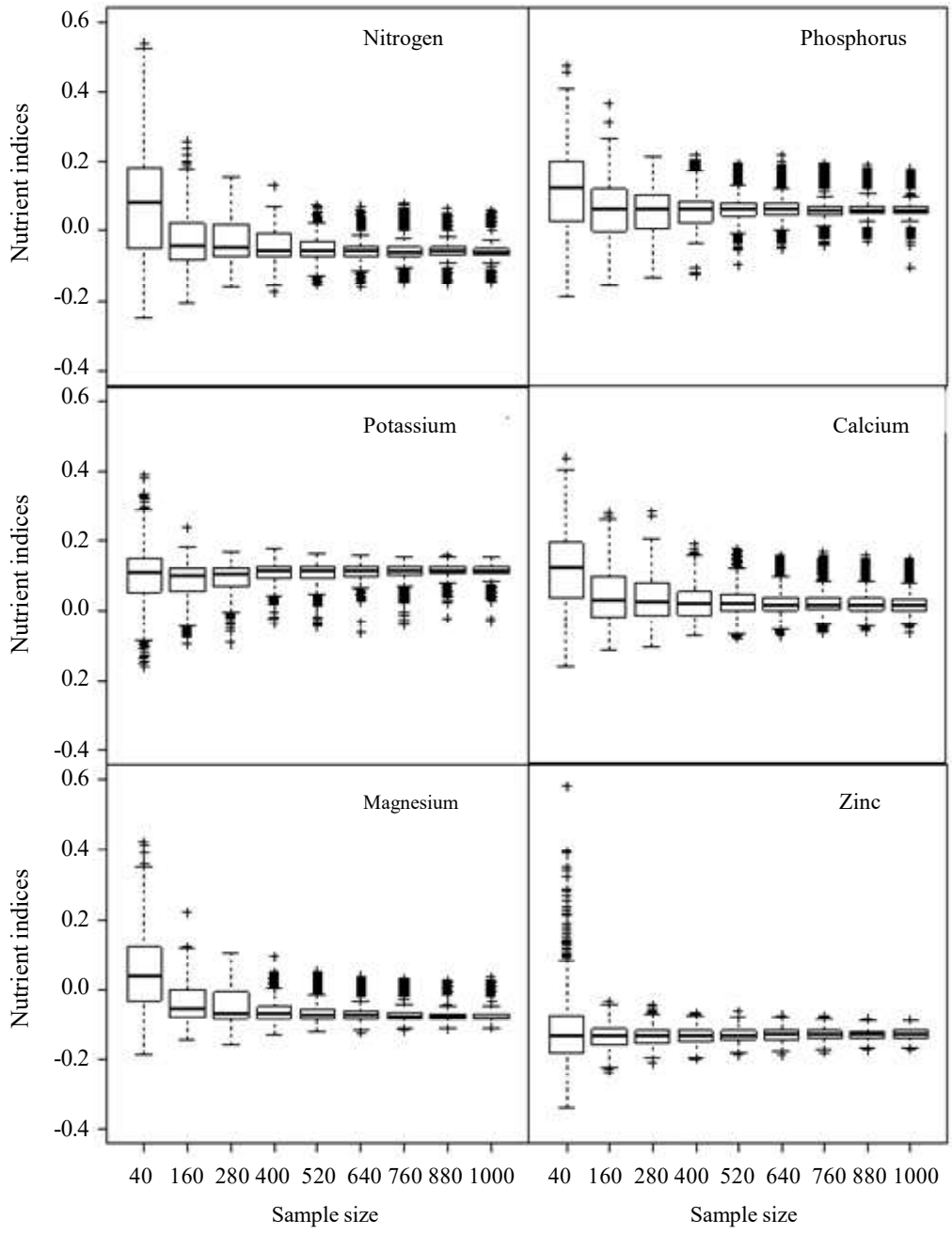

Figure 2. Boxplots of nutrient indices according to the sample sizes.

variations in soil conditions, drainage and microclimate (Sanewski *et al.*, 2018). A small sample size, may thus not capture this variability adequately, leading to a sample that is not representative of the entire field's nutrient status. This can result in inaccurate nutrient deficiency or sufficiency assessments.

With a small sample size, there is a higher risk of sampling errors such as selecting leaves from non-representative plants or overlooking

areas with different soil fertility levels. This can skew the nutrient analysis results and lead to incorrect interpretations of nutrient deficiencies or excesses. These findings suggest that considering sample size; while diagnosing nutrient in pineapple, as incorrect nutrient diagnosis, it may lead to either under-application or over-application of fertilisers, thus impacting crop health and productivity (Mourão Filho, 2004).

CONCLUSION

This study has revealed that the accuracy and efficiency of nutrient diagnoses are significantly influenced by the size of the sample used to establish DRIS norms. The optimal sample size for nutrient diagnoses in pineapple cropping in Benin is 200. Future research can focus on the spatial distribution of sampling in pineapple plantations to ensure representativeness of this size and the evaluation of varietal differences.

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