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DRIS model parameterization to access pineapple variety 'Smooth Cayenne' nutrient status in Benin (West Africa)

Author

Emile C. Agbangba
University of Parakou, Benin, Faculty of Agronomy, Department of Plant Sciences,
E mail: agbaemile@yahoo.fr

Elvire Line Sossa
University of Abomey - Calavi, Benin, Faculty of Agronomic Sciences, Department of Natural resources Management, Laboratory of Applied Ecology

Gustave D. Dagbenonbakin
National Institute of Agricultural Research of Benin, Benin, Cotton and Fiber Research Centre

Sekouna Diatta
University Cheikh Anta Diop of Dakar, Senegal, Faculty of Science and Technology, Department of Crops Science, Laboratory of Ecology and Ecohydrology

Léonard Elie Akpo
University Cheikh Anta Diop of Dakar, Senegal, Faculty of Science and Technology, Department of Crops Science, Laboratory of Ecology and Ecohydrology

Abstract

Nutritional diagnosis is an important tool for increasing fruit yield and fruit quality through efficient fertilization management. The aim of the study is to investigate whether there are specific DRIS norms for pineapple 'Smooth Cayenne' for a better soil fertility management in Benin. A preliminary Diagnosis and Recommendation Integrated System (DRIS) norms for 'Smooth Cayenne' pineapple growing in plantations of the township of Allada (Benin) are presented. DRIS norms were established from a data bank of leaf nutrient concentration (N, P, K, Ca, Mg, S and Zn) and fruit yield with 60 samples gathered from farmers' plantations. The data were divided into high-yielding (>88 t/ha) and low-yielding (<88 t/ha) sub-populations and norms were computed using standard DRIS procedures. These norms were developed with data from only one cropping region, so they should be considered as preliminary, probably requiring some modification as more data become available. The norms were significantly different from those presented in the literature. We conclude that our results revealed that DRIS is not immune to bias from locality effects.

Introduction

Nutritional diagnosis is an important tool for increasing fruit yield and fruit quality through efficient fertilization management (Mourão Filho, 2004). This aspect was pointed out by Lacoeuilhe (1984) who reviewed some relations between nutritional status of pineapple plants and fruit production. According to Marschner (1997), the use of chemical analysis of plant material for diagnostic purposes is based on the assumption that causal relationships exist between growth rates (and yield) and nutrient content in the shoot dry matter. However, foliar analysis is helpful for assessing plant nutrient status only if adequate procedures are available for making diagnoses from analytical data (Walworth and Sumner, 1987). Critical leaf nutrient concentrations have frequently been used to diagnose nutritional status of plants (Tyner, 1946; Viets *et al.*, 1954; Beaufils et Sumner, 1977).

The critical concentration approach is somewhat erroneous in that 'critical nutrient concentrations' are not independent diagnostics, but can vary in magnitude as the background concentrations of other nutrients increase or decrease in crop tissue (Walworth and Sumner, 1986; Bailey 1989, 1991). These criteria have been evaluated for a wide range of crops (Katyal and Randhawa 1985; Jones *et al.*, 1990; Westfall *et al.,* 1990; Kelling and Matocha 1990). According to Beaufils (1973) and Walworth and Sumner (1987), an alternative approach to nutritional status evaluation is the Diagnosis and Recommendation Integrated System (DRIS). This method uses a comparison of leaf tissue concentration ratios of nutrient pairs with norms developed from high-yielding populations to diagnose nutrient status. DRIS has been used successfully to interpret the results of foliar analyses for a wide range of crops such as rubber and sugarcane (Elwali and Gascho 1984), potato

(Meldal Johnson and Sumner, 1990; Mackay *et al.,* 1987), apple (Szü cs *et al.,*1990; Singh *et al.,* 2000), peach (Awasthi *et al.,* 2000), mango (Raj and Rao, 2006), sweetpotato (Ramakrishna et al., 2009), grassland swards (Bailey 1997a et b), cauliflower (Hundal *et al.,* 2003), rice (Singh and Agrawal, 2007), corn (Escano *et al.,* 1981, Elwali *et al.,* 1985, Soltanpour *et al.,* 1995) , tomatoes (Hartz et al., 1998), pineapple (Smooth cayenne) (Angeles *et al.,* 1990; Teixeira *et al.,* 2009; Dagbenonbakin *et al.,* 2010), cotton (Dagbenonbakin *et al.,* 2009) and yam (Dagbenonbakin *et al.,* 2011). The DRIS approach was designed to provide a valid diagnostic irrespective of plant age, tissue origin (Sumner, 1977a, Meldal-Johnsen and Sumner 1990, Bailey 1997a, Jones, 1993 Sumner, 1977) 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 to differences caused by leaf position, tissues age, climate, soil conditions, and cultivar effect 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 of for a given species, there appear to be specific nutrient ratios for maximum crop performance that transcend local conditions, such soil, climate and cultivars (Snyder and Kretschmer, 1988). In the other hand, using a small data base, Elwali and Gascho (1983, 1984) concluded that local calibration is necessary to improve the accuracy of DRIS diagnosis, at least when based only on a small data set. In a review paper on DRIS, Bangroo *et al.*, (2010) concluded that DRIS norms should be developed for specific conditions, in which all other factors to be correlated with yield or quality (or any other variable) be known and isolated: cultivar, climate, soil and crop management, productivity etc., attaining the specific objectives. The aim of this study is to investigate whether there are specific DRIS norms for pineapple 'Smooth cayenne' grown in the pedo-climate conditions of Benin for a better soil fertility management.

Material and methods

Material

Choice of sites

The township of Allada is one of the eight townships of the Atlantic department in Benin. It is located at the north of this department between 6° 34 ' and 6°47 ' North latitude, 1°59 ' and 2°15 ' longitude and is about 54 km from Cotonou, the economical capital of Benin. It covers 381 km² and 0.34 % of the total surface of Benin. The climate is sub-equatorial with two raining seasons (March to June and September to November) and two dry seasons (July to September and November to March). The annual rainfall varies between 1,100 and 1,400 mm. This rainfall agrees to the crop at Allada in comparison with the optima production of the pineapple of 1,200 to 1,500 mm of rain per year Scohier and Texido (2001). Acrisols are the major soils that cover mainly part of the studied area. The commune of Allada has been considered for this study because of its largest number of pineapple producers (Ouinkoun and Lalèyè, 2004). Four sub-townships have been chosen on the basis of the importance of the pineapple production and the geographical situation in order to have a big variability the sub- townships of Sékou (6°39 North, 2°13' East) and Ahouananonzoun (06°41' North 2°12' East) with high pineapple production, respectively in Perola and in the pineapple variety Smooth Cayenne, Allada-center (06°38' North, 2°10' East), whose pineapple production is average and Avakpa (06°39' North 2°02' East) with low pineapple production.

Soil sampling

Sixty soil samples have been taken with auger in the 20 first centimeters at the rate of fifteen in each district. Soil texture (table 1) is loamy-sand to sandy-loam with 78.9 to 84.8 % of sand and 4.2 to 6.8 of loam. Nitrogen content, between 0.07 to 0.08 % with an acidic (6.1) to weakly acidic (6.5) pH was middle to good. The C/N ratio (10 to 10.3) is satisfactory. The organic matter rate is weak. The potassium content, ranged from 0.03 to 0.14 Cmol kg^{-1} is weak. The phosphorus content according to Bray1, 4 $mg.kg^{-1}$ is around the critical value in Sékou and Ahouannonzoun and good (10 mg kg^{-1}) in other localities. Soils are poor (1.8 to 3.0 Cmol kg^{-1}) in Ca and Mg exchangeable. The sum of bases and the CEC between (3.06 to 5.29 Cmol kg^{-1}) were weak.

Plots installation and fruits sampling

Sixty plots of 16 m^2 (4 m × 4 m) each has been installed in farmer's plantations. Leaves samples have been taken at the flowering (45 days after the floral induction treatment). Facing to lines or bands of pineapple, the 5th, 10th, 15th, 20th, 25th, 30th, 35th, 40th, 45th and the 50th plant counting always the left extreme line in the plot has been chosen for the D leaf sampling. Ten leaves per plot have been therefore taken. The third (1/3) lower of each D leaf has been sampled (Siebeneichler *et al.,* 2002), and dried in the oven at 65°C until constant dry weight is obtained. Fruits with crown have been harvested by hand in every plot (on the 16 m^2) and immediately weighted. The fruit yield has been estimated.

Methods

Soil and plant analysis

Soil samples and leaves have been analyzed in the Soil Science, Waters and Environment Laboratory based in Agonkanmey in Benin. Soil texture (5 fractions) have been determined according to the international method modified by the use of ROBINSON pipette Tran and Boko (1978); the organic carbon by of WALKEY and BLACK method, the total nitrogen by Kjeldahl method, the pH (1/2.5 ratio soil-water), the phosphorus according to BRAY1 method, the exchangeable cations by the acetate of ammonium method. Calcium and magnesium are measured by titration with EDTA and the potassium was determined with a Flame Photometer. The phosphorus has been determined in leaves by the spectrophotometer 1,100. Zinc was determined by Atomic Absorption Spectrophotometer and sulphur by gravimetric method.

DRIS model Development and data analysis

The fruit yield and leaf tissue nutrient concentration data DRIS norms and coefficients of variation (CVs) were derived according to the procedure by Walworth and Sumner (1987). Scatter diagrams of yield versus nutrient concentrations and all conceivable nutrients ratios were constructed and subdivided into high-yielding and low-yielding sub-populations with the cut off point between the two subpopulations set at 88 t. ha-1 (mean + interval of confidence). The rational for this subdivision is that nutrient data for high-yielding plants are usually more symmetrical than those for low-yielding plants (Walworth and Sumner 1986, 1987). The yield at which the division between the two sub-populations was set was a compromise between maximizing the potential for data symmetry in the high-yielding sub-population (i.e. by excluding data for low-yielding) (Ramakrishna et al., 2009), yet including as many data points as possible for statistical credibility (Walworth and Sumner, 1987). Mean values or norms for each nutrient expression together with their associated CVs and variances were then calculated for the two sub-populations. The mean values in the high-yielding sub-population of twleve nutrient expressions involving seven nutrients (N, P, K, Ca, Mg, S and Zn) were ultimately chosen as the diagnostic norms for pineapple smooth cayenne. The selection was made along the following priorities. The first was to ensure that the leaf nutrient concentration data for the high-yielding sub-population were relatively symmetrical or unskewed, so that they provided realistic approximations of the likely range of interactive influences of different nutrients on crop productivity (Ramakrishna et al., 2009). The second priority was to select nutrient ratio expressions that had relatively unskewed distributions in the high-yielding sub-population (skewness values <1.0). The third priority was to select nutrient expressions for which the variance ratios (V low/V high) were relatively large (>1.0), thereby maximizing the potential for such expressions to differentiate between 'healthy' and 'unhealthy plants' (Walworth and Sumner 1987).

Having evaluated the model parameters, DRIS indices may then be calculated for nutrients A to N using the following generalized equations (Bailey, 1997a; Hallmark et al., 1987):

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

Where

$$f\left(\frac{X}{A}\right) = 100\left[\left(\frac{X}{A}\right) / \left(\frac{x}{a}\right) - 1\right] / CV, \quad \text{when } \frac{X}{A} > \frac{x}{a} + SD \text{ and}$$

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

$\frac{X}{A}$ is the ratio of concentrations of nutrients X and A in the sample while $\frac{x}{a}$, CV, SD are the mean, coefficient of variation, and standard deviation for the parameter $\frac{X}{A}$ in the high-yielding population respectively. Similarly, other nutrient ratios, $\frac{X}{B}$, $\frac{M}{x}$ and $\frac{N}{x}$ are calibrated against the corresponding DRIS reference parameters, $\frac{x}{b}$, $\frac{m}{b}$ and $\frac{n}{x}$. Nutrient indices calculated by this formula can range from negative to positive values depending on whether a nutrient is relatively insufficient or excessive with respect to all other nutrients considered. The more negative is the index value for a nutrient, the more limiting is that nutrient.

Descriptive statistics were determined for fruit yield, leaf nutrient concentration and nutrient ratio expression data using Minitab statistical software version 14. Descriptive included, means, medians, minimum and maximum values, variances, CV's and skewness values, where a skewness value of zero indicates perfect symmetry, and values greater than 1.0 indicate marked asymmetry.

Results

Leaf nutrients concentration statistics

Summary statistics for the fruit yield and leaf nutrient concentration data available from the pineapple field survey are given in Table 1. The fruit yield data ranged from 30.8 t.ha-1 to 125.3 t.ha-1 with a mean of 82.4 t. ha-1 in the full population.

Twenty-four (24) out of sixty (60) data points were assigned to the high-yielding subpopulation (≥ 88 t.ha-1). As regards the leaf nutrient concentrations, the data for all the nutrients N, P, K, Ca and Mg were relatively symmetrical in the both total population and High-yielding one. All of these nutrients have skewness values less than or equal to 1.2 and hence were deemed suitable for DRIS model development. Only the Zn had relatively skewed distributions in the total population (skeweness value ≥ 1.0), but it was unskewed in the reference population.

Binary nutrients ratio statistics

Binary nutrient ratio combinations of all the six nutrients were therefore calculated, and summary statistics evaluated for each of the resulting 42 nutrient ratio expressions (table 2). To determine which nutrient ratio expressions in table 2 should be included in the DRIS model, the selection priorities, previously outlined (above), were sequentially applied. Firstly, nutrient ratios were selected that had skewness values less than 1.0, thereby eliminating 24 nutrient ratio expressions. Secondly, on the basis of the variance ratios (Vlow/Vhigh), which had ratios greater than 1.0, 6 of the eighteen remaining nutrient ratio expressions were given up. Twelve ratios were ultimately chosen which are: P/N: 0.3; K/N: 2.2; Mg/N: 0.6; S/N: 0.1; Zn/N: 0.0013; Zn/P: 0.0046; K/Ca: 1.5; K/Mg: 3.6; Zn/K: 0.0007; Mg/Ca: 0.4 (table 3). The comparison of the norms to the published norms (table 4) showed that all the norms provided by this work were significantly different from those presented for pineapple 'Smooth Cayenne' by Teixeira et al. (2009).

Discussion

The leaf nutrient concentration in the reference population (the high-yielding sub-population) had relatively symmetrical distribution, so that they provided realistic approximations of the likely range of interactive influences of different nutrients on crop productivity (Ramakrishna et al., 2009). Additionally, the selection of nutrient expressions for which the variance ratios (V low/V high) were relatively large (>1.0), implies the maximizing of the potential for such expressions to differentiate between 'healthy' and 'unhealthy plants' (Walworth and Sumner 1987; Payne et al., 1990). The aim of this procedure is to determine the norms with the greatest precision (Caldwell et al. 1994). The discrimination between nutritionally healthy and unhealthy plants is maximized when the ratio of variance of low- vs. high-yielding groups is also maximized (Walworth and Sumner, 1986). All the selected ratios as DRIS norms for the pineapple Smooth Cayenne grown in Allada are significantly different from the norms provided for the same variety by Teixera (2009). This fact is opposite to one of the common advantage of DRIS approach to be less sensitive to the difference caused by climate, soil conditions effects because it uses nutrient ratios (Sanchez et al., 1991). The difference between the established norms and those developed by Teixeira et al. (2009) could be due to the difference in soil and climate conditions. Paiva da Silva et al. (2009) have notified that the nutritional demand of pineapple plants is higher than for other crops and it depends on cultivar, fruit weight, production destination and planting density and cultivation system. However, the variation in these factors is not always taken into account in fertilization tables. In a review paper on DRIS, Bangroo et al., (2010) concluded that DRIS norms should be developed for specific conditions, in which all other factors to be correlated with yield or quality (or any other variable) be known and isolated: cultivar, climate, soil and crop management, productivity etc., attaining the specific objectives.

The DRIS model for smooth cayenne, developed in this study, is then a diagnostic tool that may be used to predict if insufficiencies or imbalances in N, P, K, Ca, Mg, S and Zn supplies are occurring in that crop in Benin. Data from future field and surveys experiments may subsequently be used to enlarge the model database and allow the refinement of DRIS parameters and hopefully an expansion of diagnostic scope to include other micronutrients. As it stands, though, this preliminary DRIS model for pineapple 'Smooth Cayenne' is one of the best diagnostic tools currently available for simultaneously evaluating the N, P, K, Ca, Mg, S and Zn status of 'Smooth Cayenne' crops in Benin.

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Table1: **Summary statistics for pineapple yield and leaf nutrient concentration data for total (n=60) and high-yielding (n=24) sub-population**

Parameters	Total population (n=60)						High yielding population (n=24)					
	Mean	**CV**	**Minimum**	**Median**	**Maximum**	**Skewness**	**Mean**	**CV**	**Minimum**	**Median**	**Maximum**	**Skewness**
Yield (t.ha-1)	82.4	26.2	30.8	82.4	125.3	0.02	103.6	11.4	88	102.8	125.3	0.4
Nutrients (g.k,g-1)												
N	6.7	28.6	3.9	6.3	12.4	0.9	6.8	32.2	3.9	6.3	12.4	1.1
P	2.3	48.6	0.7	2.1	5.6	1.2	2.3	61.9	0.7	1.8	5.6	1.2
K	13.3	52.6	1.1	12.5	32.2	0.4	13.6	50.3	2.8	12.3	26.5	0.4
Ca	9.2	18.9	6.4	8.8	14.4	0.7	9.7	21.3	6.4	8.8	14.4	0.5
Mg	4.2	28.7	1.9	4.1	7.7	0.5	4.0	19.4	2.4	3.9	0.5	-0.1
S	0.5	46.1	0.1	0.5	1	-0.03	0.5	45.8	0.1	0.5	0.1	0.1
Nutrients (mg.kg-1)												
Zn	9.6	66.3	1	9	35	2.0	8	44.2	1	9	13	-0.5

Mini: Minimum   Maxi: Maximum   Skew: Skewness   CV: Coefficient of variance

Table 2. Mean values of nutrient ratios for high and low-yielding sub-populations together with their respective coefficients of variance CV's) and variances (low and high), skewness values for the high-yielding sub-population, and the variance ratios (Vlow/Vhigh)

Parameters	Low yielding sub-population (n=36)						High yielding sub-population (n=24)						Ratio VAR
	Mean	CV	Median	Min	Max	Skewness	Mean	CV	Median	Min	Max	Skewness	
N/P	3.3	46.5	2.9	1.3	9.3	1.8	3.8	54.7	3.1	1.6	10.9	1.9	0.6
P/N	0.4	42.6	0.3	0.1	0.8	1.0	0.3	41.9	0.3	0.1	0.6	0.4	1.3
N/K	0.9	132.5	0.5	0.2	6.2	3.1	0.8	124.5	0.5	0.2	4.4	3.2	1.6
K/N	2.1	58.0	2.0	0.2	5.1	0.4	2.2	49.0	2.2	0.2	4.2	0.3	1.3
N/Ca	0.8	29.2	0.7	0.4	1.2	0.6	0.7	39.1	0.7	0.4	1.7	2.0	0.6
Ca/N	1.4	27.7	1.4	0.8	2.3	0.3	1.5	31.3	1.5	0.6	2.6	0.2	0.7
N/Mg	1.7	42.4	1.5	0.9	3.8	1.2	1.8	43.3	1.5	1.0	4.3	1.8	0.9
Mg/N	0.7	35.9	0.7	0.3	1.2	0.2	0.6	32.2	0.7	0.2	1.0	-0.2	1.4
N/S	16.6	99.5	10.5	7.1	50.0	2.3	16.7	74.1	11.7	7.6	44.0	2.0	1.8
S/N	0.1	47.5	0.1	0.02	0.1	-0.8	0.1	39.1	0.1	0.02	0.1	-0.7	2.0
N/Zn	953.0	79.2	725.0	194.3	4062.5	2.3	1315.7	100.5	693.8	470.0	5000.0	1.8	0.3
Zn/N	0.002	65.6	0.001	0.0002	0.01	1.2	0.001	49.6	0.001	0.0002	0.002	-0.5	2.9
P/K	0.3	138.8	0.2	0.1	2.2	2.9	0.3	151.8	0.1	0.04	1.9	3.5	1.3
K/P	6.8	62.8	6.2	0.5	16.9	0.3	7.9	62.2	7.0	0.5	23.4	1.4	0.7
P/Ca	0.3	37.3	0.3	0.1	0.5	0.5	0.2	65.9	0.2	0.1	0.8	1.7	0.4
Ca/P	4.5	48.0	4.0	2.1	11.6	2.0	5.8	56.7	5.1	1.3	12.8	0.8	0.4
P/Mg	0.6	45.5	0.5	0.2	1.3	1.2	0.6	75.6	0.5	0.2	1.9	1.5	0.3
Mg/P	2.1	42.2	1.9	0.8	4.5	0.8	2.5	59.3	2.0	0.5	5.9	0.7	0.4
P/S	8.8	120.3	5.4	1.9	30.0	2.2	5.1	88.3	3.6	1.3	18.0	2.5	5.6
S/P	0.04	281.3	0.00	0.00	0.5	3.2	0.2	137.1	0.03	0.00	0.7	1.5	0.3
P/Zn	288.0	54.2	258.6	54.2	775.0	0.9	387.7	101.0	235.2	100.0	1800.0	2.4	0.2
Zn/P	0.005	74.5	0.004	0.001	0.02	2.1	0.005	60.6	0.004	0.001	0.01	0.3	1.8
K/Ca	1.5	60.7	1.3	0.1	4.0	0.7	1.5	57.5	1.4	0.3	3.7	0.8	1.2
Ca/K	1.2	113.6	0.7	0.2	7.3	3.3	1.0	77.4	0.7	0.3	3.6	2.1	2.9
K/Mg	3.5	68.6	2.9	0.2	11.0	0.9	3.6	59.2	3.1	0.6	8.8	1.0	1.3
Mg/K	0.7	157.0	0.3	0.1	5.6	3.6	0.4	78.6	0.3	0.1	1.5	2.3	10.6
K/S	33.1	23.5	34.6	22.7	41.0	-0.4	45.7	99.8	29.3	14.6	183.0	2.9	0.03
S/K	0.03	25.6	0.03	0.02	0.04	0.7	0.03	50.2	0.03	0.01	0.1	0.5	0.2
K/Zn	1829.4	78.5	1370.0	31.4	6166.7	1.2	2310.6	99.1	1626.3	677.8	9600.0	2.4	0.4

Zn/K	0.00	269.3	0.001	0.0002	0.03	5.5	0.001	56.1	0.001	0.0001	0.001	0.3	172.6
Ca/Mg	2.3	36.4	2.2	1.0	4.3	0.8	2.5	25.6	2.3	1.3	4.3	1.3	1.7
Mg/Ca	0.5	36.9	0.5	0.2	1.0	0.8	0.4	24.4	0.4	0.2	0.8	0.9	3.1
Ca/S	25.8	78.7	18.3	10.5	64.0	1.8	23.9	82.7	16.9	10.1	80.0	2.5	1.0
S/Ca	0.01	258.5	0.0	0.0	0.1	2.7	0.03	118.4	0.01	0.00	0.1	0.7	0.5
Ca/Zn	1276.6	75.7	901.6	228.6	5000.0	2.0	1891.1	130.3	1131.4	654.5	12800.0	4.1	0.2
Zn/Ca	0.00	69.7	0.00	0.0002	0.004	1.9	0.001	44.4	0.001	0.0001	0.002	-0.2	5.1
Mg/S	15.6	135.7	6.4	3.5	58.0	2.3	10.7	84.9	6.8	3.8	34.0	2.1	5.5
S/Mg	0.02	270.2	0.00	0.0	0.3	2.8	0.1	123.4	0.01	0.0	0.3	0.9	0.6
Mg/Zn	601.0	75.2	439.0	96.0	2233.3	1.8	775.6	111.2	433.2	223.1	4300.0	3.3	0.3
Zn/Mg	0.003	73.8	0.002	0.0004	0.01	2.2	0.002	50.4	0.002	0.0002	0.004	0.2	3.4
S/Zn	9.0	282.5	0.00	0.00	125.0	3.4	66.5	215.7	6.3	0.00	659.0	3.5	0.03
Zn/S	0.04	118.7	0.02	0.01	0.1	2.2	0.02	100.4	0.02	0.002	0.1	1.7	4.0

Mini: Minimum Maxi: Maximum Skew: Skewness

Table 3. DRIS norms, CV's and skewness values for the high-yielding sub-population, and variance ratios (Ratio VAR) of nutrient ratio expressions selected for inclusion in the DRIS model for pineapple.

Parameters	High yielding sub-population (n=24)			Ratio VAR
	Mean	CV	Skewness	
P/N	0.3	41.9	0.4	1.3
K/N	2.2	49.0	0.3	1.3
Mg/N	0.6	32.2	-0.2	1.4
S/N	0.1	39.1	-0.7	2.0
Zn/N	0.0013	49.6	-0.5	2.9
Zn/P	0.0046	60.6	0.3	1.8
K/Ca	1.5	57.5	0.8	1.2
K/Mg	3.6	59.2	1.0	1.3
Zn/K	0.0007	56.1	0.3	172.6
Mg/Ca	0.4	24.4	0.9	3.1
Zn/Ca	0.0008	44.4	-0.2	5.1
Zn/Mg	0.0021	50.4	0.2	3.4

Table 4. DRIS norms developed for 'Smooth Cayenne' pineapple growing in plantations of Allada township and comparison with some norms presented by Teixeira *et al.* (2009).

Parameters	Proposed Norms		Norms developed by Teixeira *et al*., 2009	
	Norm	CV (%)	Norm	CV (%)
P/N	0.3***	41.9	0.08	21.0
K/N	2.2**	49.0	1.69 (i)	30.0
Mg/N	0.6	32.2	0.22	41.0
S/N	0.1	39.1	-	-
Zn/N	0.0013	49.6	-	-
Zn/P	0.0046	60.6	-	-
K/Ca	1.5***	57.5	5.0 (i)	33.0
K/Mg	3.6***	59.2	7.14 (i)	27.0
Zn/K	0.0007	56.1	-	-
Mg/Ca	0.4***	24.4	0.72	11.0
Zn/Ca	0.0008	44.4	-	-
Zn/Mg	0.0021	50.4	-	-

Significant at 1 % (***), 5 % (**), (i) inverse relation in the original norm

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Appendix: At the end of the paper

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