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DRIS NUTRIENT NORMS FOR PINEAPPLE ON ALFISOLS OF INDIA

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□ *Sub-optimum production in pineapple fields in India is a common feature in Alfisols. The diagnosis and management of nutrient constraints assume a greater significance in maximizing production sustainability. DRIS norms were computed from the data bank of 324 sub-plots on leaf mineral composition, soil available nutrients, and corresponding mean yield representing three diverse pineapple belts for 3 seasons during 2002–04. DRIS norms derived primarily from basal portion of 'D'leaves sampled at 4th to 5th month suggested optimum leaf nutrient concentration* viz. *1.21–1.85% nitrogen (N), 0.13–0.18% phosphorus (P), 1.19–1.62% potassium (K), 0.27–0.35% calcium (Ca), 0.43–0.56% magnesium (Mg), and 78.4–102.5 iron (Fe), 41.5–58.3 manganese (Mn), 7.4–10.2 copper (Cu), and 12.2–15.8 zinc (Zn) (ppm) in relation to fruit yield of 55–72 tons ha*$^{-1}$. *Likewise, DRIS norms for soil fertility corresponding to similar level of fruit yield were determined. The norms were further observed validating the leaf/soil test values obtained from productive plots, suggesting the DRIS as a dynamic interpretation tool for diagnosis of nutrient constraints using both, leaf as well as soil analysis.*

Keywords: DRIS, nutrient norms, pineapple, Alfisols

INTRODUCTION

Pineapple [*Ananas comosus* (L.) Merr.] is the third most important tropical fruit, cultivated in all tropical and subtropical regions where it is extensively grown on Alfisols and Ultisols where intensive cultivation on steep slopes without contour-trench planting or terracing has accelerated the magnitude of the nutrient constraint problem by exposing the comparatively more acidic and infertile sub-surface poor in nutrient reserve, insufficient to support the optimum nutrient supply on sustained basis. Soil or leaf analysis-based nutrient constraint diagnosis has been popularly used to identify

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nutritional problems in pineapple (Godfrey-Sam-Agrey, 1970; Sumner, 1977; Letzsch and Sumner, 1984). The scope of diagnosis through conventional leaf analysis is limited due to strong influence of leaf (Srivastava and Singh, 2008) since leaf sample age in pineapple is recommended from 5th/6th month (Kar et al., 1992) to 11th month (Subramanian et al., 1974) depending upon soil, climate, cultivar, and other growing conditions. The critical nutrient concentration and sufficiency range limit developed by using index leaves as interpretation tools provide little time in the growing season for fertilizer application to be really effective (Jorgensen, 1969; Srivastava et al., 2008). Therefore, the currently available diagnostic methods are applicable only to narrowly specified developmental stage of crop (Reuter and Robinson, 1987). This is the single most important reason for sub-optimum production when compared with most productive pineapple fields maintained under best management practices across the world.

Diagnosis and recommendation integrated system (DRIS) is claimed to have certain advantages over other conventional interpretation tools (Beverly, 1987; Malavolta et al., 1993; Li et al., 1999). The DRIS approach reflects the nutrient balance, identifies the order in which nutrients are responsible for limiting the fruit yield, and its ability to make diagnosis at any stage of crop development. These merits impart DRIS the ability to identify nutrient constraints early in the crop growth and allow sufficient time for remediation of identified problem right in the same season of crop (Walworth and Sumner, 1987). Furthermore, DRIS norms, once developed out of a representative data bank, are by and large applicable under wide range of growing conditions (Beaufils, 1973). Limited efforts have been made to develop DRIS norms or any other nutrient constraint diagnostic criteria for pineapple grown in Southeast Asia including India. Elsewhere, studies in the past (Kar et al., 1992; Alvarez et al., 1993; Mohammed-Selamat and Masaud, 2005) including the studies by Angeles et al. (1990) on DRIS norms have addressed this issue employing a variety of diagnostic methods, leading to many discrepancies in the interpretation of results. Hence, the nutrient constraint diagnosis seldom addressed the original problems that existed in the field, and, therefore, failed frequently to induce the desired response of fertilization. In this background information, the studies were carried out with the three major objectives: i) identifying the leaf age suitable for nutrient constraint diagnosis, ii) developing the leaf/soil analysis-based DRIS norms in relation to fruit yield, and iii) diagnosing the frequency distribution of nutrient constraints.

MATERIALS AND METHODS

Experimental Details

Leaf Sampling Period

'D'-leaves (Singh et al., 1978) from 10 different plants were collected at 30 days interval from one representative pineapple field (Typic Haplustalf) having high planting density (43,500 plants ha^{-1} at a distance of 30 × 60 × 90 cm) established on Typic Rhodustalf. The basal 4 cm portion from each of the collected leaf samples were separated, packed in perforated polythene bags, and brought to the laboratory

Development of nutrient diagnostics:Databank on nutrient composition of 'D' leaves, soil available nutrients, and yield was developed through a total of 324 sub-plot observations from three pineapple fields(each field divided into four sub-plots blocks), three locations each in three districts namely, Kohima, Mokokchung and Dimapur of Nagaland, India representing north-east India. The same sets of sub-plots were surveyed for three consecutive years during 2002–2004. The fields were selected on the basis of uniformity in planting materials, age, condition of plant, planting distance and topography of the field. All the fields used suckers as planting materials and two-row system using plant distance of 25/30 × 60 × 90 cm (planting density of 43,500–53,330 plants ha^{-1}) with Kew variety of pineapple. The soils were taxonomically represented by Rhodustalf, Paleustalf, Haplustalf, and Orchraqualf with predominantly sandy loam to loam texture (sand 414.1–516.4 g kg^{-1}, silt 244.3–348.6 g kg^{-1}, and clay 18.4–24.6 g kg^{-1}) derived prominently from sandstone type of parent material. Both the regions were climatically classified as sub- tropical in nature with mean summer, from May–August and mean winter, from December–February varying from 22.45°C to 25.8°C and 13.07°C, to 18.2°C, respectively, with annual rainfall of 17 to 23 cm with wet monsoon.

Sampling and Analysis

'D'—leaf as the youngest physiologically 4th to 5th leaves from mature whorl (Singh et al., 1978) was collected at monthly intervals. The basal portion of all the collected leaf samples were separated, thoroughly washed, dried in oven at 68 ± 2°C, and ground to homogeneous powder. The samples were subsequently digested in concentrate sulfuric acid (H_2SO_4; 15N) by adding catalyst mixture (Jones, 1984) for nitrogen estimation and in di-acid mixture of nitric acid and perchloric acid at 4:1 ratio (Chapman and Pratt, 1961). Analysis made consisted of nitrogen (N) by micro- Kjeldahl method (Jones, 1984), phosphorus (P) using vanadomolybdophosphoric acid yellow color method (Jones, 1984), potassium (K) flame photometrically (Chapman and Pratt, 1961), calcium (Ca) and magnesium (Mg) by versene titration method (Cheng and Bray, 1951), and micronutrients [iron (Fe), manganese (Mn), copper (Cu), and zinc (Zn)] by atomic absorption spectrophotometer (Model GBC AA 908, GBC, Hampshire, IL, USA).

Simultaneously, the representative soil samples at 0–15 depth were also collected. The volume of soil samples was reduced to half kg by quartering method and dried in shade. The soil fertility analyses consisted of: alkaline potassium permanganate ($KMNO_4$) distillation for available N (Subbaiah and Asija, 1956), NH_4F (pH 8.5) extractable P as Brays—P, 1N neutral ammonium acetate (NH_4OAc) extractable—K, Ca, and Mg by versenate method through titration (Cheng and Bray, 1951) and diethylenetriamine-pentaacetic acid (DTPA)—calcium chloride ($CaCl_2$)—triethylamine (TEA) method extractable Fe, Mn, Cu, and Zn (Lindsay and Norvell, 1978).

Procedure of DRIS Norms

The following procedure as initially developed by Beaufils (1973) and modified by Bhargava (2002) was used through a PC-based program for the development of DRIS norms: i) defining the parameters to be improved and the factors likely to affect them, ii) collection of all the reliable data available the fields and experimental plots, iii) study the relationship between the yield and available nutrients in soil, iv) establishment of relationship between the yield and leaf nutrient composition. This was done using the following steps: a) each internal plant parameter is expressed in as forms as possible, e.g., N/DM, N/P, P/N, N × P etc.; b) the whole population is divided into a number of sub-groups based on the economic optimum; c) the mean of each subpopulation is calculated for the various forms of expressions; d) if necessary, class interval limits between the average and the outstanding yields are re-adjusted, so that the means of below average population remains comparable; e) chi-square test is performed to know that the population of orchards confirms a normal distribution; f) the variance ratios between the yield of sub-populations [using 65 tons ha^{-1} as cut-off yield level (average yield level usually obtained at growers field) to separate the sub-populations] for all the forms of expressions are calculated together with the co-efficient of variation; and g) the forms of expressions, for which significant variance ratios (S_A for low-yielding population/S_B for high yielding population) were obtained and essentially the same mean values for the population were selected in expression with common nutrient. The mean and co-efficient of variation (cv) values in the high-yield population for the selected ratios were used for calculating DRIS indices. The nutrient with the most negative index is considered the most deficient and most limiting to fruit yield and vice-versa. The following equations were developed for the calculation of DRIS indices based on leaf analysis:

$$N = 1/9[f(N/P) + f(N/K) + f(N/Ca) + f(N/Mg) + f(N/Fe) + f(N/Mn) + f(N/Cu) + f(N/Zn)]$$

for example

where, $f(N/P) = \frac{N/P}{n/p} - 1\left(\frac{1000}{CV}\right)$ when $N/P > n/p$

and

$$1 - \frac{n/p}{N/P}\left(\frac{1000}{CV}\right) \text{ when } N/P > n/p$$

Where N/P, actual value of the ratio of nitrogen and phosphorus in the plant under diagnosis. The n/p is the value of the norm (which is the mean value of high yielding orchards) and CV is the co-efficient of variation for population of high yielding orchards. Similarly the formula for other nutrients was developed. DRIS norms for soil were calculated in a manner identical to that described for leaf tissue data (Filho, 2004). The norms for classification of nutrients in plants were derived by following procedure given below.

The mean of high yielding orchards constituted the mean for optimum. The range of 'optimum' is the value derived form mean 4/3 to mean + 4/3 standard deviation. The range of 'low' was obtained by calculating mean −4/3 to mean −8/3 standard deviation, and the value below mean −8/3 standard deviation was considered as deficient. The value from mean +4.3 to mean +8.3 standard deviation was taken as high and the value above mean +8/3 standard deviation was taken excessive or toxic (Bhargava, 2002).

RESULTS AND DISCUSSION

Leaf Sampling Period

The primary nutrients *viz.*, N, P, and K during all the three years showed a variation of 0.81–1.15% (Figure 1), 0.29–0.59% (Figure 2) and 0.72–1.78% (Figure 3), respectively, averaging 1.03%, 0.38%, and 1.10% in 1st, 2nd, and 3rd year. All the three nutrients at 4th to 5th month of growth displayed

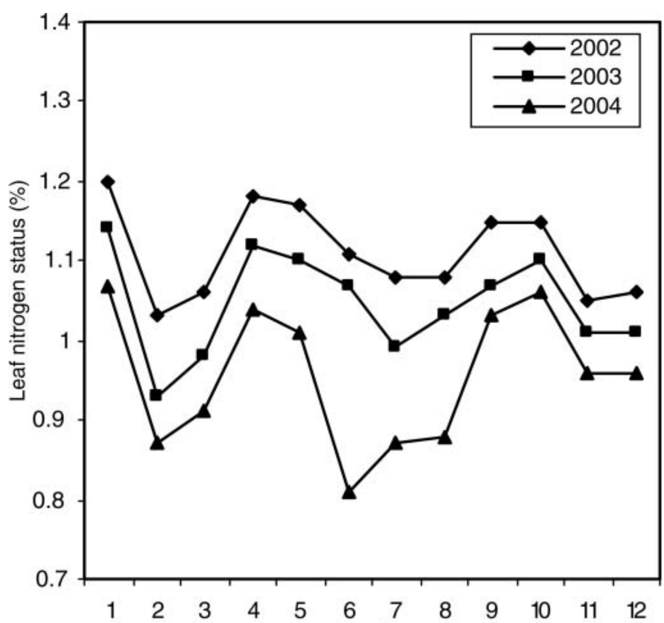

FIGURE 1 Annual variation leaf nitrogen concentration.

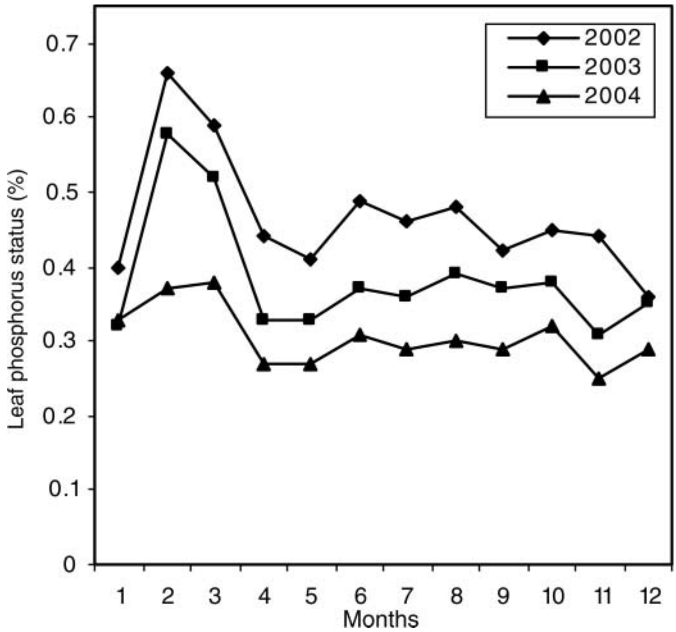

FIGURE 2 Annual variation leaf phosphorus concentration.

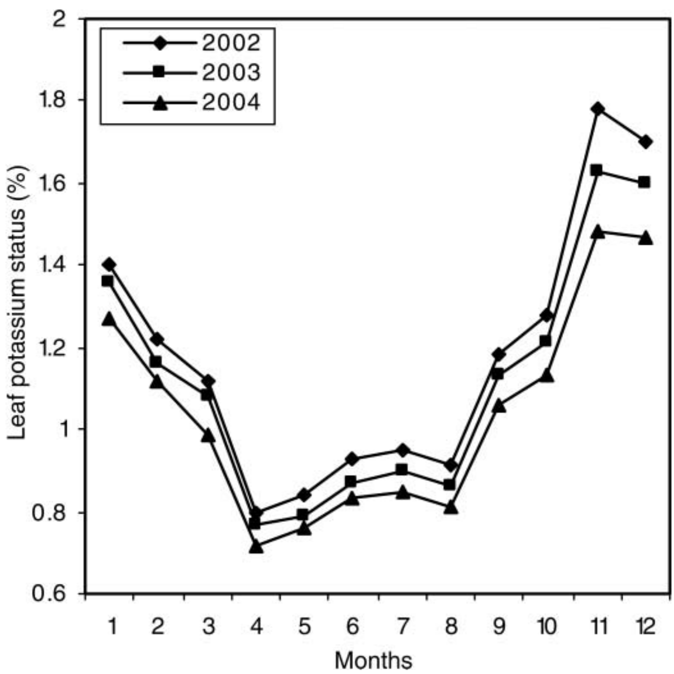

FIGURE 3 Annual variation leaf potassium concentration.

minimum change in concentration, e.g., N in concentration range of 1.17–1.18%, 1.07–1.10%, and 1.01–1.04% in 1st, 2nd, and 3rd year of experiment, respectively. Similarly, P during the same period showed a concentration of 0.41–0.44%, 0.33%, and 0.27%, respectively, with K concentration of 0.80–0.84%, 0.77–0.79%, and 0.72–0.76% corresponding to 1st, 2nd, and 3rd year of observations.

It was observed that nitrogen content of 1.4% and potassium content of 3.7% on dry weight basis in the middle one-third portion of the leaf base sampled in the fifth/sixth month could account for 90–95% of the yield (Subramanian et al., 1974). While other studies by Hariprakasa Rao et al. (1977) reported that the critical levels of nitrogen in the middle one-third leaf base (base N) sampled at 5th, 8th, and 11th month of plant growth were 1.51, 1.23, and 1.97%, respectively, in Kew pineapple. In the remainder of 'D' leaf, the critical N levels were 0.99, 0.81, and 1.37%, respectively. In Queen pineapple, the nutrient status at 11th month was better correlated with yield than the 7th month. The critical levels of N and P for basal leaf at 11th month were 1.04 and 0.16%, respectively (Subramanian et al., 1974). These studies suggest the necessity of different diagnostic norms as per cultivar.

The concentration of secondary nutrients such as Ca and Mg stabilized in the concentration range of 0.11–0.18% (Figure 4) and 0.14–0.21% (Figure 5), respectively, with mean concentration of 0.14% and 0.19% considering all the three seasons during the 4th to 5th month of observations.

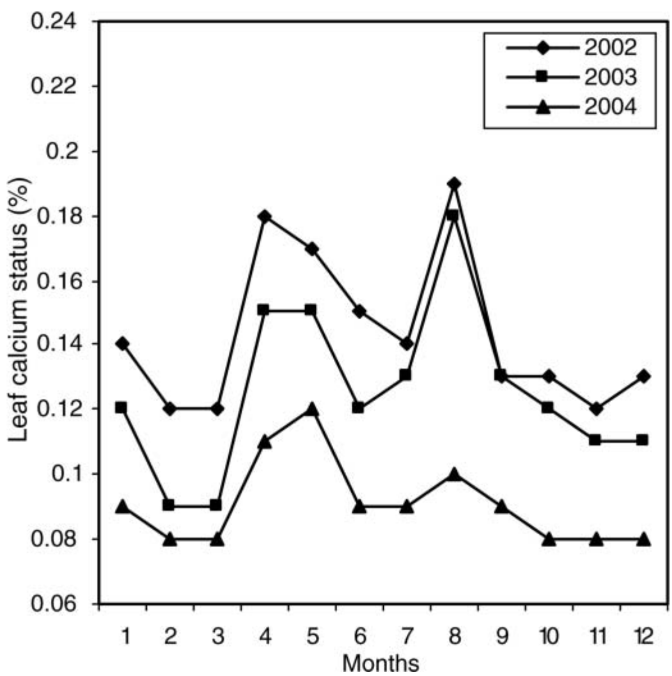

FIGURE 4 Annual variation leaf calcium concentration.

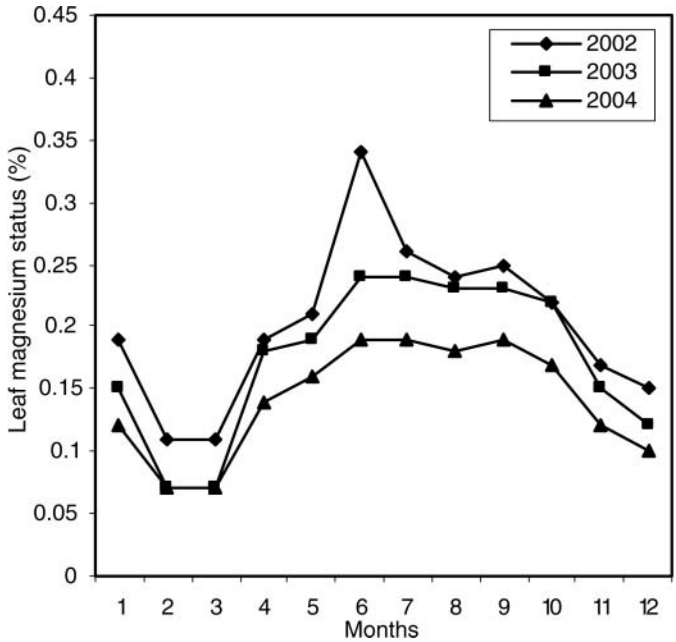

FIGURE 5 Annual variation leaf magnesium concentration.

The annual accumulation pattern of Ca and Mg showed a range of 0.08–0.18% (mean 0.12%) and 0.07–0.34% (mean 0.17%). The variation curve of Ca and Mg can be identified by lower portion (0.08–0.14% and 0.07–0.19%), middle portion (0.11–0.18% and 0.14–0.21%), and again lower bottom end portion of the curve (0.08–0.13% and 0.10–0.17%) with distinct redistribution of nutrients. These observations suggested that the mean concentration of different nutrients during the stable 4th to 5th month of growth corresponded well to mean annual concentration or even with mean concentration of all the three seasons. The higher correlation values of different nutrients (concentration during 4th to 5th month) with fruit yield (r = 0.611, $P = 0.01$ for leaf N vs yield; r = 0.702, $P = 0.01$ for leaf P vs fruit yield; r = 0.401, $P = 0.05$ for leaf K vs fruit yield; r = 0.732, $P = 0.01$ for leaf Ca vs yield; and r = 0.596, $P = 0.01$) for leaf Mg vs yield) than the correlation values for rest of the period (r = 0.289–0.316 for leaf N vs yield; r = 0.311–0.372 for leaf P vs yield; r = 0.189–0.204 for leaf K vs yield; r = 0.201–0.254 for leaf Ca vs yield; and r = 0.323–0.355 for leaf Mg vs yield) warranted that 4th- to -5th month-old growth is the ideal time for the leaf sampling.

A large variation in micronutrient concentration was prominently observed over a growing season. On the basis of pooled data for three seasons, the variation in concentration of different nutrients was observed as 93.2–117.0 mg g^{-1} Fe (mean 102.6 mg g^{-1}), 20.4–45.4 mg g^{-1} Mn (mean 29.3 mg g^{-1}), 4.4–7.2 mg g^{-1} Cu (mean 5.4–mg g^{-1}), and 3.5–9.7 mg g^{-1} Zn (mean 7.1 mg g^{-1}). All these micronutrients (Figures 6, 7, 8, and 9) showed

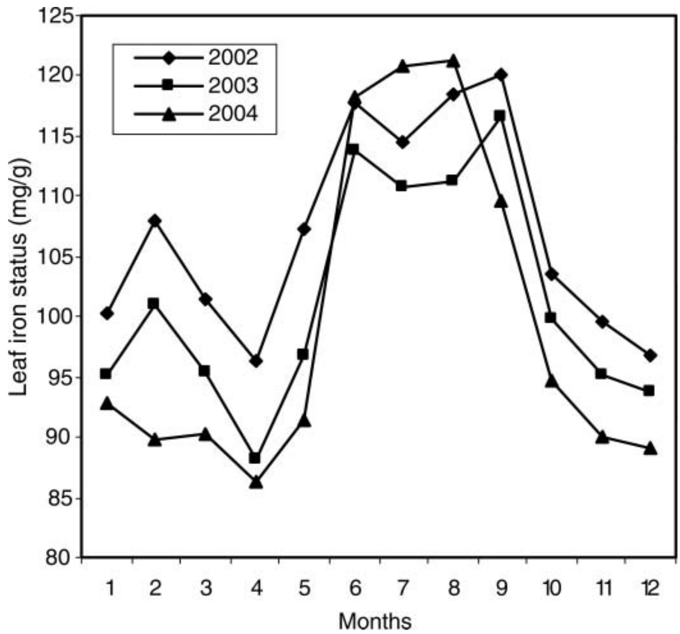

FIGURE 6 Annual variation leaf iron concentration.

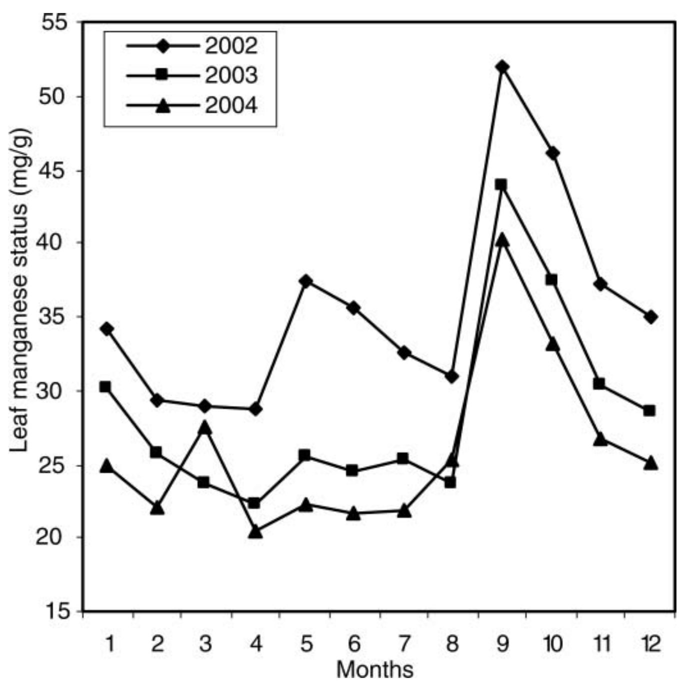

FIGURE 7 Annual variation leaf manganese concentration.

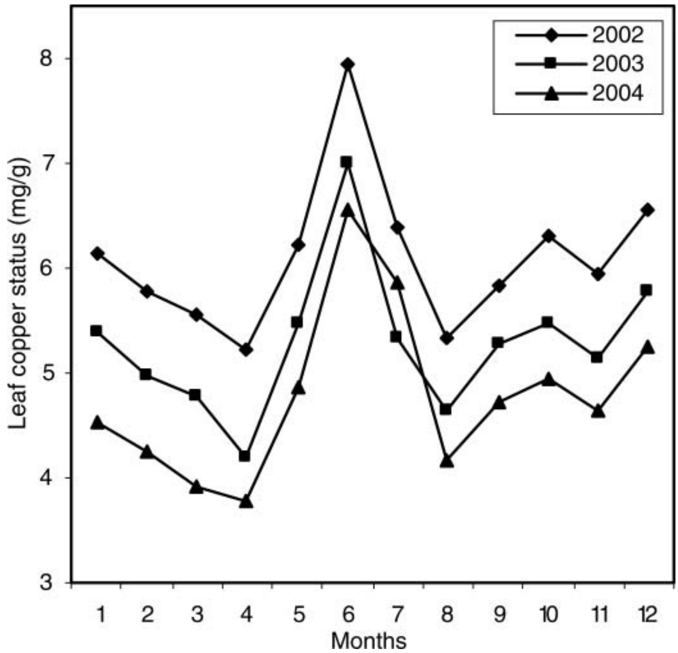

FIGURE 8 Annual variation leaf copper concentration.

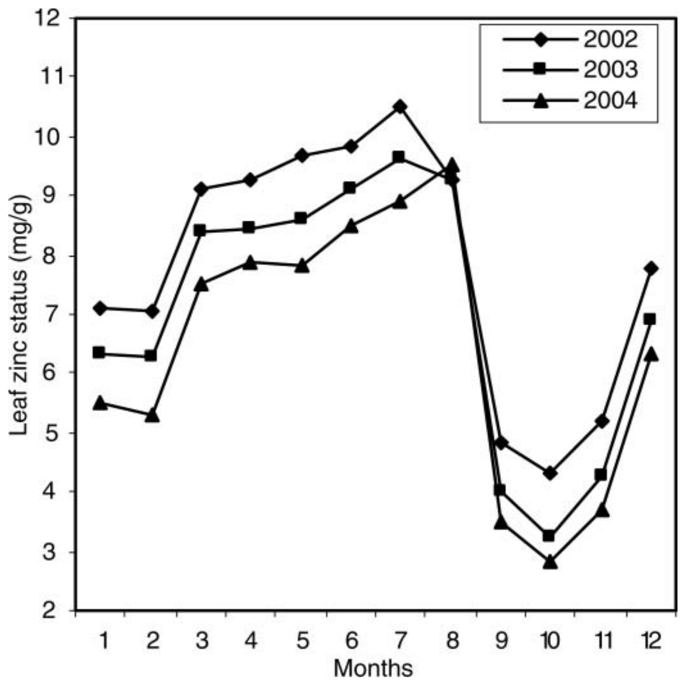

FIGURE 9 Annual variation leaf zinc concentration.

minimum change in concentration during 4th- to -5th month of growth (98.2–98.5 mg g^{-1} Fe, 20.4–23.3 mg g^{-1} Mn, 4.4–5.5 mg g^{-1} Cu, and 8.5–8.7 mg g^{-1} Zn) than the changes during rest of the period (93.2–117.0 mg kg^{-1} Fe, 25.7–43.4 mg kg^{-1} Mn, 4.9–7.2 mg kg^{-1} Cu, and 3.5–9.7 mg kg^{-1} Zn) suggesting that ideal time for leaf sampling is when leaves are 4- to 5-months old. This was further supported by higher correlation between concentration of different nutrients at 4th-5th month of leaf age and fruit yield ($r = 0.796$, $P = 0.01$ for leaf Fe vs yield; $r = 0.804$, $P = 0.01$ for leaf Mn vs yield; $r = 0.583$, $P = 0.01$ for leaf Cu vs yield; and $r = 0.811$, $P = 0.01$ for leaf Zn vs yield) than correlation values worked out for rest of the periods of sampling ($r = 0.469$–0.512, $P = 0.01$ for leaf Fe vs yield; $r = 0.211$–0.309 for leaf Mn vs yield; $r = 0.451$–0.462, $P = 0.01$ for leaf Cu vs yield; and $r = 0.216$–0.281 for leaf Zn vs yield). Verawudh et al. (1993) observed highest yield (71.4 tons ha^{-1}) of pineapple (cv 'Smooth Cayenne') associated with concentration ranges of different micronutrients viz., 26.5–36.2 ppm Fe, 5.6–9.0 ppm Cu, 13.8–14.4 ppm Zn, and 14.2–19.7 ppm B in 12- month-old D-leaf.

Leaf Analysis Based DRIS Norms

Leaf analysis as a method of assessing the crop nutrient requirements is based on the assumption that within certain limit, there exists a positive relation between doses of the nutrient supplied, leaf nutrient content, and yield (Srivastava et al., 2001). The concentration of different nutrients from the developed data bank varied in the range of: 0.92–2.32% N, 0.30–0.81%P, 0.83–1.80% K, 0.16–0.45% Ca, 0.22–0.70% Mg, 58.2–172.9 ppm Fe, 28.5–62.1 ppm Mn, 5.2–13.3 ppm Cu, and 8.2–21.3 ppm Zn. While the yield on the basis of each sub-plot varied from 21.8 to 94.3 tons ha^{-1} (data not presented). The DRIS norms developed in relation to fruit yield of 55–72 tons ha^{-1} predicted optimum value of different nutrients as: 1.21–1.85% N, 0.13–0.18% P, 1.19–1.62% K, 0.27–0.35% Ca, 0.43–0.56% Mg, 78.4–102.5 ppm Fe, 41.5–58.3 ppm Mn, 7.4–10.2 ppm Cu, and 12.2–15.8 ppm Zn (Table 1). A proportionately higher leaf nutrient level were suggested to be maintained to get the fruit yield up to or beyond > 88 tons ha^{-1}. The optimum values of N and K derived from DRIS-based norms were observed much closer to values as suggested by Angeles et al. (1990) who determined optimum value of N, P, and K as 1.43%, 0.25%, and 3.25%, respectively, through DRIS based norms which changed to 1.43%, 0.15%, and 2.77% derived from existing critical values.

The leaf nutrient standards of varying dimensions are frequently suggested to take into account, the regional differences in climate and soil site characteristics. It remains to be seen that the diagnostic norms derived from specific index leaves and fields of varying productivity levels, categorized into deficient or optimum in different leaf nutrients on the basis of nutrient concentration, has the same utility to that of norms developed through leaves

TABLE 1 Leaf nutrient norms determined from DRIS based analysis for pineapple grown in tropical India

Nutrients	Norms				
	Deficient	Low	Optimum	High	Excess
N (%)	<0.96	0.96–1.20	1.21–1.85	1.86–2.10	>2.10
P (%)	<0.09	0.10–0.12	0.13–0.18	0.19–0.22	>0.22
K (%)	<0.82	0.82–1.18	1.19–1.62	1.63–1.82	>1.82
Ca (%)	<0.18	0.18–0.26	0.27–0.35	0.36–0.42	>0.42
Mg (%)	<0.24	0.24–0.42	0.43–0.56	0.57–0.70	>0.70
Fe (ppm)	<61.1	61.1–78.3	78.4–102.5	102.6–168.1	>168.1
Mn (ppm)	<30.2	30.2–41.4	41.5–58.3	58.4–61.6	>61.6
Cu (ppm)	<5.8	5.8–7.3	7.4–10.2	10.3–12.3	>12.3
Zn (ppm)	<9.6	9.6–12.1	12.2–15.8	15.9–19.6	>19.6
Yield (tons ha^{-1})	<38	38–55	55–72	72–88	>88

sampled at other crop developmental stages (leaving the index sampling period) in order to make DRIS, a more flexible monitoring tool without affecting the production at any stage of crop (Srivastava et al., 2008).

Soil Analysis-Based DRIS Norms

Soil analysis method rests on the assumption that roots will extract nutrients from the soil in a manner comparable to chemical soil extractants, and that there is a simple direct relationship between the extractable concentration of nutrients in soil and their uptake by plants (Egashira et al., 1990). However, though there has been considerable uniformity among the soil test methods in conventional use, a great diversity still arises in the interpretation of these tests. The central element in developing the soil test norms using a particular test crop is the optimum value. Use of DRIS with soil data provides as advantage of taking into account, the nutrient balance and ranking nutrients in terms of abundance relative to optimum levels. Optimizing soil fertility has recently emerged as a new field of investigation, which ensures maximum yield under a wide range of soil conditions. Various soil fertility parameters of developed data bank varied as: 4.3–6.5 soil pH, 0.72–2.10 g kg^{-1} organic carbon, 104.1–190.4 mg kg^{-1} available N, 7.8–17.2 mg kg^{-1} P, 162.1–290.4 mg kg^{-1} K, 1.52–9.12 meq 100 g^{-1} Ca, 1.12–7.12 meq 100 g^{-1} Mg, 74.3–182.1 mg kg^{-1} Fe, 0.81–4.16 mg kg^{-1} Mn, 0.14–0.52 mg kg^{-1} Cu, and 0.38–1.28 mg kg^{-1} Zn (data not presented).

The DRIS norms developed from above databank predicted the optimum values of pH 5.6–6.5, organic carbon 1.06–1.76%, available N 145.4–167.1 mg kg^{-1}, P- 9.2–12.9 mg kg^{-1}, K 206.9–234.2 mg kg^{-1}, Ca 3.83–5.65 meq 100 g^{-1}, Mg 3.43–5.13 meq 100 g^{-1}, Fe 100.7–138.2 mg kg^{-1}, Mn 1.53–2.66 mg kg^{-1}, Cu 0.23–0.33 mg kg^{-1}, Zn 0.69–0.93 mg kg^{-1} in relation to fruit yield of 1051–1350 g $fruit^{-1}$ (Table 2). A soil-testing program,

TABLE 2 Soil fertility norms determined from DRIS based analysis for pineapple grown in tropical India

	Norms				
Parameters	Deficient	Low	Optimum	High	Excess
pH	<4.4*	4.4–4.8	4.9–6.1	6.2–7.4	>6.4**
Org. C (g kg^{-1})	<0.76	0.76–1.05	1.06–1.76	1.77–1.98	>1.98
N (mg kg^{-1})	<115.2	115.2–145.3	145.4–167.1	167.2–182.7	>182.7
P (mg kg^{-1})	<8.4	8.4–9.1	9.2–12.9	13.0–16.4	>16.4
K (mg kg^{-1})	<178.4	178.4–206.8	206.9–234.2	234.3–282.9	>282.9
Ca (meq 100 g^{-1})***	<1.62	1.62–3.82	3.83–5.65	5.66–7.12	>7.12
Mg(meq 100 g^{-1})***	<1.32	1.32–3.42	3.43–5.13	5.14–6.89	>6.89
Fe (mg kg^{-1})	<82.1	82.1–100.6	100.7–138.2	138.3–162.4	>162.4
Mn (mg kg^{-1})	<0.98	0.98–1.52	1.53–2.66	2.67–3.12	>3.12
Cu (mg kg^{-1})	<0.17	0.17–0.22	0.23–0.33	0.34–0.48	>0.48
Zn (mg kg^{-1})	<0.43	0.43–0.68	0.69–0.93	0.94–1.10	>1.10
Yield (tons ha^{-1})	<38	38–55	55–72	72–88	>88

*Very low, **Very excess, ***Exchangeable form.

thus, can identify areas, which are either under- or over-fertilized to enable more efficient use of fertilizers.

Validation of Optimum Values

Past studies (Srivastava and Singh, 2006) have established that maximum yield is achieved within the optimum range. Since, development of nutrient diagnostics is a time consuming exercise, the nutrient test values obtained from highly productive fields could well serve as reference values, and cross validate through either crop response studies or statistical modelling. The optimum nutrient values of D-leaves and soil available nutrients were observed very close to the range of values derived from productive plots (Table 3). The leaf/soil test values of highly productive fields, hence, matches to the diagnoses made by DRIS.

The DRIS norms obtained in the current study has superior precision over the others. The fact that the norms derived from critical levels proved to be as effective as those derived from the data base points to the importance of assessing nutrient balance when making diagnoses. By calculating the ratios of the critical values, balance is automatically built into the diagnosis, which the critical value approach is unable to do.

Distribution of Nutrient Constraints

Nutrient deficiencies, if not addressed in time through suitable diagnostic norms, will cause a recurrent loss in production and continue to impart imbalances in the production economics. In all cases, as the limiting nutrients are supplied, the nutrient balance index (NBI), being the sum of the

TABLE 3 Comparison of DRIS-based nutrient diagnostics with productive sub-plots of pineapple

Nutrients	DRIS-based optimum leaf nutrient norms (%)	DRIS-based optimum soil fertility norms (mg kg^{-1})	Productive sub-plots** Leaf nutrients (%)	Productive sub-plots** Soil fertility (mg kg^{-1})
N	1.21–1.85	145.4–167.1	1.46–1.92	132.1–158.4
P	0.13–0.18	9.2–12.9	0.12–0.14	8.1–11.2
K	1.19–1.62	206.9–234.2	1.42–1.60	189.3–210.3
Ca*	0.27–0.35	3.83–5.65	0.28–0.38	2.94–4.62
Mg*	0.43–0.56	3.43–5.13	0.40–0.48	3.04–4.12
Fe (ppm)	78.4–102.5	100.7–138.2	82.1–100.3	89.9–114.8
Mn (ppm)	41.5–58.3	1.53–2.66	38.3–52.6	1.14–2.12
Cu (ppm)	7.4–10.2	0.23–0.33	6.4–9.2	0.24–0.30
Zn (ppm)	12.2–15.8	0.69–0.93	13.2–14.6	0.66–0.84
Yield (tons ha^{-1})	55–72	55–72	69–94	69–94

*meq 100 g^{-1}, **Pooled values.

DRIS indices irrespective of sign, progressively decreases to a low value, thus indicating that nutrition is coming into balance (Beaufils, 1973). Nutrient deficiencies of P, Ca, Mg, N, Zn, and Cu due to their negative values in decreasing order (181 → 21) was observed (Table 4) through leaf analysis. While, other nutrients namely Fe, Mn, and K with increasing positive indices (91 to 257) were observed in high to excess limit. A large positive nutrient index indicates that the corresponding nutrient is present in relatively excessive quantity. Using progressive nutrient diagnosis, if the first limiting factor P is corrected by its supply, the next nutrient that will limit the yield is Ca. Further, if P and Ca are satisfied, the next limiting nutrient is Mg followed by N, Zn, and Cu.

Mean DRIS indices developed from soil analysis-based databank suggested low to deficient level of Ca, P, Mg, Org. C, pH, Zn, N, Cu, and Mn due to their negative values in decreasing order (142 to 17). While, those of K and Fe on account of their increasing positive indices (289 to 391) were found in high to excess limit (Table 5). Various nutrients in order of decreasing influence on yield were rated as P < Ca < Mg < N < Zn < Cu < Fe < Mn < K through leaf analysis. While through soil analysis, DRIS indices

TABLE 4 Nutrient constraints diagnosis using leaf analysis based DRIS indices in pineapple (Summarized form)

Parameters	Nutrients found low and deficient						Nutrients found high and excess			Yield (tons ha^{-1})
Nutrients	P	Ca	Mg	N	Zn	Cu	Fe	Mn	K	—
Status	0.28	0.20	0.25	1.04	10.2	4.2	172	58	1.73	34
DRIS indices	−181	−112	−61	−48	−39	−21	91	114	257	–

TABLE 5 Nutrient constraints diagnosis using soil analysis based DRIS indices in pineapple (summarized form)

Parameters	Nutrients found low and deficient									Nutrients found high and excess		Yield (tons ha^{-1})
Nutrients	Ca	P	Mg	Org. C	pH	Zn	N	Cu	Mn	K	Fe	—
Status	1.58	8.6	1.28	0.78	4.6	0.58	121.4	0.20	1.20	289.1	159.3	37
DRIS indices	−142	−132	−99	−81	−78	−61	−42	−28	−17	289	391	–

revealed slightly different nutrients to be ordered as Ca < P < Mg < Zn < N < Cu < Mn < K < Fe.

Diagnosis of nutrient constraints based on DRIS analysis showed a good agreement between leaf and soil analysis data. These observations lend a strong support for the utility of DRIS in identification and management of nutrient constraints in pineapple field. The developed yield-based soil and leaf diagnostics for pineapple are likely to provide the desired guidance to add sustainability in pineapple production much better than before.

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