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Compositional nutrient diagnosis norms (CND) for guava (*Psidium guajava* L.)

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ABSTRACT

Multivariate nutrient diagnostic norms were developed for guava using compositional nutrient diagnosis (CND) through leaf nutrient concentration *vs*. yield data bank. CND norms for N (V_N), P (V_P) and K (V_K) were 2.48, 0.23 and 2.13, respectively. Norms for N and K were much higher compared to P, indicating higher requirement of these two nutrients. CND norms are multivariate norms that consider all elements, including unmeasured factors and, therefore, has higher diagnostic sensitivity. Among micronutrients, Fe requirement was much higher than all other nutrients. Interaction among different nutrients was explained by principal component analysis conducted on log-transformed data which produced four significant PCs, explaining about 73.66% of the variance. The four Eigen values added up to 8.1 denoting the four significant PCs. The first PC was positively correlated with P, Zn and R (residue, which is a reflection of dry matter accumulation in the plant) and negatively correlated with Ca, Mg, S and Fe, indicating that P and Zn behaved in one direction and the other elements in opposite direction. In the second PC, antagonistic effect of N, Fe with P and Cu was evident. In PC3, P and Mg were negatively correlated with Mn and Cu. In PC4, N and S showed their behaviour in the same direction. Diagnostic norms developed were used for identification of yield-limiting nutrients in low-yielding orchards. Thus, diagnostic norms and nutrient interactions help evolve nutrient management strategies for guava to realize higher yields and better quality.

Key words: Nutrients, diagnosis, norms, CND, PCA, guava

INTRODUCTION

In guava, a crop grown successfully in a variety of soils with pH ranging from 5.5 to 8.0, deficiency of both major and micronutrients is reported extensively (Pathak and Pathak, 1993). Besides, in India, the crop is scarcely fertilized. Incipient deficiency or hidden hunger is causing considerable damage to guava crop, resulting in economic losses (Singh and Singh, 2007). In order to avoid yield loss, nutrient management strategies need to be evolved for this crop based on comprehensive nutrient diagnostic norms. Several approaches are adopted for identification of nutrient imbalances, a recent one being the Compositional Nutrient Diagnosis (Parent and Dafier, 1992). CND norms are multivariate norms that give due weightage to all the elements, including unmeasured factors and, therefore, have higher diagnostic sensitivity. The present investigation was carried out to develop multivariate diagnostic norms using CND to improve diagnostic precision and to understand interaction among different nutrients governing yield and quality of the guava crop.

MATERIAL AND METHODS

Sampling

During July-August, a survey was conducted in guava orchards cultivating 'Allahabad safeda' in and around Bangalore and Kolar (mostly alfisols) in Karnataka, and, 280 leaf samples were collected to develop nutrient diagnostic norms. Samples were collected from 70 orchards (around 15 years of age) by selecting the 3rd pair of leaves from apex, which provides the index leaf (recently matured leaf) in guava. From each orchard, 25 to 30 trees were selected and 50 leaves per plant were collected randomly at chest height from all sides of the tree to form a composite and representative sample (Bhargava and Chadha, 1993). The leaf samples were decontaminated by washing in a sequentially with tap water, 0.2% detergent solution, N/10 HCl and, finally, with double distilled water. Leaf samples were dried at 65-70^{o}C for 48 h. The samples were then powdered in a Cyclotec Mill and analyzed for different nutrients by digesting 1g tissue in di-acid mixture (9:4 ratio of nitric acid and perchloric acid) using standard analytical methods (Jackson, 1973). Phosphorus was analyzed by vanado-molybdate method, K by flame-photometer and S by the turbidity method. Ca, Mg, Fe, Mn, Zn and Cu were analyzed using Atomic Absorption Spectrophotometer (Perkin-Elmer-A-Analyst-200). N was separately estimated by micro-Kjeldhal method. Thus, nutrient 'concentration *vs*. yield' data bank was established for developing nutrient diagnostic norms.

Compositional Nutrient Diagnosis

CND norms were developed by adopting the procedure outlined by Parent and Dafir (1992). Full composition array for nutrient proportions (D) in plant tissues was described by the following simplex (S^D) contained to 100%:

$$S^D=[(N, P, K,\ldots R): N>O, P>O, K>O,\ldots,R>O; N+P+K+\ldots+R=100\%] \quad — 1$$

where, 100% is dry matter content (i.e., the invariable sum of all the components or full relative composition of the diagnostic tissues); N, P, K are nutrient concentrations and R is filling value between 100% and sum of the nutrient concentrations. The value of R is, thus, composed of undetermined components as well as experimental error, and was required to linearize compositional data.

Bounded sum constraint to 100% of compositional data was alleviated by correcting nutrient concentrations by geometric mean (G) of all the D components, including R.

$$G = [N \times P \times K \times \ldots \times R]^{1/D} \quad —— 2$$

Row centered log-ratios were generated for V_N to V_{Zn} as follows:

$$V_N = \ln(N/G),\ldots,V_{Zn} = \ln(Zn/G) \quad —— 3$$

Expressions such as N/G,… Zn/G are multi-nutrient ratios, since, each nutrient is divided by the geometric mean of all components (the nutrients determined and the filling value). Row-centered log-ratios are linearized (undistorted) estimates of the original components fully compatible with PCA.

V^*_N to V^*_{Zn} and SD^*_N to SD^*_{Zn} are CND norms (indicated by asterisks), i.e., mean and standard deviation of each row-centered log ratios in the high-yielding population. The standardized variables $(V_N - V_N^*) / SD^*_N$ to $(V_{Zn} - V^*_{Zn}) / SD^*_{Zn}$ are CND nutrient indices.

$$I_N = (V_N - V^*_N) / SD^*_N,\ldots I_{Zn} = (V_{Zn} - V_{Zn}^*) / SD^*_{Zn} \quad — 4$$

Independent values for V_N to V_{Zn} were introduced in the equation for diagnostic purpose.

Principal component analysis (PCA)

PCA application could lead to greater understanding of nutrient interactions in the plant. PCA reduces the number of interdependent variables to a smaller number of independent PCs that are linear combinations of original variates. Therefore, PCA was performed on log-transformed data of the original nutrient concentrations, prior to statistical computation that followed normal distribution.

Selection criteria

To be declared significant, PCs must have Eigen values >100/P, where P is the total number of varieties under diagnosis. Alternatively, PCs showing Eigen values <1 were considered not significant. PC loadings in Eigen vectors having values greater than selection criterion (SC) only are considered significant. Selection criterion was computed as follows:

SC = 0.50 / (PC eigen values)$^{0.5}$

RESULTS AND DISCUSSION

Nutrient concentration range

The mean N concentration was 1.91% and ranged from 1.33 to 2.48% (Table 1). Maximum yield in guava was reported when N concentration in the leaf ranged between 1.40 and 2.0% (Singh and Rajput, 1981). The mean P concentration was 0.20% and varied from 0.14 to 0.26%, which was comparable to the values (0.18 to 0.24%) published earlier by Khanduja and Garg (1980). The mean K concentration was 1.35% and varied widely between 0.90 and 1.85%. Higher range of Ca concentration (1.50 to 2.60%) was observed, whereas, a majority of the samples were in the optimum range with regard to Mg (0.30 to 0.75%). The mean S concentration was 0.37% and was comparable to the earlier report. Concentrations of Fe and Mn ranged from 104 to 197 and 25 to 98 ppm, respectively. The mean Zn concentration was 56 ppm.

Table 1. Mean and range of nutrient concentration for guava

Nutrient	Unit	Mean	Minimum	Maximum
N	%	1.91	1.33	2.48
P	%	0.20	0.14	0.26
K	%	1.35	0.90	1.85
Ca	%	1.14	0.53	2.41
Mg	%	0.43	0.33	0.57
S	%	0.38	0.21	0.53
Fe	ppm	148.90	104.00	197.00
Mn	ppm	56.86	25.00	98.00
Zn	ppm	31.66	21.00	47.00
Cu	ppm	8.37	4.30	13.60

CND norms

CND norms for N (V_N), P (V_p) and K (V_K) for guava were 2.48, 0.24 and 2.13, respectively. CND norms are multivariate norms with due weightage to all the other elements, including unmeasured factors. Sum of the tissue components is 100% and, therefore, the sum of row-centered log ratios (including filling value) is zero (Table 2). CND norm values developed were difficult to comprehend compared to nutrient concentrations, expressed as % or ppm. However, CND norms have higher diagnostic precision compared to the bivariate values, as in the case of diagnosis and recommendation integrated system (Walworth and Sumner, 1987). The Ca norm (1.91) was twice as high as that of Mg (0.99). Among micronutrients, Fe had higher norm value of –2.377 and, therefore, its requirement was much higher, compared to Mn, Zn or Cu.

Principal component analysis

PCA conducted on log-transformed data produced four significant PCs and four Eigen values added up to 8.10 explaining about 73.66% of variance (Table 3). Since PCs are the linear contrasts among nutrients, interpretation of PCs considers the sign of the variate. The first PC was positively correlated with K, Fe, Zn and R (residue, which is a reflection of dry matter accumulation in the plant) and was negatively correlated with Ca, Mg, and S indicating that K, Fe, and Zn behaved in one direction and the rest of the elements in an opposite direction. In the second PC, antagonistic effect of N and Fe with P and Cu was evident. In PC3, P and Mg were negatively correlated to Mn. In PC4, N and S were isolated (Raghupathi *et al*, 2002). These nutrient interactions need to be considered for correction of nutrient deficiencies and for evolving nutrient management strategies for guava for realizing higher yield and better quality.

Table 2. Compositional nutrient diagnosis norms for guava

CND variate	CND norm	SD
V_N	2.480	0.120
V_P	0.236	0.140
V_K	2.131	0.191
V_{Ca}	1.906	0.319
V_{Mg}	0.987	0.117
Vs	0.844	0.164
V_{Fe}	-2.377	0.172
V_{Mn}	-3.383	0.311
V_{Zn}	-3.932	0.201
V_{Cu}	-5.291	0.283
V_R	6.394	0.083

Table 3. Principal component analysis (PCA) loading performed on log- transformed data

Nutrient	PC1	PC2	PC3	PC4
N	0.196	0.572*	0.322	0.547*
P	0.242	-0.414*	0.591*	0.026
K	0.800*	-0.127	-0.034	0.354
Ca	-0.837*	0.145	0.117	-0.139
Mg	-0.598*	0.099	0.631*	-0.274
S	-0.714*	0.045	0.058	0.556*
Fe	0.431*	0.635*	0.091	-0.358
Mn	0.002	0.349	-0.795*	-0.139
Zn	0.677*	-0.280	-0.028	0.077
Cu	-0.094	-0.813*	-0.123	-0.142
Residue	0.712*	0.198	0.432*	-0.268
Eigen values	3.46	1.852	1.713	1.075
% Variance	31.49	49.32	63.89	73.66
Selection criteria	0.268	0.367	0.382	0.482

* Significant over selection criteria

Table 4. CND indices for selected, low-yielding orchards of guava

N	P	K	Ca	Mg	S	Fe	Mn	Zn	Cu	R
-0.80	1.23	1.44	0.53	-0.28	0.95	-0.61	-0.45	-0.07	-0.77	-1.53
2.24	-0.53	-0.52	0.92	2.32	-0.08	0.00	1.70	-0.61	-0.77	0.16
-0.32	-0.35	0.76	-0.38	-0.88	-0.21	0.10	-0.25	1.27	0.16	-0.01
-1.09	-1.07	-0.85	-0.05	-1.49	-0.87	-0.33	0.75	1.22	1.40	-0.06
0.90	0.70	0.29	-0.61	-0.57	-0.86	-0.81	1.58	1.03	2.15	-0.11
2.83	-1.22	1.25	-0.58	-1.12	-0.54	0.05	0.40	-0.96	-1.35	1.08
-0.02	0.17	1.86	-0.73	-1.21	-1.28	0.24	-0.19	1.27	0.42	1.49
-0.08	0.21	2.18	-0.79	-1.55	-0.48	0.64	-1.07	1.66	-0.27	0.97
-0.21	-0.55	1.57	1.94	0.21	-0.29	-0.82	0.47	-0.64	2.01	0.85
0.53	1.21	1.38	2.20	-0.58	-0.78	0.56	1.56	2.52	0.67	1.57
-0.74	0.12	1.10	-1.52	-0.15	-1.24	0.36	-1.38	2.02	1.73	0.89
-0.41	1.51	-1.19	1.76	2.04	0.58	-1.29	-0.70	-0.63	-1.64	-0.19
0.64	1.48	1.62	1.05	-1.01	2.10	0.07	1.55	-0.10	0.32	-1.07
-1.66	0.09	1.01	-1.09	-2.38	-2.69	-0.63	2.15	1.47	1.17	-1.09
-2.46	0.30	1.16	-0.61	-1.61	-1.63	-0.43	1.45	1.38	0.43	-0.74
2.29	-0.71	-0.14	1.13	-1.32	0.72	0.69	1.81	1.23	2.07	-0.66
-0.27	-2.06	-1.05	1.49	0.36	1.44	-0.41	0.23	-0.32	-0.36	-1.91
1.37	-3.19	-0.64	0.82	-0.86	2.29	-0.53	0.27	-0.04	0.41	-2.38

R = Residue

CND indices

Independent values were introduced from low-yielding orchards for the purpose of diagnosis of a nutrient that limits the yield. Among the eighteen low-yielding orchards studied, N was found to limit yield in as many as ten orchards, whereas, P was low in nine and K in six orchards. The micronutrients were also found to be either low or deficient, as reflected by the indices (Table 4). However, no single nutrient was found solely responsible for low yield. Correlation among indices indicated that N indices correlated with none of the nutrient indices, whereas, there was an overwhelming negative correlation between K and Ca indices, indicating their antagonism. Indices for Zn were negatively correlated with S and positively correlated with Fe. Multi-nutrient diagnosis developed through CND and nutrient interactions elucidated through PCA were found to have higher precision in diagnosing nutrient imbalance in guava and, are thus helpful in evolving nutrient management strategies.

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