DOI : 10.5958/0974-0112.2018.00003.8

Indian J. Hort. 75(1), March 2018: 15-20

Multivariate interpretation of the foliar chemical composition of essential nutrients in mango under Peninsular India

H.B. Raghupathi* and V.M. Shilpashree

ICAR-Indian Institute of Horticultural Research, Hessaraghatta, Bengaluru 560 089

ABSTRACT

The nutrient concentration vs yield performance data bank was established for *Alphonso* mango grown in Peninsular India to develop multivariate diagnostic norms with high diagnostic sensitivity. Well performing orchards in Ramanagara, Srinivaspur, Chittoor, Krishnagiri, Vengurla and Ratnagiri regions were intensively surveyed to develop the data bank. The diagnostic norms for N, P, K, Ca, Mg, S, Fe, Mn, Zn, Cu, B and Mo were developed by using compositional nutrient diagnosis (CND) technique. The interactions among different nutrients were elucidated by principal component analysis (PCA). It was evident that wide variation in plant nutrient concentration exists in different geographic locations. The mean N concentration showed wide variations from 1.03% to 2.87%, P from 0.09 to 0.33 % and that of K from 0.78 to 1.35% depending upon the geographic location. Among the micronutrients, Zn concentration showed variation from 14.01 to 24.97 mg kg^{-1} and B from 3.50 to 16.63 mg kg^{-1}. The CND norms showed higher diagnostic precision compared to the bivariate techniques. The application of PCA indicated that as many as eight nutrient elements were found integrated with first principal component in many locations. Involvement of several nutrients in a single principal component indicated that it was not possible to diagnose nutrient imbalance of any particular nutrient in isolation in mango and multi nutrient involvement on governing yield potential. The extent to which a particular nutrient interacting with other nutrients was a function of nutrient in question and geographic location. The nutrient interaction observed for different locations in general mimicked nutrient behaviour reported earlier. There is a need for integration of the all nutrients for diagnosis of nutrient imbalance in high performing fruit crop like mango.

Key words: *Mangifera indica*, nutrient concentration, compositional nutrient diagnosis (CND), principal component analysis (PCA).

INTRODUCTION

The essential nutrient composition of plant tissue is of interest for plant physiology, plant nutrition, fertilization, ecology and environmental protection. Foliar analysis is a common method for assessment of nutrient status in mango like in many other crops, while analysis is often restricted to essential nutrients to evolve management strategies. Since nutrients largely govern plant growth and yield potential in many crops, the optimum ranges have been defined through use of leaf nutrient interpretation techniques in mango (Anonymous, 1). The leaf nutrient interpretation often becomes complex because of interaction among nutrients with in plant (Raghupathi et al. 6). A further step in studying interaction among nutrients is to use multivariate statistical methods.

Several approaches were adopted for developing diagnostic norms and for identification of nutrient imbalance, the recent being compositional nutrient diagnosis-CND (Parent and Dafier 5), which provides undistorted variates amenable to Principal Component Analysis (PCA). There are no or little information in the literature on the use of multivariate nutrient diagnosis in mango. The diagnostic precision increases when a large number of nutrients are included in the interpretation process. Further, a reasoned application of PCA could lead to the greater understanding of the nutrient interaction. The present investigation was carried out to develop multivariate diagnostic norms and to understand multivariate nutrient behaviour in mango grown in Peninsular India.

MATERIALS AND METHODS

The first step in implementing CND is the establishment of the standard values or norms. A data bank of nutrient concentration vs. performance was established based on regional survey carried out in six different potentially mango growing regions viz. Ramanagara, Srinivaspur, Chittoor, Krishnagiri, Vengurla and Ratnagiri regions of Peninsular India. The four to seven-month old leaf along with petiole from the vegetative shoots (non-fruiting terminal, in the middle of the whorl) was collected. Four to five samples were collected depending up on the size of the individual land holding. The information on yield was obtained based on the visual performance of the orchard and interaction with the farmer. The entire data set was included for norms deriving purpose

*Corresponding author's E-mail: hbraghu@iihr.res.in

although there was difference in performance in individual cropping enterprises.

The foliar samples were dried at 70°C. The samples were wet digested with H_2SO_4 and H_2O_2 and analyzed for N by Kjeldahl method (Jones et al. 3). Another part of the sample was digested with HNO_3: $HClO_4$ (9:4 v/v). The ICP- OES system was used for determining P, K, Ca, Mg, Fe, Mn, Zn, Cu, B and Mo. The soil samples were analyzed for different parameters as out lined by Page *et al.*, 4). The compositional nutrient diagnosis (CND) which has been proposed for nutritional diagnosis includes physiological concept, such as nutrient interaction in plant and also mathematical constraint to a closed system known as bounded sum constraint (Parent and Dafir 5). The full composition array for the nutrient proportions (D) in plant tissues was described by the following simplex (S^D) contained to 100%:

S^D=[(N, P, K,… R) where N+P+K+…+R =100%]

Where, 100% is the dry matter content (i.e., the invariable sum of all the components or the full relative composition of the diagnostic tissues). N, P, K are the nutrient concentrations and R is the 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. The 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.

$G = [N \times P \times K \times ….. \times R]^{1/D}$

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

$V_N = \ln (N/G),…..,V_{Zn} = \ln (Zn/G)$

Expressions such as N/G, Zn/G are multi-nutrient ratios, since each nutrient is divided by geometric means of all the components (the determined nutrients and the filling value). The row -centered log-ratios are linearized (undistorted) estimates of the original components that are fully compatible with PCA. V^*_N to V^*_{Zn} and SD^*_N to SD^*_{Zn} are the CND norms (indicated by asterisks), i.e., mean and standard deviation of each row cantered log-ratios in the high yielding population. The standardized variables $(V_N - V_N^*) / SD^*_N$ to $(V_{Zn} - V^*_{Zn}) / SD^*_{Zn}$ are the CND nutrient indices.

A reasoned application of PCA could lead to the greater understanding of the effect of fertilization treatments on leaf composition. PCA reduces the number of interdependent variables into smaller number of independent PCs that are linear combinations of original variates (Schleppi et al. 9) A PCA was performed on log transformed nutrient concentration data. According to distribution of data, all the measured concentration was transformed to their logarithms prior to statistical computation. It was shown that, the assumption of log normal distribution was reasonable. 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 non-significant. Only PC loading in eigen vectors having values greater than the selection criterion (SC) are given significance. The selection criterion was computed as: SC = 0.50 / (PC eigen values)$^{0.5}$

RESULTS AND DISCUSSION

The mean N concentration showed wide variations from 1.03 % to 2.87% depending up on the geographic location. Mean N was highest in Konkan region of Maharashtra where in traditionally best mango is grown. The soils were rich in organic carbon level and high nitrogen level in leaf is reflected. There was nearly threefold difference in P concentration in leaf samples of different locations. The P concentration of the Konkan region was higher when compared to the other regions. Potassium being a major dry matter building component showed less variation among different locations when compared to N and P. Calcium concentration was the lowest in Konkan region and the highest in Chittoor region. The soil available Ca also was very high in this region indicating that high levels of Ca in soil is reflected in plant as well. Magnesium concentration showed far less variations compared to Ca. Iron concentration was generally low in most of the places except that of Konkan region. The information on micronutrient levels for Alphonso mango was published earlier (Raghupathi and Bhargava 8). The variation in Zn concentration among different location was not very wide and the lowest concentration of 14.0 mg kg^{-1} was recorded in Krishnagiri and the highest of 24.97 mg kg^{-1} in Vengurla region (Table 1). Boron concentration varied from 3.56 ppm to 16.63 mg kg^{-1} while within the Konkan region mean B concentration showed only marginal differences. Molybdenum concentration although varied considerably among different regions, with in the Konkan region the difference was very narrow.

The CND norms for N (V_N), was higher for Vengurla and Ratnagiri followed by Srinivaspur region (Table 3). The difference in the norm value were not high among different locations for N. Whereas norm value for P (V_P) was particularly high for Konkan region when compared to the norm values developed for Karnataka. Potassium norm (V^*_K) for mango varied narrowly among different regions indicating similar requirement of K for *Alphonso* mango irrespective of the geographic location. As expected the norm value for Ca was far lower for Konkan region when compared the mango

Table 1. Mean concentration of different nutrients in mango leaf under different geographic locations.

Nutrient	Unit	Ramanagara	Srinivaspur	Chittoor	Krishnagiri	Vengurla	Ratnagiri
N	%	1.71	1.74	1.03	1.23	2.87	2.73
P	%	0.11	0.09	0.12	0.13	0.29	0.33
K	%	0.92	0.78	1.13	1.35	0.86	0.94
Ca	%	0.68	0.73	1.34	1.25	0.35	0.35
Mg	%	0.19	0.18	0.31	0.26	0.29	0.28
S	%	0.15	0.15	0.16	0.17	0.17	0.19
Fe	mg kg^{-1}	87.44	78.16	80.53	80.09	260.39	240.10
Mn	mg kg^{-1}	146.70	162.93	68.10	47.23	265.57	227.24
Zn	mg kg^{-1}	19.76	20.96	17.42	14.01	24.97	21.96
Cu	mg kg^{-1}	3.56	3.50	7.57	10.76	5.06	5.97
B	mg kg^{-1}	9.94	9.40	8.47	3.56	16.63	15.59
Mo	mg kg^{-1}	1.33	1.50	1.94	2.28	3.60	2.92

grown in other regions as lateritic soil of the coastal region were low in available Ca (Table 2). Similar was the case with Mg as well indicating in general lower levels of both Ca and Mg for *Alphonso* of Konkan region. Sulphur norm value showed less variation and was independent of the location. The CND norms are multivariate norms with due weight-age for all the other elements including the unmeasured factors. The sum of the tissue components is 100 % and, therefore, the sum of the row centred log ratios including the filling value is zero. The CND norm values developed were difficult to comprehend compared to the nutrient concentration expressed as % or ppm (Raghupathi et al 6). However, the CND norms are having higher diagnostic precision compared to the bi-variate values as in case of diagnosis and recommendation integrated system as outlined by Walworth and Sumner (10).

Among the micronutrients the order of requirement was Mn>Fe>Zn>Cu>B>Mo with the exception in Ramanagara and Srinivaspur region where B requirement was much higher compared to Cu. The variations were observed in diagnostic norms value of Fe in different locations. Although the absolute values for Zn showed marginal difference among different

Table 2. Mean physico-chemical soil properties in different locations.

	Unit	Srinivaspur	Ramanagara	Chittoor	Krishnagiri	Vengurla	Ratnagiri
pH		6.25	6.16	7.16	6.82	6.39	5.76
EC	dSm^{-1}	0.22	0.13	0.19	0.28	0.07	0.11
OC	g kg^{-1}	5.50	8.10	7.90	8.60	22.4	4.40
N	mg kg^{-1}	88.7	131.2	128	139	364	71.3
P	mg kg^{-1}	19.9	22.24	15.5	15.94	9.09	9.49
K	mg kg^{-1}	141	94	133	124	135	163
Ca	mg kg^{-1}	1021	1173	2583	3023	1090	1211
Mg	mg kg^{-1}	222	303	296	361	249	398
S	mg kg^{-1}	44.63	14.46	6.72	4.40	66.1	64
Fe	mg kg^{-1}	28.7	30.3	9.56	8.04	71.32	23.4
Mn	mg kg^{-1}	24.8	37.5	13.04	16.46	18.09	12.0
Zn	mg kg^{-1}	1.1	1.05	1.80	1.76	0.84	1.13
Cu	mg kg^{-1}	2	2.24	2.25	2.80	2.52	4.43
Silt	%	12	14	8	11	14	16
Clay	%	24	26	14	20	34	24
Sand	%	64	60	78	69	52	60

Table 3. CND diagnostic norms for mango for different regions of peninsular India.

CND variate	Ramanagara		Srinivaspur		Chittoor		Krishnagiri		Vengurla		Ratnagiri	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
V_N	3.95	0.27	3.97	0.21	3.31	0.21	3.55	0.24	4.00	0.24	3.98	0.23
V_P	1.18	0.32	1.01	0.22	1.18	0.16	1.34	0.25	1.70	0.24	1.71	0.63
V_K	3.34	0.20	3.11	0.44	3.40	0.23	3.66	0.22	2.81	0.17	2.92	0.20
V_{Ca}	3.04	0.24	3.11	0.15	3.59	0.10	3.57	0.20	1.91	0.13	1.93	0.14
V_{Mg}	1.73	0.24	1.69	0.19	2.11	0.16	1.99	0.24	1.71	0.17	1.72	0.18
V_S	1.49	0.19	1.50	0.21	1.42	0.17	1.56	0.17	1.20	0.19	1.33	0.17
V_{Fe}	-1.43	0.41	-1.47	0.31	-1.49	0.23	-1.52	0.31	-0.79	0.40	-0.83	0.40
V_{Mn}	-1.20	0.83	0.48	0.29	-1.87	0.60	-2.19	0.60	-0.81	0.53	-0.88	0.44
V_{Zn}	-2.81	0.17	0.06	0.01	-3.08	0.19	-3.22	0.21	-3.16	0.46	-3.25	0.44
V_{Cu}	-4.72	0.62	0.01	0.00	-3.94	0.31	-3.58	0.43	-4.66	0.31	-4.49	0.33
V_B	-3.49	0.14	0.03	0.00	-3.86	0.41	-4.63	0.31	-3.45	0.25	-3.49	0.24
V_{Mo}	-5.65	0.53	0.00	0.00	-5.33	0.39	-5.10	0.39	-5.03	0.38	-5.23	0.40

locations, the diagnostic norms value for Zn was far lower for Ratnagiri region. The diagnostic norm value for B was the lowest for Krishnagiri region.

Barring that of Ratnagiri region N was a component of the first PC in all the regions (Fig. 1). As many as eight nutrient elements were found integrated with first PC in many locations. Earlier studies have also indicated that involvement of several nutrients in a single PC and it was not possible to diagnose nutrient imbalance of any particular nutrient in isolation in mango (Raghupathi *et al*., 7). Barring that of Mo all the nutrient elements were having significant loadings in Vengurla region. The contrast indicates a very close association between foliage N and B concentration. However, the relationship between N and B was less conspicuous in Konkan region. Mo was not involved in any significant interaction with any nutrient element in mango except in Ratnagiri region where it was found to have some positive relationship with P. The second PC showed a very significant close association between N and Fe with positive loading and between Ca and Mg with negative loadings (Table 4). The PCs indicated the trend in build-up of nutrients in mango leaf. For example, the first PCs in Ramanagara region indicated that build up in concentration of N, P, K, Mg, Zn and B which resulted in accompanying

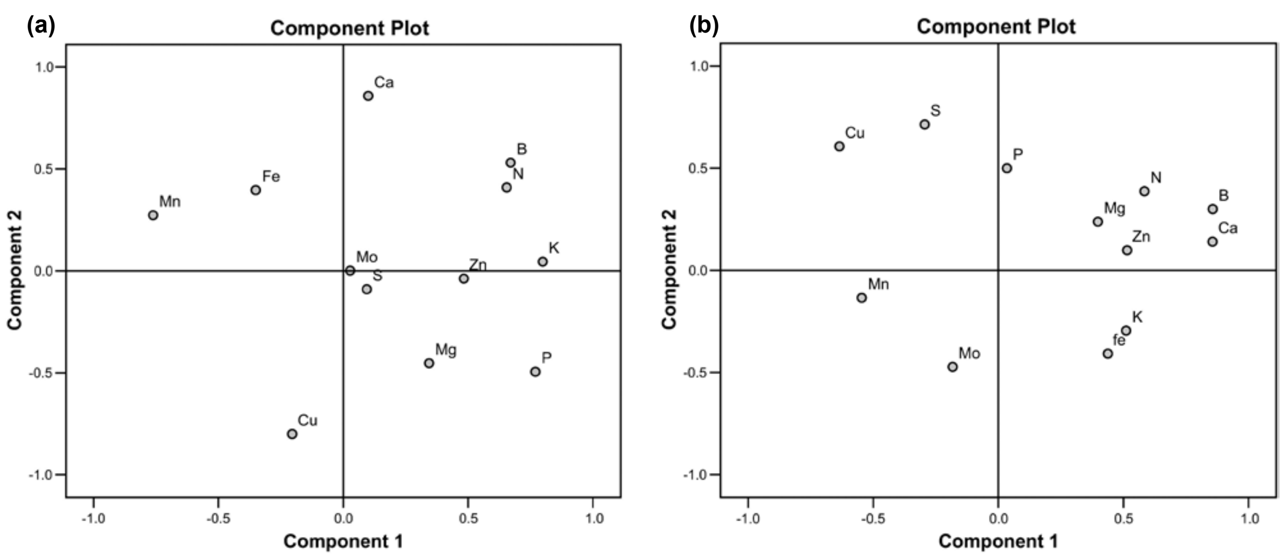

Fig. 1. First two principal components and variable cluster derived from the log transformed nutrient concentration for Ramanagara (a) and Srinivaspur (b).

decrease in concentration of Fe and Mn. The build-up in Ca concentration was found to the central cause for changes in other nutrient concentration. The two eigen values explained about 45 to 51% of the total variance in different regions. The involvement of several nutrients in a single PC indicated multi-nutrient interaction in mango, although some interactions like Zn and K in Ratnagiri region was difficult to explain. The total variance was less effectively captured by PCA in some regions like Ratnagiri when compared to other regions indicating influence of other factors on growth and productivity (Fig. 3). Calcium was excluded from the first PC in both Ramanagara and Chittoor regions (Fig. 2), while N was part of the group with positive loading having close association with P, K, S and Zn. The positively loaded Fe showed a close association

Table 4. Principal component analysis of log transformed nutrient concentrations in mango.

Nutrient	Ramanagara		Srinivaspur		Chittoor		Krishnagiri		Vengurla		Ratnagiri	
	PC1	PC2	PC1	PC2	PC1	PC2	PC1	PC2	PC1	PC2	PC1	PC2
N	0.655*	0.410*	0.584*	0.387*	0.204	0.694*	0.507*	0.227	0.344*	0.895*	0.008	-0.050
P	0.770*	-0.495*	0.034	0.500*	0.603*	0.070	0.880*	0.003	0.344*	0.895*	-0.559*	-0.583*
K	0.799*	0.045	0.511*	-0.295	0.716*	-0.223	0.704*	0.172	0.325*	0.080	-0.267	0.478*
Ca	0.100	0.859*	0.856*	0.140	-0.211	0.658*	-0.661*	0.526*	0.843*	-0.074	0.743*	-0.068
Mg	0.344*	-0.453*	0.398*	0.238	-0.128	-0.641*	0.226	0.662*	0.658*	-0.412*	0.636*	0.258
S	0.094	-0.090	-0.294*	0.714*	0.391*	0.538*	-0.157	0.583*	0.569*	-0.657*	0.241	0.314*
Fe	-0.351*	0.397*	0.438*	-0.408	-0.005	-0.127	-0.724*	0.142	-0.641*	-0.192	0.093	0.427*
Mn	-0.762*	0.273	-0.546*	-0.134	-0.538*	0.172	-0.421*	-0.569*	-0.577*	-0.251	0.596*	-0.317*
Zn	0.483*	-0.038	0.515*	0.098	0.623*	-0.049	0.548*	0.469*	-0.565*	0.061	-0.460*	0.444*
Cu	-0.205	-0.800*	-0.635*	0.607	0.668*	-0.390*	0.609*	-0.485*	0.479*	-0.567*	0.048	0.683*
B	0.670*	0.531*	0.857*	0.300	-0.558*	-0.481*	-0.593*	0.214	0.621*	0.188	0.484*	-0.345*
Mo	0.028	0.002	-0.183	-0.473	-0.268	0.238	-0.275	-0.292	-0.068	0.182	-0.230	-0.433*
Eigen Value	3.224	2.519	3.508	1.947	2.630	2.150	3.830	2.060	3.490	2.707	2.264	1.992
% Variance	26.87	47.86	29.23	45.46	21.98	39.95	31.99	49.21	29.12	51.68	18.86	35.47
SC	0.278	0.315	0.267	0.358	0.308	0.341	0.255	0.348	0.268	0.304	0.332	0.354

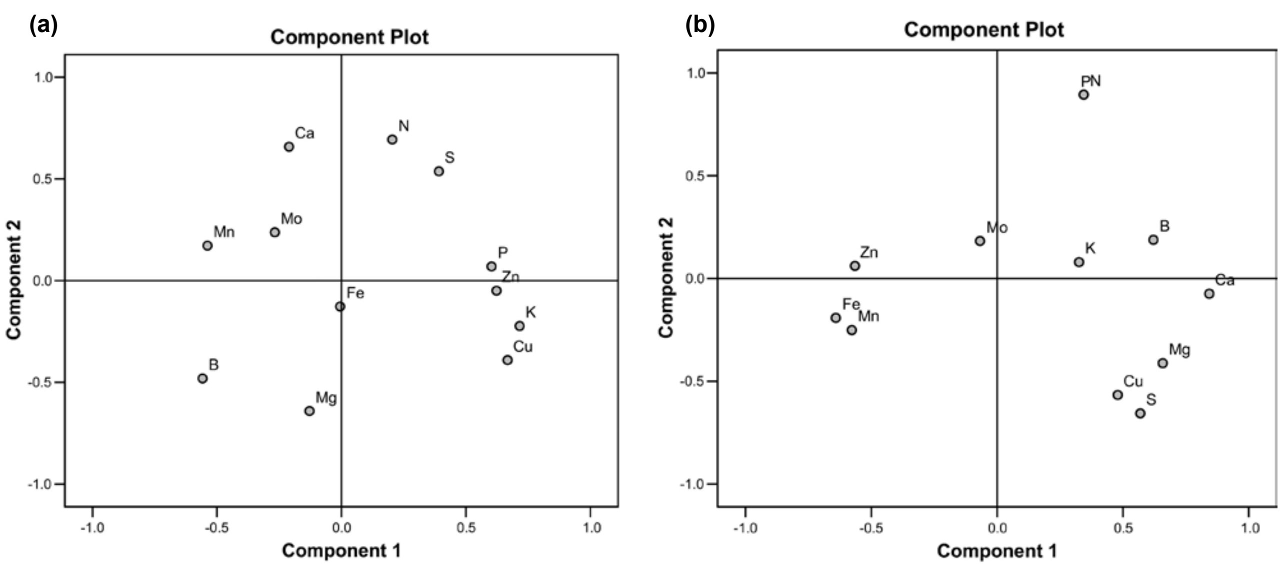

Fig. 2. First two principal components and variable cluster derived from the log transformed nutrient concentration for Chittoor (a) and Krishnagiri (b).

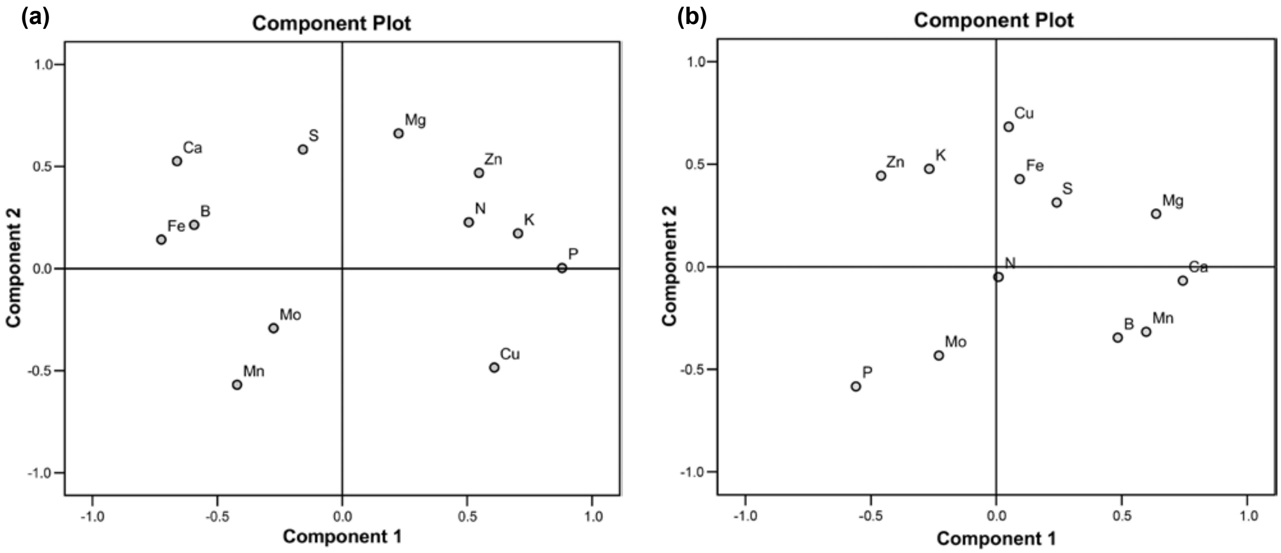

Fig. 3. First two principal components and variable cluster derived from the log transformed nutrient concentration for Vengurla and Ratnagiri.

with K in Srinivaspur region. The positive loading for P and Zn in many locations indicated existence of no antagonistic relations between two as reported in many crops. Notwithstanding twofold higher levels of Fe in Konkan region no accompanying relationship with major nutrient was noticed (Fageria 2). The inclusion of many nutrients elements indicated importance of no single element in growth and production of mango.

REFERENCES

1. Anonymous 2004. Leaf analysis in fruit crops Extension folder No 45-07, Indian Institute of Horticultural Research Hessaraghatta, Bengaluru, 560 089.
2. Fageria, V.D. 2001. Nutrient interaction in crop plants. *J. Plant Nutri*. **24**: 1269-90.
3. Jones Jr. J.B., Wolf, B. and Mills, H.A. 1991. Plant Analysis Handbook - A Practical Sampling, Preparation, Analysis and Interpretation Guide. Micro-Macro Publishing Inc., Athens, USA, 213 p.
4. Page, A.I. Miller, R.H. and Keeny, D.R. 1982. Methods of Soil Analysis Part 2 America Soc Agron Inc. Madison, USA, pp. 403- 30.
5. Parent, L.E. and Dafier, M. 1992. A theoretical concept of compositional nutrient diagnosis. J American Soc. Hort. Sci. **117**: 239-42.
6. Raghupathi, H.B. Reddy, B.M.C. and Srinivas, K. 2002. Multivariate diagnosis of nutrient imbalance in banana. Comm. Soil Sci. Plant Anal. **33**: 2143-43.
7. Raghupathi, H.B. Reddy, Y.T.N., Kurian Reju, M. and Bhargava, B.S. 2004. Diagnosis of nutrient imbalance in mango by DRIS and PCA approaches. *J. Plant Nutri.* **27**: 1131-48.
8. Raghupathi, H.B. and Bhargava, B.S. 1999. Preliminary nutrient norms for Alphonso mango using diagnosis and recommendation integrated system. *Indian J. Agri. Sci*. **69**: 648-50.
9. Schleppi, P. Tobler, L. Bucher, J. B. and Armim, W.A. 2000. Multivariate interpretation of foliar chemical composition of Norway spruce (*Picea abies*). *Plant Soil*, **219**: 252-262.
10. Walworth, J.L. and Sumner, M.E. 1987. The Diagnosis and Recommendation Integrated System (DRIS). In: Advances in Soil Science Vol 6. pp. 149-87 Springer Verlag, New York.

Received : July, 2016; Revised : December, 2017; Accepted : February, 2018