Indian Journal of Agricultural Sciences **80** (9): 835–7, September 2010

Multivariate nutrient diagnostic norms for Coorg mandarin (*Citrus reticulata*)*

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Received: 22 October 2009; Accepted: 11 June 2010

Key words: Coorg mandarin, Diagnostic norms, Nutrition

The satisfactory production of Coorg mandarin (*Citrus reticulata*) grown in the coffee-based multi-storied cropping system largely depend upon the sustenance of healthy and vigorous canopy development. The major vegetative flushes in Coorg mandarin under Kodagu ecosystem occurs normally during September–October that is crucial to the flowering of main crop in March–April of the following year. The second flowering occurs in October–November and the fruits are harvested during June–July. On an average, Coorg mandarin takes about 9 to 10 months to attain maturity. In recent years, owing to erratic rainfall patterns, the defined flowering seasons however overlap and erratic flowering is observed. Citrus trees demand lot of nutrients and therefore are prone to many disorders related to mineral nutrition. In Kodagu region, the continuous cultivation of citrus plant with little or no replenishment of nutrients often resulted in multinutrient deficiency. Therefore, monitoring of leaf nutrient concentration is essential to rejuvenate and increase the yield levels of many of the orchards that are showing the symptoms of decline in the recent years.

The leaf nutrient guides for Nagpur mandarin were developed earlier (Srivastava and Shyam Singh 2003). The nutrient diagnostic norms are usually developed based on the localized survey of orchards and therefore such norms are region-specific although norms developed for on region could find application with slight adjustment for similar growing conditions elsewhere. Both the plant analysis information as well as diagnostic norms is required for evolving nutrient management strategies in Coorg mandarin production.

Several approaches were adopted for identification of nutrient imbalance, the recent being compositional nutrient diagnosis-CND (Parent and Dafier 1992), 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 citrus. The diagnostic precision increases when a large number of nutrients are included in the interpretation process. Further, a reasoned application of principal component analysis could lead to the greater understanding of the nutrient interaction in Coorg mandarin. Principal component analysis reduces the number of interdependent variables into smaller number of independent principle components that are linear combinations of original variates. Therefore, the present investigation was carried out to develop multivariate diagnostic norms for Coorg mandarin suffering from declining symptoms. Principal component analysis was performed on log transformed nutrient concentration data to understand nutrient behaviour in plant.

The leaf nutrient concentration VS yield data bank was developed based on the survey carried out in different orchards of Coorg mandarin involving collection of leaf samples from trees of approximately 20 to 25 years of age in the sampling units. Leaf samples from 233 sampling units were collected, of which 74 represented budded plants and 159 represented seedling plants representing all the 3 districts of Kodagu. The yield of less than 50 to 60 kg/tree was classified as low. The growers in the region adopted no exclusive fertilization package for Coorg mandarin cultivation, as the crop was grown mainly as a mixed crop with coffee.

The leaf samples from 4 to 5 months old non-fruiting terminals at 3/4 leaf expansion stage were collected randomly from the different orchards in December–January. About 100 leaves were sampled from around 5 to 10 trees/sample. The soils were acidic in reaction and were dominantly Alfisols belonging to great group Typic Paleustalfs. The samples were washed in sequence with liquid detergent, dilute HCl and with double distilled water. The leaf samples were dried, wet digested and analyzed for N by Kjeldahl method. Another part of the sample was digested with $HNO_3 : HClO_4$ (9:4 v/v). Phosphorus was estimated by vanado-molybdate method and K was estimated by flame photometer (Bhargava

*Short note

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and Raghupathi 2005). Atomic absorption spectrophotometer (Perkin Elmer AA Analyst 200) was used for determining Ca, Mg, Fe, Mn and Zn in the acid digest.

Compositional Nutrient Diagnosis technique as outlined by Parent and Dafir 1992, was adopted for deriving multi-nutrient norms. The technique effectively addresses the problem of nutrient interactions, dilution or accumulation in plant tissues.

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): N>O, P>O, K>O, …, R>O; 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.

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.

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

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

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

Expressions such as N/G, Zn/G are the 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 the linearized (undistorted) estimates of the original components that are fully compatible with principal component analysis.

V^*_N to V^*_{Zn} and SD^*_N to SD^*_{Zn} are the Compositional Nutrient Diagnosis norms (indicated by asterisks), ie mean and standard deviation of each row centered log-ratios in the high-yielding population. The standardized variables.

$$(V_N - V^*_N)/SD^*_N \text{ to } (V_{Zn} - V^\times_{Zn})/SD^\times_{Zn}$$

are the nutrient indices (Table 1).

The range of N concentrations in seedling plants were

Table 1 Compositional nutrient diagnostic norms for Coorg mandarin (V values) in sampled units of Kodagu region

CND variate	Budded		Seedlings	
	Norms	Standard deviation	Seedlings	Standard deviation
V_N	2.20	0.134	1.973	0.290
V_P	0.36	0.394	0.140	0.508
V_K	1.83	0.279	1.542	0.350
V_{Ca}	1.76	0.324	1.869	0.451
V_{Mg}	–0.015	0.155	0.082	0.226
V_{Fe}	–3.299	0.406	–3.328	0.424
V_{Mn}	–4.140	0.393	–3.935	0.562
V_{Zn}	–4.653	0.217	–3.99	0.653

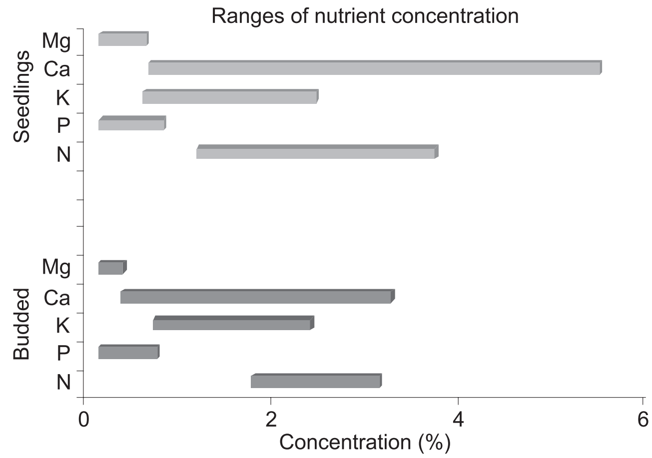

Fig 1 Ranges of major nutrient concentration in Coorg mandarin leaf samples

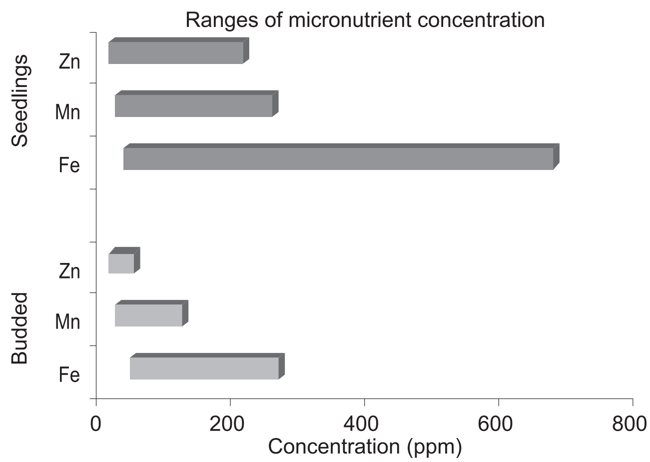

Fig 2 Ranges of micronutrient concentration in Coorg mandarin leaf samples

much wider when compared to budded plants. Phosphorus and K concentration range between budded and seedling plants indicated only marginal differences (Fig 1). Calcium and Mg concentration varied more widely in seedling plant compared to budded plants. In general, concentration of Fe in seedling plant was higher compared to budded plants and both Mn and Zn showed greater variation in seedling plants (Fig 2). Seedling plants tended to have deeper rooting system as compared to budded plants.

The multivariate diagnostic norms generated higher values of N, P and K for budded plants as compared to the seedlings. Such a trend suggested greater requirements of N, P and K for budded plants. Differences in norms were also recorded for Ca and Mg for budded and seedling plants. The V_{Ca} and V_{Mg} norms values were 1.76 and 1.86, –0.015 and 0.082 for budded and seedlings plants, respectively. The Compositional Nutrient Diagnosis norms for Fe in respect of budded plants (V_{Fe} –3.299) were marginally higher as compared to the seedling plants (V_{Fe}–3.328). The norms for Mn and Zn were

Table 2 Principal component loadings for leaf nutrient concentration in Coorg mandarin

Variate	Budded plants			Seedlings	
	PC1	PC2	PC3	PC1	PC2
N	0.845*	–0.104	0.228	0.786*	–0.388
P	0.226	–0.155	0.845	0.014	–0.408
K	0.072	0.849*	–0.207	0.075	0.812*
Ca	0.878*	–0.123	–0.045	0.068	0.817*
Mg	0.808*	0.217	0.034	0.634*	0.568*
Fe	0.886*	0.055	0.196	0.667*	0.414*
Mn	–0.032	0.647*	0.596	0.933*	0.003
Zn	0.717*	0.440*	0.152	0.941*	0.138
EV	3.714	1.381	1.061	3.481	1.908
SC	0.259	0.425	0.485	0.172	0.361
Variance (%)	46.42	17.25	13.26	43.51	23.85

PC, Principal component; EV, eigen values; SC, selection criteria

higher for seedlings as compared to the budded plants. The differences in concentration of nutrients between budded and seedling plants may be attributed to stionic effect between rootstock and scion in budded plants while it is straight translocation of nutrients from roots.

Principal component analysis elucidated the interactions among the different nutrients. For budded plants, the first principle component explained nearly 46% of the total variance and the loadings for N, Ca, Mg, Fe and Zn were positive and significant. In the second principle component, the loadings for K, Mn and Zn were significant and in the third principle component, the loadings for P and Mn were significant indicating their mutual associations (Table 2). In the seedling plants, in first principle component, the loadings for N, Mg, Fe, Mn and Zn were significant. As many as 4 nutrient elements, viz K, Mg, Fe and Zn were significant in the second principle component indicating that the first principle component has not fully explained the variations among the nutrient concentrations in the seedling plants (Table 2). The interaction between Zn and P is well-documented crop plants (Fageria 2001).

The leaf nutrient concentration in Coorg mandarin budded plant as a group varied markedly from that of the seedlings. The N, P, K and Fe requirements of budded plants were much higher as compared to the seedlings while nutrients like that of Ca, Mg, Mn and Zn requirements of seedling plants were higher. The multivariate diagnostic technique and application of principal component analysis indicated that the nutrients build-up or depletion in Coorg mandarin, irrespective of their budded or seedling status does not occur in isolation. Therefore, multi-nutrient applications and monitoring of leaf nutrient concentrations are needed to avoid any nutrient imbalances affecting crop health in the long run.

SUMMARY

A data bank of leaf nutrient concentration vs yield was established for Coorg mandarin through survey of coffee-based cropping system of Kodagu region for developing leaf nutrient diagnostic norms. Multivariate compositional nutritional diagnosis norms were derived for diagnostic purpose and for identification of yield-limiting nutrients. Principal component analysis was used to extract the correlation structure among different nutrient elements. The mean concentrations of N, P and K between budded and seedling plants indicated only marginal differences. The mean concentrations of Ca, Mg, Fe, Mn and Zn however were much lower in budded plants as compared to their concentrations in seedling plants. The compositional nutritional diagnosis norms for N, P and K were higher for budded plants as compared to the seedlings. Differences in compositional nutritional diagnosis norms were also observed for Ca and Mg in respect of budded and seedlings plants. The compositional nutritional diagnosis norm for Fe was marginally higher for budded plant as compared to the seedling plants. The compositional nutritional diagnosis norms for Mn and Zn were higher for seedling as compared to budded plants. Principal component analysis indicated the existence of multinutrient interaction in Coorg mandarin and correction of nutrient imbalance cannot be done in isolation and therefore multinutrient diagnostic norms are required for identification of nutrient deficiency or excess.

ACKNOWLEDGEMENT

The authors are grateful to the Department of Horticulture, Government of Karnataka for providing *grant-in-aid* to the *ad-hoc* projects of Rejuvenation of Coorg mandarin and Diagnostic approaches and development of management strategies for rejuvenation of Coorg mandarin.

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