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Evaluating the primary yield limiting leaf nutrient deficiency of coconut (*Cocos nucifera* Linn.) in a major coconut growing zone of Tamil Nadu

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Abstract

The present study was conducted to evaluate the yield relationship of leaf nutrient status in two major coconut growing districts (Coimbatore and Tiruppur) of Tamil Nadu. Leaf samples and yield data were collected from coconut gardens and the nutrient contents were analysed. Leaf nitrogen, phosphorus and potassium status in the study area ranged between 0.71 to 2.63, 0.05 to 0.15 and 0.51 to 1.76 per cent with a means of 1.42, 0.11 and 0.99 per cent, respectively. The leaf calcium, magnesium and sulphur contents were in the range of 0.54 to 1.92, 0.11 to 1.51 and 0.16 to 2.14 per cent with the mean values of 0.88, 0.48 and 0.62 per cent, respectively. The leaf micronutrient status were in the range between 37 to 392 mg kg^{-1} of Fe, 158 to 634 mg kg^{-1} of Mn, 6.6 to 40.7 mg kg^{-1} of Zn, 2.0 to 54.8 mg kg^{-1} of Cu and 3.2 to 23.8 mg kg^{-1} of B. The mean values of Fe, Mn, Zn, Cu and B were 230.7, 315, 19.3, 10.8 and 12.6 mg kg^{-1} respectively. Significant and positive correlation coefficient was observed between yield with leaf magnesium (0.269**), nitrogen (0.260**) and potassium (0.200**). Stepwise multiple regression analysis revealed that leaf potassium, nitrogen and magnesium are the most important yield influencing leaf nutrients in the study area.

Keywords: Coconut, leaf nutrients, yield limiting factors

Introduction

The coconut palm (*Cocos nucifera* Linn.) is grown globally around 93 countries worldwide. In India, coconut is grown in 1.97 million hectares (2014-15) with a production of 14,067 million nuts and an average productivity of 7,141 nuts ha^{-1} $year^{-1}$. In Tamil Nadu state, coconut is raised extensively in Coimbatore, Tiruppur, Thanjavur, Dindigul, Kanyakumari, Vellore, Erode, Tirunelveli, Theni, Krishnagiri, Salem and Madurai districts.

Leaf analysis has been recognized as a more reliable method for detecting nutrient deficiencies in perennial crops. In tree crops like coconut, the plant diagnostic methods provide more reliable information on the nutritional status of plants in relation to soil fertility potential. Wahid *et al.* (1974) studied the relationship between yield and content of mono and divalent cations in coconut that was found to be governed by their ratios in soil. Due to the variations in climate, soil condition, crop management *etc*., it is difficult to define standard nutrient management package with spatially wide applicability. Therefore, the yield relationship with the leaf nutrient status and its deficiencies, that are site specific, are more appropriate to define the limiting nutrients and yield response in a closely defined condition. With these backgrounds, the study was conducted to find out the primary yield limiting nutrients through understanding the relationship between the leaf nutrient status and coconut yield in the two major coconut growing districts of Tamil Nadu.

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Materials and methods

The present study was conducted in the coconut land cover of Coimbatore and Tiruppur districts of Tamil Nadu state which is geographically positioned within 10°10' and 11°30' North latitude and between 76°40' and 77°30' East longitude. Geographical area of Coimbatore district is 4,722 km^2 and that of Tiruppur district is 5,186.34 km^2. Coconut is one of the major crops in Coimbatore district which has an area of 83,789 ha and a productivity of 10,262 nuts ha^{-1} $year^{-1}$, while Tiruppur district has 56,808 ha of coconut with the productivity of 9,191 nuts ha^{-1} $year^{-1}$ (CDB, 2015). In the present study, an extensive survey was carried out randomly covering 110 sample coconut gardens located across the study area leaf samples and corresponding yield of the coconut plantations were collected.

Leaf sample collection and analysis

The middle three leaflets of both the sides of the index leaf (14^{th} frond) of all the sampled palms were collected. Samples were processed and wet digestion of a known quantity of plant material was carried out with di-acid mixture (H_2SO_4 and $HClO_4$ in the ratio of 5:2, respectively) for N estimation, di-acid mixture of HNO_3 and $HClO_4$ in the ratio of 9:4 respectively, for S estimation and tri-acid mixture (nitric, sulphuric and perchloric acid in the ratio of 9:2:1) for P, K, Ca, Mg, Fe, Mn, Zn, Cu and B estimation (Piper, 1966).

The leaf nitrogen was analysed by Micro Kjeldahl method (Humphries, 1956), leaf phosphorus by vanadomolybdate yellow colour method (Jackson, 1973; Piper, 1966), leaf potassium by flame photometry (Stanford and English, 1949), leaf calcium and magnesium by the Versenate titration method (Diehl *et al.*, 1950), sulphur by turbidimetry (Chaudry and Cornfield, 1966), micronutrients (Fe, Mn, Zn and Cu) using atomic absorption spectrophotometer (Jackson, 1973; Piper, 1966) and leaf boron content by azomethane H reagent method (Berger and Troug,1939).

Yield data collection

Coconut yield of the sampled palms were collected by counting all the nuts of all bunches. Total nut yield of the palms were calculated by adding the matured nuts (above fist sized nut) and 30 per cent of the small nuts (below fist sized nuts) from each sampled palms as per the setting percentage of the flowers.

Statistical analysis

The Pearson product moment correlation coefficient (r) was worked out to define the relationship between the nutrient status and the coconut yield.

Measures of relationships between the variables

Simple form of correlation between the variables was worked out. The Pearson product moment correlation coefficient (r) giving both the strength and direction of linear relationship was used and is expressed by:

$$r = \frac{n(\Sigma xy) - (\Sigma x)(\Sigma y)}{\sqrt{[n(\Sigma x^2) - (\Sigma x)^2][n\Sigma y^2 - (\Sigma y)^2]}}$$

Where, r = Pearson product-moment correlation coefficient (a measure of the linear relationship between two variables); n = number of observation. When r = ± 1, a perfect linear correlation is attained, and r = 0 implies that two variables have no linear relationship (Best and Kahn, 2003). The coefficient of determination was used to measure the proportion of variation in one of the variables as explained by the variation in another variable. Simple linear regression was worked out to model the relationship between the leaf nutrient content and the yield.

Stepwise multiple regression analysis was performed using SPSS 16.0 to identify the most yield influencing leaf nutrient in the study area.

Result and discussion

Leaf nutrient status and yield

The range, mean and per cent CV of the coconut leaf nutrient status and yield were worked out (Table 1). In the study area, leaf nitrogen ranged between 0.71 and 2.63 per cent with a mean of 1.42 per cent and CV of 32 per cent. The leaf phosphorus ranged from 0.05 to 0.15 per cent and the mean was 0.11 per cent and CV was 20 per cent. The coconut leaf potassium was found to be in the range of 0.51 to 1.76 per cent and the mean and CV was 0.99 and 24 per cent,

Table 1. Leaf nutrient content and yield of coconut observed in the study area

S. No.	Parameter	Range	Mean	CV (%)
1.	Leaf N (%)	0.71 - 2.7	1.42	32
2.	Leaf P (%)	0.05 - 0.1	0.11	20
3.	Leaf K (%)	0.51 - 1.8	0.99	24
4.	Leaf Ca (%)	0.54 - 1.9	0.88	31
5.	Leaf Mg (%)	0.11 - 1.5	0.48	47
6.	Leaf S (%)	0.16 - 2.1	0.62	65
7.	Leaf Fe (mg kg^{-1})	37.0 - 392.0	230.70	30
8.	Leaf Mn (mg kg^{-1})	158.0 - 634.0	315.00	33
9.	Leaf Zn (mg kg^{-1})	6.6 - 40.7	19.30	44
10.	Leaf Cu (mg kg^{-1})	2.0 - 54.8	10.80	67
11.	Leaf B (mg kg^{-1})	3.2 - 23.8	12.60	36
12.	Yield (nuts $palm^{-1}$ $year^{-1}$)	48.0 - 168.0	90.60	25

respectively. The leaf calcium ranged between 0.54 to 1.92 per cent and mean was 0.88 per cent with the CV of 31 per cent. The coconut leaf magnesium range was observed to be from 0.11 to 1.51 per cent with the mean and CV was 0.48 and 47 per cent. The range of leaf sulphur was found to be from 0.16 to 2.14 per cent and mean was 0.62 per cent with the CV of 65 per cent.

The leaf iron content was in the range between 37 to 392 mg kg^{-1} and the mean was 230.7 mg kg^{-1} with the CV of 30 per cent. Leaf manganese content was observed between 158 to 634 mg kg^{-1} and the mean was 315 mg kg^{-1} and CV was 33 per cent. Coconut leaf zinc content was ranging from 6.6 to 40.7 mg kg^{-1} with the mean of 19.3 mg kg^{-1} and CV of 44 per cent. The leaf copper content recorded was between 2.0 to 54.8 mg kg^{-1} and the mean was 10.8 mg kg^{-1} and CV was 67 per cent. Boron content of the leaf was observed between 3.2 to 23.8 mg kg^{-1} with the mean of 12.6 mg kg^{-1} and CV of 36 per cent. Coconut yield ranged from 48 to 168 nuts $palm^{-1}$ $year^{-1}$ with a mean of 91 nuts $palm^{-1}$ $year^{-1}$ and CV of 25 per cent. The detailed spatial information on the leaf nutrient status of the study area is has been reported earlier by Selvamani and Duraisami (2014).

Statistical relationship between leaf nutrients and yield

Simple correlation

Relationship between leaf nutrient content and the yield was studied by working out the Pearson product-moment correlation coefficients using all 110 samples (Table 2). Highest, significant and positive correlation (0.269**) was observed between leaf magnesium content with coconut yield. Deficient samples (leaf magnesium less than 0.3 per cent) observed in the study area were around 18 per cent with a CV of 47. Though the per cent deficiency observed is low, magnesium showed highest correlation with yield mainly because in coconut, magnesium is found to be more important and falls only next to potassium. Magnesium deficiency leads to loss of chlorophyll since it is an important constituent of the chlorophyll. Moreover, it plays a key role as an activator of many enzyme reactions and also a carrier for phosphorus. Apart from this, magnesium has a special importance to the formation of oil seeds. Similar yield contributing nature of magnesium was also reported by Manicot *et al.* (1979).

Table 2. Correlation coefficients (r) of relationships between leaf nutrient content and coconut yield (nuts $palm^{-1}$ $year^{-1}$)

Nutrient	r
N	0.260**
P	0.042
K	0.200*
Ca	-0.036
Mg	0.269**
S	-0.034
Fe	0.087
Mn	0.112
Zn	0.179
Cu	0.067
B	0.149

**Correlation is significant at 0.01 level; *Correlation is significant at 0.05 level; N=110

Closely following magnesium, significant and positive correlation coefficient was also obtained for leaf nitrogen (0.260**) and yield. Nitrogen is essential for the growth and metabolism of coconut palms. It increases button setting and improves production of nuts per year. This could be a reason that, significant and positive relationship might have been observed in this study. In addition to its importance, in the study area, nitrogen deficiency (leaf nitrogen less than 1.8 per cent) appeared to be widespread (around 70 per cent of the samples showed nitrogen deficiency). Therefore, leaf nitrogen status emerged as an important yield limiting nutrient in this area.

Next to nitrogen and magnesium, highly significant positive correlation was observed with leaf potassium (0.200**) and yield. Eventhough, the deficiency samples (leaf potassium content less than 0.8 per cent) observed in the study area was only around 15 per cent, the leaf potassium status was found to influence yield strongly. This is because, in coconut, potassium is the nutrient which is absorbed in largest quantity and is considered most important for nut production. Considerable quantity of potassium is present in the husk. Potassium shows a significant role in fruit setting and in the number of inflorescences, female flowers and nuts produced (Ollivier, 1993a). Apart from this, potassium plays a vital role in the metabolism, metabolite transfer, cellular division, enzyme activation and stomatal movement. Gopalasundaram and Yusuf (1989) also expressed that K and N are the most important nutrients for coconut yield.

Positive but non significant correlations were obtained for leaf manganese (0.112), zinc (0.179) and boron (0.149) with the yield. The correlations of leaf phosphorus, calcium, sulphur, iron and copper against yield were very low and non significant. The cause of the observed low correlation may be the occurrence of multi nutrient deficiency observed in the samples having these nutrient deficiencies.

Simple linear regression models

Simple linear regression was worked out to model the relationship between the leaf nutrient content and the yield under deficient condition so as to understand the yield response for the increase in the nutrient status. To model this relationship of a particular nutrient, the samples which showed deficiency of a single nutrient element and sufficiency in all other nutrients, were used. Samples having single nutrient deficiency were available only for nitrogen (samples leaf nutrient content less than 1.8%) and phosphorus (samples leaf nutrient content less than 0.12%). The r^2 obtained for leaf nitrogen against yield was 0.77 and for phosphorus against yield resulted 0.59. Singh *et al.* (2016) also reported that increased dose of nitrogen and phosphorus was significantly correlated with different growth and yield characters of guava. In the sample set, except N and P, deficiency was in multiple nutrient deficiency status for all other elements. Co-limitation of one or more of other nutrients occurred. This multiple deficiency resulted with lower r^2 values except for potassium which showed r^2 of 0.81 even in multiple nutrient deficiency conditions. This showed the strong influence of potassium on coconut yield. In coconut, luxury consumption of potassium often takes place since the coconut husk contains significant percentage of total potassium uptake. Linear relationship for potassium with yield was also reported by Palaniswami *et al*. (2010).

The correlation between magnesium and yield was found to be low among the deficient samples because of the occurrence of multiple nutrient deficiencies. After removing the samples having co-limitation of potassium deficiency from the set of magnesium deficient samples, the coefficient of determination of leaf magnesium content with yield was improved and found high (0.79). Hence, under potassium sufficiency condition, the magnesium levels show a highly positive yield response. Manicot *et al.* (1979) also reported that the main effect of Mg could be as much as 40 per cent when K was in the sufficiency level. This finding is in line with that of Ollivier (1993b), who reported that number of green

Table 3. Relationship between leaf nutrient content (below critical level) and yield of coconut (nuts palm^{-1} year^{-1}) in the study area

S. No.	Nutrient	Critical level	Model	r^2
1.	Nitrogen (%)	1.80 (%)	y = 61.449x + 15.109	0.77
2.	Phosphorus (%)	0.12 (%)	y = 830.8x + 31.908	0.59
3.	Potassium (%)	0.80 (%)	y = 157.12x - 28.077	0.81
4.	Magnesium (%)	0.30 (%)	y = 253.33x + 26.171	0.79
5.	Boron (mg kg^{-1})	10 (mg kg^{-1})	y = 0.0923x - 0.6187	0.60

Table 4. Stepwise multiple regression model of the relationship between the leaf nutrient status and coconut nut yield in the study area

Model	R	R square	Adjusted R square	Sig.
Nut Yield = 20.945+ 35.487* Leaf K + 17.166* Leaf N + 21.583* Leaf Mg	0.479[c]	0.230	0.208	0.000[c]

c. Predictors: (Constant), Leaf K%, Leaf N%, Leaf Mg%

leaves in the crown is correlated with the magnesium levels once any potassium deficiency prevailing is corrected and also reported that magnesium affects the number of nuts produced per tree and thereby influence the yield.

Among the micronutrients, boron showed high r^2 value (0.60). The r^2 value of iron, manganese, zinc and copper were non significant since the effect of the deficiency of these nutrients which were in multiple nutrient deficient status, were affected by the nutrient status of the other nutrients in the present set of samples. Therefore, the other co-limiting nutrients interfere with the relationship between the varying levels of the nutrient and yield leading to the non significant correlation of these nutrients with the yield.

Stepwise multiple regression analysis

Stepwise multiple regression analysis was employed to identify the degree of influence of the leaf nutrient status on the coconut yield. The following model was developed for the study area and showed R value of 0.479 and R square value of 0.230 (Table 4). Multiple regression analyses was also used to identify the major factors influencing the mango yield by Kumar *et al.* (2013) and found that the extent of variability in fruit yield as influenced by leaf nutrient contents were up to 66 to 73 per cent in high and low productive mango orchards, respectively in the four districts studied. The results of stepwise multiple regression analysis in this study showed that leaf K, leaf N and leaf Mg were found to have significant influence on the yield (Table 5) in the study area. Around 37 per cent of yield variation was contributed by the leaf K status, therefore, emerging as most important yield limiting nutrient wherever it is deficient.

Leaf nitrogen content found to be the second nutrient contributing to the coconut yield variation and found to be up to 34.1 per cent. The third nutrient which showed significant influence on the yield was leaf magnesium content that contributed up to 19.0 per cent of the variation in the yield. All other nutrients were found to be non significant in increasing the R square value of the prediction model, therefore, excluded by the stepwise regression process. Though, the other nutrient status and deficiency influence coconut yield, the masking effect of K, N and Mg deficiency in the multiple nutrient deficiency status could have resulted with the non significant influence of other nutrients on the yield.

Table 5. Standardized coefficients of the independent variables of the stepwise multiple regression model of leaf nutrient status and coconut nut yield in the study area

Independent variables	Standardized Coefficients Beta	Sig.
(Constant)		0.103
Leaf K%	0.370	0.000
Leaf N%	0.341	0.000
Leaf Mg%	0.190	0.030

Conclusion

This study showed that the primary yield limiting nutrients observed in the study area for coconut are N, Mg, K, B and P. The most important yield limiting nutrient deficiencies identified by multiple regression analysis are in the order of leaf potassium, nitrogen and magnesium. These findings are important while developing nutrient management strategies for the coconut land cover of the study area in order to improve and maintain the soil fertility and coconut productivity.

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