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Effect of Different Planting Density in Cocoa (*Theobroma cacao l.*) on Leaf Macro and Micronutrient Levels Grown under Coconut Ecosystem

Mohanalakshmi. M [a], V. Jegadeeswari [b*], K. R. Vijayalatha [b], K. Padmadevi [c], G. Sidhdharth [b] and J. Kalaivani [b]

[a] Horticultural College and Research Institute, Coimbatore, India.
[b] Horticultural College and Research Institute for Women, Tiruchirappalli, India.
[c] Agricultural College and Research Institute, Karur, India.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

An experiment investigating the impact of different cocoa densities on leaf macro and micronutrient levels within a coconut ecosystem was conducted at the Coconut Farm of the Horticultural College and Research Institute, Tamil Nadu Agricultural University, Coimbatore. The study employed a Randomized Block Design (RBD) comprising eight treatments, each replicated three times.

**Corresponding author: E-mail: jegadeeswari.v@tnau.ac.in;*

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Notably, among the various spacing configurations, T1 (3m x 1.2m) exhibited the highest levels of leaf nitrogen (1.86%), phosphorus (0.084%), potassium (1.39%), and boron (91.33 ppm) content. This suggests that under Tamil Nadu conditions, high-density planting in the T1 treatment not only resulted in elevated nutrient levels but also correlated with a notable increase in revenue. These findings underscore the potential benefits of adopting high-density planting practices in cocoa cultivation within coconut ecosystems. Further research is warranted to explore the long-term implications of spacing configurations and nutrient interactions on crop productivity and profitability.

Keywords: Cocoa; spacing; macro and micro nutrients.

1. INTRODUCTION

Cocoa, originating from the Amazon region, serves as a vital cash crop in the humid tropics spanning from 20º N to 20º S of the equator [1]. Its optimal growth conditions include an elevation of approximately 300 meters above sea level, with an annual rainfall of 1500-2000 mm and temperatures ranging from 15-39°C. Adequate humidity levels are crucial for its cultivation. While the Theobroma genus comprises over 20 species, only T. cacao is commercially grown. In India, cocoa farming commenced in the 1970s, primarily in South India, notably Kerala, where it is commonly intercropped with coconut. Kerala dominates the cocoa cultivation scenario, contributing to 76% of the area and 78% of total production, while Karnataka and Tamil Nadu also partake in cocoa cultivation.

High density planting (HDP), developed in the 1980s by the Ministry of Agriculture, Land and Marine Resources (MALMR), is an alternative to low density planting (LDP) systems, aiming to optimize yield per unit area of land [2,3,4]. Despite lower yields per plant, HDP leads to significantly higher cumulative yields due to a larger plant population [5]. The main goal of HDP is to increase productivity and profitability while addressing shrinking land-holdings and promoting sustainable agricultural practices [6,7,8,9].

Osei Bonsu et al. [10] propose a profitable intercrop system for cocoa farmers in Ghana by implementing high density planting techniques. This method involves planting double rows of cocoa plants between coconut rows. Early plant training for compact canopy development, followed by regular pruning to maintain canopy structure and health, is essential. This approach encourages better early canopy formation and establishes a microclimate environment. Nutrient management is crucial, as standard fertilizer doses may result in low yields. Properly arranged high density cocoa within widely spaced coconut trees is suggested to enhance productivity and profitability. With this aim, the experiment on “Effect of different density in cocoa on leaf macro and micro nutrient levels grown under coconut ecosystem” in Tamil Nadu has been initiated. The objectives of the experiment to study effect of different density in cocoa on leaf macro nutrients such as N, P and K and micro nutrient such as boron, zinc and iron.

2. MATERIALS AND METHODS

The study titled "Impact of varied cocoa densities on leaf macro and micronutrient content within coconut farming settings" was carried out at the Department of Spices and Plantation Crops, Horticultural College and Research Institute, Tamil Nadu Agricultural University, located in Coimbatore, Tamil Nadu. The variety used in this study was Forastero.

Table 1. Experimental details

Design	:	RBD
Treatments	:	Eight
Replications	:	Three
Age of the crop	:	4 years

Table 2. Treatment details

Treatment	Details
Double row of cocoa between two coconut rows	
T1	3m x 1.2m
T2	3m x 2m
T3	3m x 2.5m
T4	3m x 3m
Single row of cocoa between two coconut rows	
T5	1.5m
T6	2m
T7	2.5m
T8	3m

2.1 Nutrient Analysis

Table 3. Range of macro nutrients

	Criteria according to Loue (1961)			Criteria according to Murray (1967)		
Nutrient	**Normal**	**Moderately deficient**	**Severely deficient**	**Normal**	**Moderately deficient**	**Severely deficient**
N (%)	2.35-2.50	1.80-2.00	<1.80	>2.00	1.80-2.00	<1.80
P (%)	>0.18	0.10-0.13	0.08-0.10	>0.20	0.13-0.20	<0.13
K (%)	>1.20	1.00-1.20	<1.00	>2.00	1.20-2.00	<1.20

Table 4. Range of micronutrients

Nutrient	Normal range (ppm)	Deficiency range (ppm)
Fe (Iron)	65-175	50
Zn (Zinc)	30-65	15-20
B (Boron)	25-75	8.5-11

Leaf nitrogen, phosphorus, and potassium levels were analyzed using various methods for samples collected from cocoa trees grown under different spacing conditions. Total nitrogen content in leaf blades and petioles was determined using the Microkjeldahl method [11], [12] and reported as a percentage. Phosphorus levels in leaf samples were measured in a triple acid extract using a colorimetric method [13,14] and expressed as a percentage. Potassium content in leaf and petiole samples was assessed from the triple acid extract using a Flame Photometer [13,15] and values were reported as a percentage. The concentrations of these major leaf nutrients were categorized according to Wessel [16] to differentiate between normal and deficient cocoa leaves.

Leaf zinc, iron, and boron levels were assessed using various methods for samples collected from cocoa trees grown under different spacing conditions. Total zinc and iron content in leaf blades and petioles were determined from the triple acid extract using an atomic absorption spectrophotometer [13,14] and expressed in parts per million (ppm). Total boron content in leaf blade and petiole samples was estimated using the caramine method [17] and expressed in ppm. The concentrations of these minor leaf nutrients were categorized according to de Geus [18] to distinguish between normal and deficient cocoa leaves.

2.2 Statistical Analysis

The results of the experiment were statistically analyzed by adopting the procedure suggested by Panse and Sukhatme [19].

3. RESULTS AND DISCUSSION

The study underscores significant variations in leaf nutrient content across diverse spacing treatments, providing crucial insights into the impact of spacing on cocoa plant nutrition. Table 5 and Fig. 1 denotes the effect of different spacing in cocoa on Nitrogen, Phosphorous and Potassium.

Table 5. Effect of different spacing in cocoa on Nitrogen, Phosphorous and Potassium

Treatment	Nitrogen (%)	Phosphorous (%)	Potassium (%)
T1 – 3m x 1.2m	1.86	0.084	1.39
T2 – 3m x 2m	1.79	0.079	1.21
T3 – 3m x 2.5m	1.34	0.043	0.94
T4 - 3m x 3m	1.53	0.067	1.06
T5 - 1.5m	1.72	0.081	1.31
T6 – 2m	1.69	0.055	1.28
T7 - 2.5m	1.17	0.032	0.86
T8 – 3m	1.45	0.066	1.13
Mean	1.56	1.14	1.14
SE(d)	0.03	0.02	0.01
CD (0.05)	0.069**	0.049**	0.040**

*** - Highly significant*

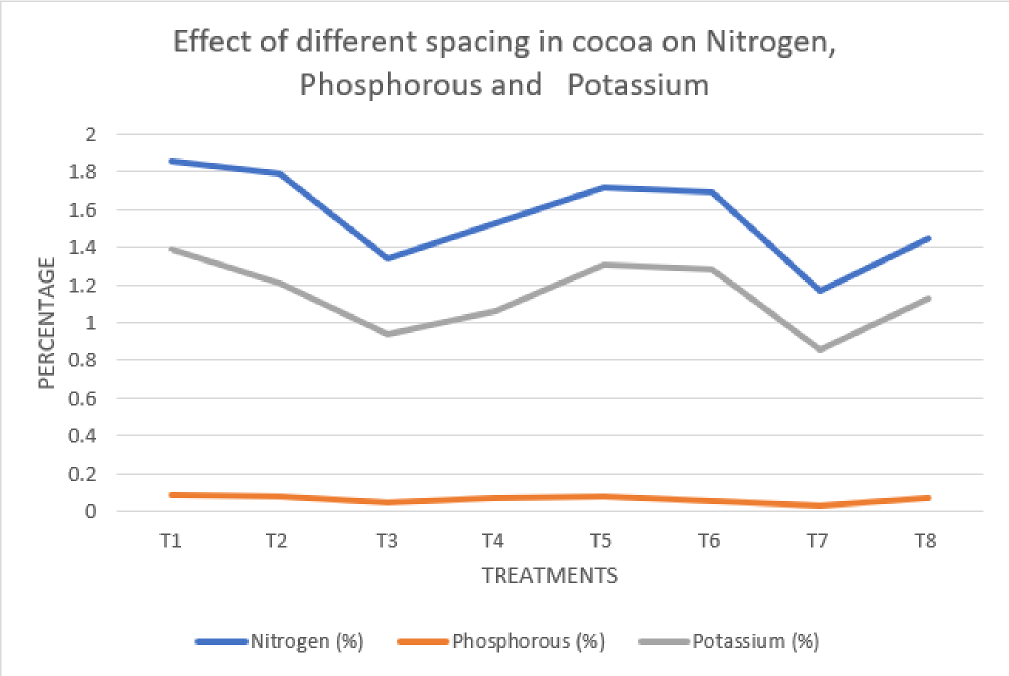

Fig. 1. Effect of different spacing in cocoa on Nitrogen, Phosphorous and Potassium

Table 6. Effect of different spacing in cocoa on Boron, Iron and Zinc

Treatment	Boron (ppm)	Iron (ppm)	Zinc (ppm)
T1 – 3m x 1.2m	91.33	297.48	202.29
T2 – 3m x 2m	86.48	306.62	321.64
T3 – 3m x 2.5m	53.36	192.78	213.00
T4 - 3m x 3m	69.82	211.55	205.60
T5 - 1.5m	82.57	273.37	237.90
T6 – 2m	61.65	124.70	119.87
T7 - 2.5m	44.71	156.56	151.91
T8 – 3m	75.24	249.12	224.20
Mean	70.64	226.52	209.55
SE(d)	1.28	5.25	3.96
CD (0.05)	2.75**	11.27**	8.50**

*** - Highly significant*

Notably, T1 (3m x 1.2m) emerges as the optimal spacing configuration, displaying the highest nitrogen content at 1.86%, closely followed by T2 (3m x 2m) at 1.79%, highlighting the pivotal role of spacing in nitrogen assimilation efficiency. Furthermore, phosphorus content exhibited notable disparities, with T1 registering the highest (0.084%) and T7 (2.5m) the lowest (0.032%), emphasizing the profound influence of spacing on phosphorus uptake. The potassium content also varied significantly among spacing treatments, with T1 showcasing the highest (1.39%) and T7 the lowest (0.86%), indicating the critical importance of spacing in potassium acquisition.

Table 6 depicts the effect of different spacing in cocoa on Boron, Iron and Zinc. Additionally, boron content was substantially elevated in T1 (91.33 ppm) compared to T7 (44.71 ppm), underscoring the intricate relationship between spacing and micronutrient availability. Furthermore, iron content peaked in T2 (306.62 ppm) and zinc content in T2 as well (321.64 ppm), elucidating the crucial role of spacing in facilitating essential micronutrient uptake in cocoa leaves. These findings accentuate the imperative of optimal spacing management practices to enhance nutrient absorption efficiency and ultimately boost cocoa yield and quality.

The analysis of leaf samples reveals significant disparities in nutrient status among different spacing treatments. Notably, T1 (3m x 1.2m) exhibited the highest percentages of nitrogen, phosphorus, and potassium indicating superior nutrient uptake efficiency in closely spaced trees. However, this heightened nutrient status in tighter spacing configurations may necessitate increased inputs for sustained productivity in the long term, as highlighted by Alex and Valle [20],[21]. In terms of micronutrients, T2 (3m x 2m) showcased the maximum zinc and iron content crucial for chlorophyll synthesis, essential for photosynthesis and overall plant vigor. Conversely, boron content, pivotal for crop yield, was notably elevated in T1 (3m x 1.2m). These findings suggest the positive influence of micronutrients like iron, zinc, and boron on various physiological functions, potentially enhancing tree yield and pod quality, as emphasized by Shoeib and El sayed [22],[23,21].

4. CONCLUSION

The analysis of leaf macronutrient content across varying crop spacing configurations revealed notable disparities. T1 (3m x 1.2m) consistently exhibited the highest values for leaf nitrogen (1.86%), leaf phosphorus (0.084%), and leaf potassium (1.39%) content, underscoring the significance of spacing in nutrient uptake efficiency. Furthermore, the examination of micronutrient content in cocoa leaves across different spacing levels unveiled significant findings. T1 (3m x 1.2m) emerged with the highest boron content at 91.33 ppm, highlighting its critical role in cocoa plant development. Additionally, T2 (3m x 2m) demonstrated maximum iron and zinc content at 124.70 ppm and 321.64 ppm, respectively, emphasizing the importance of adequate spacing in facilitating optimal micronutrient uptake. These findings underscore the pivotal role of spacing management strategies in optimizing both macro and micronutrient assimilation in cocoa cultivation, thereby contributing to enhanced yield and quality. It's important to note that this finding is preliminary, given that the field trial was conducted during the initial years of establishment. Further field trials are warranted in subsequent years to comprehensively assess the impact of spacing and plant interaction. Additionally, factors such as crop age, competition effects, and resource management efficiency of cocoa and coconut under different spacing configurations are crucial considerations before the widespread adoption of high-density planting technology.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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