Original Research Article

EFFECT OF SPACING ON PHYSIOLOGICAL CHARACTERS IN COCOA

Abstract

The experiment titled "Effect of spacing on physiological characters in cocoa" was conducted at the Coconut Farm of the Horticultural College and Research Institute, Tamil Nadu Agricultural University, Coimbatore. Employing a Randomized Block Design (RBD) with eight treatments replicated three times, the study aimed to explore how different spacing levels influence physiological traits in cocoa cultivation. The treatments involved in the experiment included a double row of cocoa planted between two rows of coconut trees, with spacing configurations as follows: T1 (3m x 1.2m), T2 (3m x 2m), T3 (3m x 2.5m), and T4 (3m x 3m). Additionally, a single row of cocoa between two coconut rows was examined, with spacings represented by T5 (1.5m), T6 (2m), T7 (2.5m), and T8 (3m). Results indicated distinct patterns among spacing treatments, with significant differences observed in various physiological characters. Notably, T1 (3m x 1.2m) demonstrated the highest leaf area (462.71cm2) and leaf area index (4.85), while T8 (3m) exhibited the highest light interception (74.12%). Additionally, T3 (3m x 2.5m) showcased the highest chlorophyll index (40.52) in cocoa leaves. These findings underscore the importance of spacing configurations in influencing key physiological parameters in cocoa cultivation, providing valuable insights for optimizing planting practices.

Keywords: Cocoa, spacing, leaf area, chlorophyll

Introduction

Cocoa, originally hailing from the Amazon region, holds significant agricultural importance as a plantation crop within the Theobroma genus of the Malvaceae family. Thriving in the humid tropics between 20º N and 20º S, it flourishes best at around 300 meters above sea level, with an annual precipitation ranging from 1500 to 2000mm and temperatures between 15 and 39°C(Goradevaishali, 2015). The plant's growth is heavily reliant on high humidity levels. Among the numerous species within the Theobroma genus, T. cacao stands out as the sole cultivable species. Its cultivation traces back to the early 1970s in India, primarily in South India, notably Kerala. The global demand for cocoa is steadily increasing, with projections estimating a need for an additional one million metric tonnes by 2030. Cocoa cultivation predominantly serves the chocolate industry, with its by-products

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utilized across various sectors. The cocoa tree is relatively small, reaching heights of 8-12 meters, characterized by simple, shiny, dark green leaves. Its flowers are small and range from yellowish-white to pale pink, appearing directly on the trunk or branches (cauliflorous), and the plant is self-incompatible. The fruit, an indehiscent drupe or pod, encases 20-60 seeds enveloped in sweet mucilage (Afoakwa, 2014).

During the 1980s, the Ministry of Agriculture, Land, and Marine Resources (MALMR) introduced High Density Planting (HDP) technology as an alternative to traditional Low Density Planting (LDP) systems (Kamaldeo et al., 2003). HDP aims to achieve earlier cropping, consistent high yields, and improved farm management practices, ultimately increasing productivity and profitability by maximizing yield per unit area of land (Ladaniya*et al.*, 2020; Anthony and Minas., 2021)(Cortes and Perez, 1986). Despite potentially lower yield per plant, HDP significantly boosts overall yield due to a larger plant population (Olufemi *et al.*, 2020)(Armstrong, 1976), aligning with the primary goal of enhancing productivity and sustainability within limited land resources (Rajbhar et al., 2016).

In cocoa cultivation, HDP involves planting double rows of cocoa plants between two rows of coconut trees. Early-stage plant training and regular pruning are vital for canopy structure and health, facilitating better early canopy formation and creating a favorable microclimate. Proper nutrient management is crucial to prevent reduced yields from standard fertilizer doses. The concept of arranging high-density cocoa within widely spaced coconut trees has been suggested as a profitable intercrop system for cocoa farmers, particularly in Ghana (Osei Bonsu et al., 2002). As part of this objective, an experiment titled "Effect of spacing on physiological characters in cocoa" has been initiated in Tamil Nadu. This experiment aims to investigate the impact of different spacing levels on physiological characteristics in cocoa.

Materials and methods

The study titled "Effect of spacing on physiological characters in cocoa" was conducted at the Department of Spices and Plantation Crops, Horticultural College and Research Institute, Tamil Nadu Agricultural University, situated in Coimbatore, Tamil Nadu. The research extended over a year and centered on cocoa trees grown using high-density techniques at the Coconut Farm in Coimbatore. Assessment of the physiological characteristics of cocoa trees was carried out during two distinct seasons: July to December and January to June.The variety was Forestro.

Experimental details are as follows:

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- Design: Randomized Block Design (RBD)
- Treatments: Eight
- Replications: Three
- Age of the crop: 4 years

Table 1. Treatmentdetails

Treatment	Details
Doublerowofcocoabetween two coconut rows	
T1	3m x1.2m
T2	3mx2m
T3	3m x2.5m
T4	3m x3m
Singlerow of cocoabetween two coconutrows	
T5	1.5m
T6	2m
T7	2.5m
T8	3m

Observations recorded

Various physiological parameters were examined during the study. Leaf area was determined by measuring the length and breadth of the standard leaf in five plants per replication under different spacing conditions for both seasons, with averages calculated accordingly. The leaf area was estimated using a formula incorporating the cocoa leaf calibration factor, as suggested by Bismark (2011). Leaf area was estimated using the formula: Leaf Area = Length × Breadth × (0.666 + 0.73) .

Leaf area index (LAI) was computed according to the method outlined by Williams (1946) for each season and spacing condition.It is calculated as the total leaf area of a plant divided by the ground area occupied by the plant (spacing).

Light penetration was assessed using a Konica Minolta light meter across the different spacing setups for both seasons. Additionally, total chlorophyll content was measured using a chlorophyll index (Konica Minolta) to gauge leaf chlorophyll levels under varying spacing conditions. This method, proposed by Yadava (1986), utilizes non-destructive measurement techniques, calculating SPAD values based on light intensities in specific wavelength bands associated with chlorophyll absorption**.**

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Result and discussion

Leaf area of cocoa plants exhibited significant differences across various spacing configurations in both seasons. In Season I, the maximum leaf area was observed in T1 (3m x 1.2m), while T8 (3m) recorded the minimum leaf area. Similarly, in Season II, T1 (3m x 1.2m) showed the highest leaf area, whereas T4 (3m x 3m) exhibited the lowest. Leaf area index also varied significantly among different spacings, with T1 (3m x 1.2m) consistently showing the highest values.

Table 2. Effect of different spacing on leaf area for different seasons in cocoa

Treatment	Leafarea(LA)(cm^2)		
	SeasonI	SeasonII	Mean
T1– 3m x1.2m	428.59	490.79	462.71
T2– 3mx2m	386.94	412.98	426.77
T3– 3m x2.5m	292.13	478.79	400.53
T4-3m x3m	276.45	302.51	339.14
T5-1.5m	247.74	340.29	328.50
T6– 2m	225.27	317.08	326.56
T7-2.5m	241.09	486.62	359.04
T8– 3m	220.81	389.27	353.39
Mean	**289.88**	**402.29**	
SE(d)	**6.54**	**10.54**	
CD(0.05)	**14.03****	**22.62****	

**** -Highlysignificant**

Season I– Julyto December	SeasonII-JanuarytoJune

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Table 3. Effect of different spacing on leaf area index for different seasons in cocoa

Treatment	Leafarea index(LAI)		
	SeasonI	SeasonII	Mean
T1– 3m x1.2m	4.69	5.02	4.85
T2– 3mx2m	1.97	2.24	2.11
T3– 3m x2.5m	0.99	1.62	1.30

T4-3m x3m	0.59	0.81	0.70
T5-1.5m	0.66	1.20	0.93
T6– 2m	0.46	0.59	0.53
T7-2.5m	0.24	0.55	0.40
T8– 3m	0.23	0.25	0.24
Mean	**1.22**	**1.53**	
SE(d)	**0.54**	**0.02**	
CD(0.05)	**1.17****	**0.06****	

Light penetration, expressed as the percentage of light interception, differed significantly across spacings in both seasons. T8 (3m) had the highest light interception in Season I, while in Season II, it was statistically on par with T6 (2m) and T7 (2.5m). The lowest light interception was observed in T1 (3m x 1.2m) during both seasons. Total chlorophyll content showed significant differences only in Season II, with T5 (1.5m) exhibiting the highest value and T7 (2.5m) the lowest. These findings highlight the influence of spacing on leaf area, light penetration, and chlorophyll content in cocoa plants across different seasons.

Table 4. Effect of different spacing on light interception for different seasons in cocoa

Treatment	**Lightinterception(percent)**		
	SeasonI	**SeasonII**	**Mean**
T1– 3m x1.2m	73.30 (58.88)	79.15 (62.83)	76.22
T2– 3mx2m	73.75 (59.18)	80.17 (63.55)	76.96
T3– 3m x2.5m	86.30 (68.27)	86.88 (68.76)	86.59
T4-3m x3m	90.89 (72.43)	86.44 (68.39)	88.66
T5-1.5m	90.77 (72.31)	87.10 (68.95)	88.93
T6– 2m	92.30 (73.89)	91.26 (72.80)	91.78

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T7-2.5m	88.48 (70.16)	89.39 (70.99)	88.93
T8– 3m	92.32 (73.91)	92.72 (74.34)	92.52
Mean	**86.01 (68.03)**	**86.63 (68.56)**	
SE(d)	**1.05**	**1.58**	
CD(0.05)	**2.27****	**3.40****	

Physiological parameters such as leaf area, leaf area index, chlorophyll content, and light penetration play crucial roles in determining the optimal growth and yield of cocoa crops. In the present study, maximum leaf area was observed in treatment T1 (3m × 1.2m), indicating a dense canopy and consequently lower light interception. Canopy spread, influenced by leaf number and area, is pivotal for effectively harnessing light energy for photosynthesis (Triadiati et al., 2011). As indicated by Ewel et al. (1982), leaf area is inversely related to light transmission. The results of the current investigation revealed that treatment T8 (3m) exhibited the least leaf area and highest light transmission, resulting in prolific flowering. Asomaning et al. (1971) reported a decrease in yield when the received light falls below 1800 hours per year. Similarly, Koko et al. (2013) demonstrated a positive correlation between incident light and cocoa yields, emphasizing its significance in determining plant vigor. Thus, incident light serves as a valuable indicator for optimizing the spatial arrangement of cocoa under coconut canopy. Treatment T5 (1.5m) exhibited higher chlorophyll content due to its greater light interception (72.31%).

Table 5. Effect of different spacing on total chlorophyll content for different seasons incocoa

Treatment	**Totalchlorophyllcontent (SPAD value)**		
	SeasonI	**SeasonII**	**Mean**
T1– 3m x1.2m	33.25	46.42	39.78
T2– 3mx2m	34.48	39.87	40.49
T3– 3m x2.5m	34.60	46.81	40.52
T4-3m x3m	34.10	43.96	37.02

T5-1.5m	36.02	51.07	37.94
T6– 2m	34.26	48.51	37.04
T7-2.5m	30.00	50.14	38.56
T8– 3m	31.66	40.84	39.02
Mean	**33.54**	**42.09**	
SE(d)	**3.80**	**1.00**	
CD(0.05)	**8.15^{NS}**	**2.14****	

Conclusion

The examination of physiological characters under varied crop spacing conditions revealed notable findings. Specifically, T1 (3m x 1.2m) exhibited the highest leaf area of 462.71cm2 and leaf area index of 4.85, indicating a robust canopy structure conducive to efficient photosynthesis. Conversely, T8 (3m) demonstrated the highest light interception at 74.12 per cent, suggesting effective light utilization despite potentially sparse foliage. Additionally, T3 (3m x 2.5m) showcased the highest chlorophyll index at 40.52, indicative of optimal leaf health and photosynthetic activity. These results underscore the intricate relationship between crop spacing and physiological parameters, highlighting the importance of strategic spacing configurations in maximizing cocoa plant performance and yield.

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