Original Research Article

EFFECT OF DIFFERENT SPACING LEVELS ON YIELD AND YIELD CONTRIBUTING CHARACTERS IN COCOA (*Theobroma cacao L.*)

Abstract

The experiment titled "Effect of different spacing levels on yield and yield contributing characters in cocoa" was conducted at the Coconut Farm of the Horticultural College and Research Institute, Tamil Nadu Agricultural University, Coimbatore. Utilizing a Randomized Block Design (RBD) with eight treatments replicated three times, the study aimed to investigate the impact of spacing levels on cocoa yield traits. 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 revealed significant variations among spacing treatments, with cocoa at 3m spacing demonstrating the highest productivity, yielding 43.47 pods per tree and 1021.48 g of dry beans per tree. Noteworthy findings included T1 (3m x 1.2m) exhibiting the longest pods (16.64 cm), T6 (2m) the widest pod girth (21.67 cm), and T8 (3m) producing the heaviest pods (204.50 g). Additionally, T6 yielded the highest total beans per pod (37.34) and dry bean weight (25.44 g), T4 had the heaviest single fresh bean (1.63 g), and T2 demonstrated the highest single dry bean weight (0.70 g). These findings offer valuable insights for optimizing cocoa cultivation practices, emphasizing the importance of spacing configurations in maximizing yield and bean characteristics.

Keywords: Cocoa, planting density, pod yield, bean yield

Introduction

Cocoa, originating from the Amazon, is a vital plantation crop in the Theobroma genus of the Malvaceae family, thriving in humid tropics between 20º N and 20º S (Goradevaishali, 2015). Cultivated primarily for the chocolate industry, its demand is steadily increasing, with projections indicating a need for an additional one million metric tonnes by 2020(Vooraet *al.*, 2019). T. cacao, the only cultivable species among numerous Theobroma genus members, has been cultivated since the early 1970s in India, notably Kerala. Cocoa trees are relatively small, reaching heights of 8-12 meters, with simple, shiny, dark green leaves, small cauliflorous flowers, and an indehiscent fruit encasing 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 conventional Low Density Planting (LDP) systems (Kamaldeo et al., 2003). HDP was designed to achieve earlier cropping, consistently high yields, and improved farm management practices, thereby enhancing productivity and profitability by optimizing yield per unit area of land(Ladaniyaet *al.*, 2020; Anthony and Minas., 2021)(Cortes and Perez, 1986). Despite the potential for reduced yield per individual plant, HDP significantly increases overall yield by leveraging a greater plant population(Olufemi *et al.*, 2020)(Armstrong, 1976), aligning with the overarching objective of enhancing productivity and sustainability within constrained land resources (Tripathi et al., 2020;Rajbhar et al., 2016).

In cocoa cultivation, HDP entails planting double rows of cocoa plants between two rows of coconut trees. Early-stage plant training and regular pruning play pivotal roles in fostering canopy structure and health, facilitating optimal early canopy formation and creating an advantageous microclimate. Effective nutrient management is imperative to mitigate the risk of yield reduction associated with standard fertilizer doses. The concept of implementing high-density cocoa amidst widely spaced coconut trees has been advocated as a lucrative intercrop system for cocoa farmers, notably in Ghana (Osei Bonsu et al., 2002). To further advance this objective, a comprehensive study titled "Effect of different spacing levels on yield and yield contributing characters in cocoa" has been launched in Tamil Nadu. This research endeavors to meticulously investigate the impact of diverse spacing configurations on the yield attributes of cocoa. Through systematic examination, it aims to provide valuable insights into how varying planting densities can affect cocoa production, thereby contributing significantly to the enhancement of cultivation practices and the optimization of cocoa yields.

Materials and methods

The study titled "Effect of different spacing levels on yield and yield contributing characters in cocoa" 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. This research spanned over a year and focused on cocoa trees cultivated using high-density techniques at the Coconut Farm in Coimbatore. The assessment of cocoa tree yield characteristics was conducted meticulously over two distinct seasons: from July to December and from January to June. The study conducted thorough assessments over both wet and dry seasons to capture diverse environmental influences on cocoa production. This approach yielded robust data, enabling nuanced analysis of spacing's impact on cocoa yield across varying climatic conditions and growth stages. The study utilized a Randomized Block Design (RBD) with eight treatments replicated three times, focusing on four-year-old cocoa crops. This design facilitated a systematic evaluation of the effects of spacing configurations on cocoa cultivation, ensuring observed variations in yield could be attributed to spacing differences. The multiple replications enhanced the reliability of findings, offering valuable insights into spacing's impact on cocoa production.The variety used in this study was Forastero.

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

The total number of pods harvested from each tree in both seasons under various spacing arrangements was directly counted in the field, and the overall pod count was recorded and expressed numerically. Bean length, bean girth, number of bold beans per pod, and number of flat beans per pod were assessed under various spacing conditions for both seasons. Bean length was measured using thread and scale, with twenty beans randomly selected from each pod for observation, and the average length was expressed in centimeters. Similarly, bean girth was measured using the same method, with twenty beans randomly chosen from each pod for observation, and the average girth was expressed in centimeters. The number of bold beans and flat beans per pod was determined by counting twenty pods under different spacing conditions, calculating the average number of each type per pod in each tree, and expressing them numerically.

For both seasons and under different spacing conditions, twenty pods were randomly selected from each tree. These pods were opened, and the wet beans inside were collected and weighed using a balance. The average wet bean weight per pod for each tree was then calculated and expressed in grams. Additionally, fermented beans from twenty randomly selected pods for each season and spacing were dried in an oven at 50-60°C for 3-4 days. The dried seeds were weighed to determine the dry bean weight per pod, with the average dry bean weight expressed in grams. Subsequently, the dry bean yield per tree was calculated by multiplying the mean dry weight of beans per pod (for both seasons) by the total number of pods per tree per year and expressed in grams.

Results and discussion

The number of pods harvested per tree varied significantly across different cocoa spacing treatments in both seasons. In Season I, the maximum number of pods per tree (37.33) was observed in T8 (3m), while the minimum (19.98) was recorded in T1 (3m x 1.2m). Similarly, in Season II, significant differences were noted, with T8 (3m) yielding the highest number of pods per tree (49.62) and T1 (3m x 1.2m) yielding the lowest (21.83). These findings underscore the impact of crop spacing on pod yield per tree across different seasons.

Table 2. Effect of different spacing on number of pods harvested per tree per season for different seasons in cocoa

Treatment	Numberofpodsharvestedpertree		
	SeasonI	SeasonII	Mean
T1– 3m x1.2m	19.98	21.83	20.90
T2– 3mx2m	21.85	22.54	22.19
T3– 3m x2.5m	23.01	23.92	23.46

T4-3m x3m	24.27	25.31	24.79
T5-1.5m	28.76	30.12	29.44
T6– 2m	29.54	32.95	31.24
T7-2.5m	31.62	33.48	32.55
T8– 3m	37.33	49.62	43.47
Mean	**27.04**	**29.97**	
SE(d)	**0.45**	**0.56**	
CD(0.05)	**0.96****	**1.21****	

**** -Highlysignificant**

Season I– Julyto December	SeasonII-JanuarytoJune

Bean length in cocoa exhibited significant variability across different spacings during both seasons of the study. For instance, in Season I (July 2016 to December 2016), the longest beans, measuring 2.89cm, were observed in T1 (3m x 1.2m), with statistically similar lengths noted in T2 (3m x 2m) (2.63cm) and T8 (3m) (2.48cm), while the shortest beans (2.03cm) were recorded in T7 (2.5m). Likewise, in Season II (January 2017 to June 2017), bean lengths varied significantly across spacings, with the longest beans (3.01cm) found in T1 (3m x 1.2m) and the shortest (2.21cm) in T7 (2.5m). Bean girth also demonstrated notable differences between spacing configurations. During both seasons, the widest beans were observed in T1 (3m x 1.2m), while the narrowest were consistently recorded in T7 (2.5m).

Table 3. Effect of different spacing on bean length for different seasons in cocoa

Treatment	**Beanlength(cm)**		
	SeasonI	**SeasonII**	**Mean**
T1– 3m x1.2m	2.89	3.01	2.95
T2– 3mx2m	2.63	2.84	2.73
T3– 3m x2.5m	2.11	2.79	2.45

T4-3m x3m	2.37	2.54	2.45
T5-1.5m	2.39	2.62	2.50
T6– 2m	2.43	2.76	2.59
T7-2.5m	2.03	2.21	2.12
T8– 3m	2.48	2.38	2.43
Mean	**2.40**	**2.64**	
SE(d)	**0.19**	**0.06**	
CD(0.05)	**0.41****	**0.13****	

Table 4. Effect of different spacing on bean girth for different seasons in Cocoa

Treatment	Beangirth (cm)		
	SeasonI	**SeasonII**	**Mean**
T1– 3m x1.2m	3.30	3.46	3.38
T2– 3mx2m	2.96	3.13	3.04
T3– 3m x2.5m	2.74	3.29	3.01
T4-3m x3m	3.13	3.04	3.08
T5-1.5m	2.88	2.45	2.66
T6– 2m	2.86	2.61	2.73
T7-2.5m	2.49	2.89	2.69
T8– 3m	3.07	2.67	2.87
Mean	**2.93**	**2.94**	
SE(d)	**0.0485**	**0.0484**	
CD(0.05)	**0.1040****	**0.1038****	

The number of bold beans per pod and flat beans per pod also showed significant variations across different spacings, with T8 (3m) consistently yielding the highest number of bold beans and T1 (3m x 1.2m) producing the fewest flat beans. Similarly, the total number of beans per pod exhibited notable differences, with T8 (3m) consistently yielding the highest total number of beans per pod and T7 (2.5m) the lowest across both seasons of the study.

Table 5. Effect of different spacing on number of bold beans per pod for different seasons in cocoa

Treatment	Numberof bold beansperpod		
	SeasonI	**SeasonII**	**Mean**
T1– 3m x1.2m	31.41	36.00	33.70
T2– 3mx2m	28.75	33.07	30.91
T3– 3m x2.5m	27.70	28.93	28.31
T4-3m x3m	28.71	35.16	31.93
T5-1.5m	31.37	37.28	34.32
T6– 2m	32.78	35.97	34.37
T7-2.5m	23.19	26.32	24.75
T8– 3m	37.26	42.01	39.63
Mean	**30.15**	**34.34**	
SE(d)	**0.52**	**0.89**	
CD(0.05)	**1.13****	**1.92****	

Table 6. Effect of different spacing on number of flat beans per pod for different seasons in cocoa

Treatment	Numberofflatbeansperpod		
	SeasonI	**SeasonII**	**Mean**

T1– 3m x1.2m	0.66	0.92	0.79
T2– 3mx2m	3.55	8.01	5.78
T3– 3m x2.5m	2.91	4.09	3.50
T4-3m x3m	3.30	2.54	2.92
T5-1.5m	2.49	2.77	2.63
T6– 2m	2.67	1.17	1.92
T7-2.5m	4.08	2.39	3.23
T8– 3m	1.25	1.83	1.54
Mean	**2.61**	**2.96**	
SE(d)	**0.074**	**0.076**	
CD(0.05)	**0.159****	**0.164****	

The economic components of cocoa, namely pods and beans, significantly influence yield. In the study, parameters such as number of pods harvested per tree, dry bean yield per tree, and cumulative yield per unit area varied significantly across the spacing levels. Treatment T8 (3m) exhibited high number of pods harvested per tree and dry bean yield per tree, with a decreasing trend observed under closer spacing. However, cumulative yield per unit area was highest in T1 (3m x 1.2m) due to increased plant population with decreased spacing. Similarly, MAFUTA, 2017 and Mooleedhar, 1986 found higher average dry bean yield under closer spacing compared to wider spacing. Hosseini-Bai *et al.*, 2019and Shripat and Bekele (1996) reported that cocoa yield increased linearly as spacing decreased.Koko *et al.*, 2013and Baihaqi*et al.*, 2003 observed a sharp increase in yield with planting density. However, Olufemi *et al.*, 2020Souza *et al.*, 2009 noted that yield in high-density planting decreased over time due to increased competition and disease incidence. Pod and bean characteristics such as pod length, pod girth, bean length, bean girth, pod weight, and bean weight varied significantly under different spacings. Maximum pod weight, number of beans per pod, and fresh and dry bean weight per pod were recorded under wider spacing T8 (3m), possibly due to maximum nutrition availability (Mhetre, 2011).

Table 7. Effect of different spacing on total number of beans per pod for different seasons in cocoa

Treatment	Totalnumberofbeansperpod		
	SeasonI	SeasonII	Mean
T1– 3m x1.2m	31.63	37.06	34.34
T2– 3mx2m	28.38	36.17	32.27
T3– 3m x2.5m	32.28	37.13	34.70
T4-3m x3m	32.86	36.94	34.90
T5-1.5m	33.88	40.55	37.21
T6– 2m	36.10	38.59	37.34
T7-2.5m	30.00	28.34	29.17
T8– 3m	27.26	44.50	35.88
Mean	**32.73**	**37.41**	
SE(d)	**3.72**	**0.64**	
CD(0.05)	**7.99 NS**	**1.38****	

Fresh bean weight per pod exhibited significant variability across different spacings in cocoa during both seasons of the study. In Season I (July 2016 to December 2016), the highest fresh bean weight per pod (63.22g) was observed in T8 (3m), while the lowest weight (28.80g) was recorded in T7 (2.5m). Similarly, in Season II (January 2017 to June 2017), significant differences were observed, with the highest fresh bean weight per pod (54.79g) found in T8 (3m) and the lowest (23.03g) in T7 (2.5m).

Table 8. Effect of different spacing on fresh bean weight per pod for different seasons in cocoa

Treatment	Freshbeanweight perpod (g)		
	SeasonI	**SeasonII**	**Mean**
T1– 3m x1.2m	55.90	54.37	55.13
T2– 3mx2m	48.99	48.27	48.63
T3– 3m x2.5m	29.58	39.45	34.51
T4-3m x3m	49.21	48.43	48.82
T5-1.5m	51.13	52.16	51.64
T6– 2m	38.33	46.28	42.30
T7-2.5m	28.80	23.03	25.91
T8– 3m	63.22	54.79	59.00
Mean	**45.64**	**45.84**	
SE(d)	**1.09**	**1.13**	
CD(0.05)	**2.35****	**2.43****	

Dry bean weight per pod also demonstrated notable differences between spacing configurations. In Season I, the maximum dry bean weight per pod (21.33g) was observed in T6 (2m), while the minimum (8.25g) was recorded in T7 (2.5m). In Season II, maximum dry bean weight per pod (29.65g) was observed in T2 (3m x 2m), with the lowest (7.65g) in T7 (2.5m). Dry bean yield per tree also showed significant differences across spacings. In Season I, the maximum dry bean yield per tree (682.39g) was registered in T8 (3m), whereas the minimum (334.52g) was recorded in T7 (2.5m). In Season II, the highest dry bean yield per tree (1360.58g) was observed in T8 (3m), while the lowest (314.06g) was in T7 (2.5m).

Table 9. Effect of different spacing on dry bean weight per pod for different seasons in cocoa

Treatment	Drybean weightperpod (g)		
	SeasonI	SeasonII	Mean
T1– 3m x1.2m	19.61	27.42	23.51
T2– 3mx2m	11.35	29.65	20.50
T3– 3m x2.5m	11.62	28.59	20.10
T4-3m x3m	17.08	16.59	16.83
T5-1.5m	20.70	27.97	24.33
T6– 2m	21.33	29.55	25.44
T7-2.5m	8.25	7.65	7.95
T8– 3m	12.19	16.02	14.10
Mean	**15.26**	**22.93**	
SE(d)	**0.41**	**0.49**	
CD(0.05)	**0.88****	**1.06****	

Table 10. Effect of season for spacing on dry bean yield per tree for different seasons in cocoa

Treatment	Drybeanyieldpertree (g)		
	SeasonI	SeasonII	Mean
T1– 3m x1.2m	478.38	1124.62	801.50
T2– 3mx2m	394.24	780.12	587.18

T3– 3m x2.5m	354.75	910.87	632.81
T4-3m x3m	467.52	318.31	392.91
T5-1.5m	458.76	806.65	632.70
T6– 2m	528.52	406.70	467.61
T7-2.5m	334.52	314.06	324.29
T8– 3m	682.39	1360.58	1021.48
Mean	**462.38**	**752.73**	
SE(d)	**10.22**	**15.71**	
CD(0.05)	**21.94****	**33.70****	

Conclusion

Cocoa cultivated at a spacing of 3 m emerges as the most productive spacing configuration, boasting the highest yield parameters with 43.47 pods harvested per tree and a dry bean yield of 1021.48 g per tree. Notably, T1 (3m x 1.2m) stands out for its long pods at 16.64 cm, while T6 (2m) showcases the widest pod girth at 21.67 cm, and T8 (3m) delivers the heaviest pods at 204.50 g. Moving to bean characteristics, T1 impresses with the longest beans (2.95 cm) and widest bean girth (3.38 cm), coupled with the fewest flat beans (0.79), contrasting with T8's notable performance, presenting the highest number of bold beans per pod (39.63) and the most substantial fresh bean weight per pod (59.00 g). Moreover, T6 exhibits the highest total number of beans per pod (37.34) and dry bean weight per pod (25.44 g), while T4 boasts the heaviest single fresh bean (1.63 g), and T2 shines with the highest single dry bean weight per pod (0.70 g). These findings underscore the nuanced impact of crop spacing on cocoa yield and bean characteristics, providing valuable insights for optimizing cultivation practices.

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