Original Research Article

EFFECT OF SPACING ON SOIL MICROBIAL POPULATION, PEST AND DISEASES INCIDENCE IN COCOA

Abstract

An experiment examining the "Effect of spacing on soil microbial population, pest, and disease incidence 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 assess the impact of different spacing configurations on cocoa cultivation. Results revealed that T7 (2.5m) exhibited the lowest incidence of pod rot (0.48), while T6 (2m) had the least mealy bug infestation (0.55). Notably, T6 showed the highest bacterial population (7.33 × 106 CFU g-1), whereas T4 (3 x 3 m) and T7 (2.5m) demonstrated higher fungal populations (3.33 × 104 CFU g-1). Furthermore, T3 (3m x 2.5m) displayed the highest actinomycetes population (4.33 × 103 CFU g-1). These findings underscore the importance of spacing configurations in influencing soil microbial populations and pest and disease incidence in cocoa cultivation.

Keywords: Cocoa, spacing, pod rot, mealy bug, microbes

Commented [D1]: No background included here

Commented [D2]: This two words are already present in the tittle. Why you need included in keywords?

Introduction

Cocoa, scientifically known as Theobroma cacao L., originates from the Amazon region of South America and holds significant importance as a plantation crop. Belonging to the Malvaceae family, cocoa is cultivated predominantly in the humid tropics between 20º N and 20º S latitude, with optimal growth occurring between 10º N and 10º S (Goradevaishali, 2015). It thrives best at an elevation of around 300 meters above sea level, requiring annual precipitation between 1500-2000 mm and temperatures ranging from 15-39°C, with an optimum temperature of approximately 25°C. High humidity levels are essential throughout the year for its optimal growth. While there are over 20 species in the Theobroma genus, T. cacao is the only cultivable species, characterized by its diploid nature with 20 chromosomes in somatic cells (2n=20).

Although cocoa has a long history of cultivation in Central America, its introduction to Africa and Asia is more recent. Commercial cultivation began in India in the early 1970s, with

South India being the primary focus. In South India, cocoa is typically intercropped with coconut plantations, except in Kerala where it is grown alongside forest trees and rubber. Kerala contributes to the majority of cocoa cultivation in India, with about 76% of the area and 78% of the total production, while Karnataka and Tamil Nadu also contribute to production.

The global demand for cocoa beans has been steadily rising, with an estimated additional one million metric tonnes required by 2030 to meet demand (Voora *et al*., 2019). However, the supply of cocoa beans from major producing countries has been inconsistent, particularly due to low output from Côte d'Ivoire, the largest cocoa-producing country. Cocoa cultivation primarily serves the production of chocolate, with various by-products utilized in industries such as cosmetics, confectioneries, perfumeries, and pharmaceuticals (Afoakwa, 2014).

The high-density planting (HDP) method, developed in the 1980s by the Ministry of Agriculture, Land, and Marine Resources (MALMR), offers an alternative to conventional low-density planting (LDP) systems, to boost crop productivity and profitability (Kamaldeo et al., 2003). HDP aims to maximize yield per unit area by increasing plant density, leading to higher overall yields despite lower individual plant yields (Ladaniya *et al*., 2020; Anthony and Minas., 2021; Olufemi *et al*., 2020; Cortes and Perez, 1986; Armstrong, 1976). The primary objective is to enhance productivity and sustainability by extracting the maximum useful biomass from limited land resources, particularly crucial given the diminishing size of land holdings (Tripathi et al., 2020; Rajbhar et al., 2016).

Commented [D3]: Use the same Italic or normal

In cocoa farming, HDP may involve planting double rows of cocoa plants between coconut rows, followed by early plant training and regular pruning to optimize canopy development and microclimate conditions (Osei Bonsu et al., 2002). Effective nutrient management is essential in HDP systems to prevent decreased yields associated with conventional fertilizer applications. The adoption of well-organized high-density cocoa within coconut plantations has demonstrated potential for profitability, as proposed for consideration by cocoa growers in Ghana (Osei Bonsu et al., 2002).

Materials and methods

The research, titled " Effect of spacing on soil microbial population, pest and diseases incidence in cocoa" was conducted at the Department of Spices and Plantation Crops, Horticultural College and Research Institute, which is part of the Tamil Nadu Agricultural University situated

in Coimbatore, Tamil Nadu. Over one year, cocoa trees planted using high-density methods at the Coconut Farm in Coimbatore were evaluated for productivity and quality during two specific seasons: July to December and January to June.

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

The study involved assessing the incidence of pests and diseases, specifically the number of cocoa pods affected by pod rot caused by Phytophthora palmivora, as well as the number of pods affected by mealy bugs, across different spacing treatments during both seasons. Additionally, microbial parameters were examined by analyzing soil samples to enumerate total bacteria, fungi, and actinomycetes using serial dilution and plating techniques. Enumeration of bacterial populations was conducted on soil extract agar medium, while enumeration of fungal populations was carried out on Rose Bengal Agar medium. References for the enumeration methods include James (1958) for bacterial population enumeration and Parkinson et al. (1971)

for fungal population enumeration. The enumeration of actinomycetes population under varied spacing conditions was conducted using Kenknight's Agar medium. After a 7-day incubation period at 37°C, actinomycetes colonies were counted and expressed as colony-forming units per gram of dry soil, following the methodology outlined by Wellington and Toth (1964).

Results and discussion

Commented [D4]: The discussion is not dimply discussed

The incidence of pod rot in cocoa pods exhibited notable variations across different spacing treatments during both seasons of the study. In the first season, the lowest number of pods affected by pod rot (0.13) was observed under T7 (2.5m), while the highest number (4.01) occurred under T1 (3m x 1.2m). Similarly, during the second season, significant differences were noted, with the minimum number of affected pods (0.83) recorded under T7 (2.5m), and the maximum number (8.16) observed under T1 (3m x 1.2m).

Among the eight spacing configurations studied, significant differences were observed in the number of pods affected by mealy bugs per tree during the first season. The lowest number (0.44) of affected pods per tree was recorded under T6 (2m), while the highest number was observed under T2 (3m x 2m) (4.22).

In the second season, significant variations were also noted in the number of pods affected by mealy bugs across different spacing treatments. The minimum number of affected pods (0.21) was observed under T8 (3m), whereas T2 (3m x 2m) showed the highest level of infestation (7.39).

Table 3. Effect of different spacing on number of pods affected by pod rot (Phytophthora palmivora) for per tree for different seasons in cocoa

Treatment	Number of pods affected by pod rot (*Phytophthora palmivora)* per tree		
	Season I	**Season II**	**Mean**
T1 – 3m x 1.2m	4.01	8.16	6.08
T2 – 3m x 2m	2.47	3.07	2.77
T3 – 3m x 2.5m	1.24	2.27	1.75
T4 - 3m x 3m	1.09	1.49	1.29

T5 - 1.5m	2.63	2.81	2.72
T6 – 2m	2.41	2.71	2.56
T7 - 2.5m	0.13	0.83	0.48
T8 – 3m	1.02	1.72	1.37
Mean	**1.87**	**2.88**	
SE(d)	**0.049**	**0.041**	
CD (0.05)	**0.10****	**0.08****	

**** - Highly significant**

Season I – July to December	Season II- January to June

The findings of the current study indicate that the lowest incidence of pod rot was observed in T7 (2.5m), possibly due to increased light penetration and decreased field humidity, conditions that are less conducive to pathogen survival. This aligns with the observations of Kamaldeo et al. (2003), who reported reduced inoculum pressure of pathogens under low-density planting. However, it's noted that higher levels of management within high-density planting (HDP), including regular pruning and shade management, along with the cultivation of cocoa clones tolerant to black pod disease, can further reduce the incidence of pod rot even at closer spacing.

Table 4. Effect of different spacing on number of pods affected by mealy bug per tree for different seasons in cocoa

Treatment	**Number of pods affected by Mealy bug per tree**		
	Season I	**Season II**	**Mean**
T1 – 3m x 1.2m	0.94	1.92	5.52

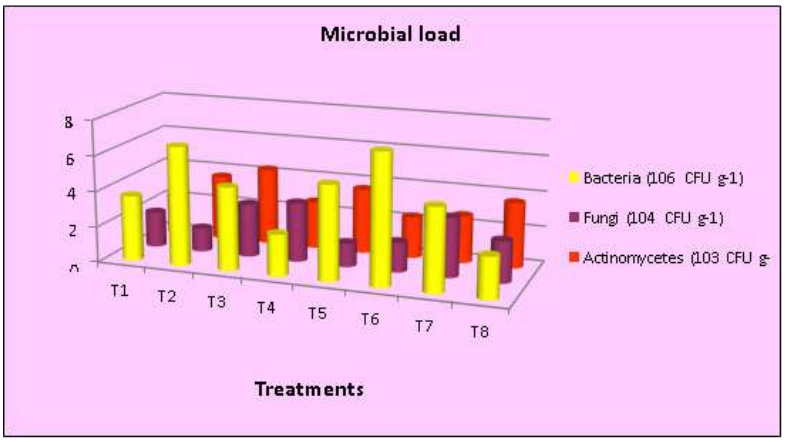
T2 – 3m x 2m	4.22	7.39	5.77
T3 – 3m x 2.5m	1.66	0.76	1.43
T4 - 3m x 3m	4.16	6.82	1.21
T5 - 1.5m	0.55	2.19	1.37
T6 – 2m	0.44	0.67	0.55
T7 - 2.5m	1.44	3.46	2.45
T8 – 3m	0.97	0.21	0.59
Mean	**1.79**	**2.92**	
SE(d)	**0.05**	**0.08**	
CD (0.05)	**0.12****	**0.17****	

**** - Highly significant**

Season I – July to December	Season II- January to June

The bacterial population exhibited notable variations among the treatments studied, with the highest population (7.33 x 106 CFU g-1) observed in T6 (2m), while T4 (3m x 3m) and T8 (3m) showed the lowest values (2.33 x 106 CFU g-1). Similarly, significant differences were noted in the fungal population across different spacing treatments. The maximum fungal population (3.33 x 104 CFU g-1) was recorded under T4 (3m x 3m) and T7 (2.5m), while the lowest population (1.33 x 104 CFU g-1) was observed in T2 (3m x 2m) and T5 (1.5m). In terms of actinomycetes population, significant variations were observed among the spacing levels. The highest population (4.33 x 103 CFU g-1) was found in T3 (3m x 2.5m), while the lowest (2.33 x 103 CFU g-1) was registered in treatments T1 (3m x 1.2m) and T6 (2m).

Fig 1. Effect of different spacing on bacteria, fungi and bacterial population in soil



The impact of various cocoa spacing configurations on soil microbial populations, including bacteria, fungi, and actinomycetes, exhibited significant variations. The highest bacterial population was observed in T6 (2m), while T4 (3m x 3m) and T7 (2.5m) showed the highest fungal population. Additionally, T3 (3m x 2.5m) demonstrated the highest population of actinomycetes. The association of cocoa with coconut has been reported to enhance microbial numbers within the coconut rhizosphere (Nair and Rao, 1977). This phenomenon can be attributed to the increased light interception within widely spaced cropping systems, creating conditions conducive to microbial proliferation.

Table 5. Effect of different spacing on bacteria, fungi and bacterial population in soil

Treatment	Bacteria Population × 10^6 CFU g^{-1}	Fungi Population × 10^4 CFU g^{-1}	Actinomycetes Population × 10^3 CFU g^{-1}
T1 – 3m x 1.2m	3.67 (0.56)	2.00 (0.30)	2.33 (0.37)
T2 – 3m x 2m	6.67 (0.82)	1.33 (0.12)	3.67 (0.56)
T3 – 3m x 2.5m	4.67 (0.67)	3.00 (0.48)	4.33 (0.64)

T4 - 3m x 3m	2.33 (0.37)	3.33 (0.52)	2.67 (0.43)
T5 - 1.5m	5.33 (0.73)	1.33 (0.12)	3.67 (0.56)
T6 – 2m	7.33 (0.87)	1.67 (0.22)	2.33 (0.37)
T7 - 2.5m	4.67 (0.67)	3.33 (0.52)	2.67 (0.43)
T8 – 3m	2.33 (0.37)	2.33 (0.37)	3.67 (0.56)
Mean	**4.625 (0.67)**	**2.29 (0.36)**	**3.16 (0.38)**
SE(d)	**0.119**	**0.011**	**0.011**
CD (0.05)	**0.257****	**0.025****	**0.025****

**** - Highly significant**

Season I – July to December	Season II- January to June

Conclusion

It can concluded that the incidence of pests and diseases, T7 (2.5m) exhibited the lowest number of pods affected by pod rot (0.48), while T6 (2m) showed the lowest number of pods affected by mealy bugs (0.55). In terms of soil microbial characteristics analyzed under different cocoa spacing, T6 (2m) recorded the highest bacterial population (7.33 × 106 CFU g-1), while T4 (3 x 3 m) and T7 (2.5m) showed higher fungal populations (3.33 × 104 CFU g-1). Additionally, the actinomycetes population was notably higher in T3 (3m x 2.5m), reaching 4.33 × 103 CFU g-1.

Commented [D5]: This is not conclusion, it is result so revise it again

Reference

1. Afoakwa, E. O. (2014). *Cocoa production and processing technology*. CRC Press.

2. Anthony, B. M., & Minas, I. S. (2021). Optimizing peach tree canopy architecture for efficient light use, increased productivity and improved fruit quality. *Agronomy*, *11*(10), 1961.
3. Cortes, S. and A. Perez. 1986. Influence of high planting densities on yields and bean quality. **In:** Min. of Agric. Lands and Marine Resources, Trinidad., **4(2):** 29-39.
    a. Goradevaishali, S. (2015). *Identification of molecular marker for self-incompatibility in selected germplasm accessions of cocoa (Theobroma cacao L.)* (Doctoral dissertation, College of Horticulture, Vellanikkara).
4. James, N. 1958. Soil extract in soil microbiology. **Can. J. Microbiol., 4:** 363-370.
5. Kamaldeo, M., T. Indalsingh, D. Ramnath and A. Cumberbatch. 2003. High Density Planting of Cacao: The Trinidad and Tobago Experience. **In:** International Workshop on Cocoa Breeding for Improved Production Systems, Accra, Ghana., **pp:** 171-182.
6. Ladaniya, M. S., Marathe, R. A., Das, A. K., Rao, C. N., Huchche, A. D., Shirgure, P. S., & Murkute, A. A. (2020). High density planting studies in acid lime (Citrus aurantifolia Swingle). *Scientia Horticulturae*, *261*, 108935.
7. Nair, S. K. and Rao, N. S. S. 1977b. Distribution and activity of phosphate solubilising microorganisms in the rhizosphere of coconut and cacao under mixed cropping. **J. Plantation Crops., 5:** 67-70.
8. Osei-Bonsu, K., K. K. Opoku-Ameyaw, F. M. Amoah and F. K. Oppong. 2002. Cacao-coconut intercropping in Ghana: agronomic and economic perspectives**. Agrofor. Syst.,**55:1–8.
9. Parkinson P., T. R .G .Gray and S. T. William. 1971. Methods for studying the ecology of soil microorganisms. Blackwell Scientific Publication Oxford**, pp:**116.
10. Rajbhar, Y.P., S.D. Singh, M. Lal, G. Singh and P.L. Rawat. 2016. Performance of high density planting of Mango (*Mangifera indica* L.) under mid-Western plain zone of Uttar Pradesh. **Int. J. Agri. Sci., 12[2]:** 298-301.
11. Tripathi, V. K., Kumar, S., Dubey, V., & Nayyer, M. A. (2020). High-Density Planting in Fruit Crops for Enhancing Fruit Productivity. In *Sustainable Agriculture* (pp. 253-267). Apple Academic Press.
12. Voora, V., Bermúdez, S., & Larrea, C. (2019). *Global market report: Cocoa* (p. 12).

Winnipeg, MB, Canada: International Institute for Sustainable Development.

13. Wellington, E. M. H and I. K. Toth. 1964. Actinomycetes. In: Weaver R.W, Angle J. S, Bottomley P. S, editors. Methods of Soil Analysis. Part 2-Microbiological and Biochemical Properties. Madison, WI: SSSA, 269–90.