Influence of zinc levels on growth, chlorophyll content and biomass allocation of cocoa varieties

ABSTRACT

A pot experiment conducted at ICAR-CPCRI, RS, Vittal, provided practical insights into the effects of varying zinc levels (0.25, 0.75, and 1.25 mg/7Lpot) on the growth, chlorophyll content and biomass allocation of eight cocoa varieties. The study revealed significant varietal differences and a positive influence of zinc application on growth parameters. Notably, the variety VTLCC-1 exhibited the highest plant height (138.73 cm) and stem diameter (11.40 mm) under the medium zinc level, as well as the greatest leaf count (70.33) under the high zinc level. In contrast, VTLCH-4, grown with a low zinc level, recorded the highest total chlorophyll content (4.79 mg g^{-}1). Additionally, VTLCS-1, grown with a low zinc level showed a higher shoot-to-root ratio of 8.74, and varieties ~~plants of~~ VTLCH-4 and VTLCS-1 recorded the highest root-to-shoot ratio of 0.25 at a high Zn level. This underscores the unique responses of different cocoa varieties to varied Zn levels in terms of growth, chlorophyll content and the allocation of biomass, providing valuable information for sustainable cocoa production.

Keywords: Chlorophyllcontent, Cocoavarieties, Growthparameters, Zinclevels,pot experiment

1. INTRODUCTION

Cocoa (*Theobroma cacao* L.), revered as the 'Food of Gods', holds significant importance as a beverage crop, ranking next to tea and coffee. Native to the Amazon basin in South America, cocoa was domesticated by indigenous cultures such as the Mayas, Aztecs, and Pipil-Nicaraos and subsequently distributed to various regions of the world (Wood 1991). Thriving in the humid tropics, cocoa is a shade-loving plant often cultivated as an under-storey crop in agroforestry systems across Latin American and African countries. It has also found adaptation as a mixed crop in palm-based cropping systems in Asian and Pacific nations. In South India, it is mainly grown as an ~~intercrop~~inter crop in arecanut and coconut plantations, and to a lesser extent, in oil palm gardens (Peter and Chandramohanan, 2011).

Zinc (Zn) is a key component of various enzymes within plants, facilitating multiple metabolic reactions. It is required in small but critical concentration for the functioning of several physiological functions of plants like aiding in photosynthesis, maintaining cell membrane integrity, synthesizing proteins, fostering pollen formation, resistance against diseases, and elevating the levels of antioxidants and chlorophyll in plant tissues (Jerlin *et al*., 2017). Zn deficiency is observed in cocoa grown on Oxisol and Ultisol soils (Marschner, 1995; Alloway, 2008). There is a lack of comprehensive information regarding the influence of Zn on the growth, chlorophyll and biomass allocation in cocoa plants. To address this knowledge gap, a study was undertaken to assess the impact of three levels of Zn on the growth, chlorophyll content and biomass allocation in eight varieties of cocoa.

2. MATERIALS AND METHODS

The experiment was conducted in a glass house at ICAR-CPCRI, Regional Station, Vittal, during 2020-2021. Eight cocoa varieties (VTLCH-1, VTLCH-2, VTLCH-3, VTLCH-4, VTLCH-5, VTLCC-1, VTLCS-1 and VTLCS-2) and three Zn levels (0.25, 0.75 and 1.25 mg Zn per pot) were arranged in 8×3 factorial complete randomized block design with three replications. The seedlings were raised in a sterile silica sand bed, and forty-days-old, uniform, and vigorous seedlings were transferred to ten-liter plastic pots containing seven liters of modified Hoagland nutrient solution. Along with Zn, the nutrient solution contained 80, 20, 80, 50, 12.15, 20, 0.8, 0.08, 5, 0.5 and 0.05 ppm of N, P, K, Ca, Mg, S, B, Cu, Fe, Mn and Mo, respectively. Aeration was provided with a 1.5 HP electric compressor through 2mm lateral tubes. During the growth, glass house temperature varied from 22-40℃, and relative humidity varied from 70–90 percent. pH adjusted to ~5.7-6.0 once every two days by adding appropriate amounts of 0.2 mM Sodium carbonate. The growth parameters *viz*. plant height, number of leaves and stem diameter were recorded at eight months after transplanting just before destructive sampling. Leaf samples were collected in the early morning for estimation of chlorophyll by DMSO method (Wellburn, 1994). Subsequently, plants were removed from pots, separated into leaves, stems, and roots, and dried at 65°C until a constant weight was achieved. The shoot-to-root ratio was then calculated by dividing the shoot (leaves and stem) dry weight by the root dry weight and the root-to-shoot ratio was calculated by dividing the root dry weight by shoot dry weight.Analysis of variance was performed to compare the effects of different varieties, Zn levels, and their interactions on plant height, number of leaves, stem diameter, shoot-to-root ratio and root-to-shoot ratio. The critical difference (CD) at the 0.05 probability level were calculated wherever the F-test was significant.

3. RESULTS AND DISCUSSION

3.1 Growth parameters

Significant effects of varieties, Zn levels, and their interaction were observed on growth parameters of cocoa (Table 1). The variety VTLCC-1 exhibited the highest plant height, number of leaves and stem diameter. Increasing Zn levels had a significant positive impact on all the parameters. Plants of VTLCC-1 grown with high Zn level exhibited a greater plant height (138.73 cm) and higher leaf count (70.33) whereas, higher stem diameter (11.40 mm) was observed when grown with medium Zn level. Zinc is involved in enzymatic activation and fosters the synthesis of tryptophan, a precursor for auxin formation, pivotal for cell elongation (Pedler *et al*., 2000), contributing to taller plants. Further, Zn facilitates chlorophyll production, enhancing photosynthesis (Marschner, 1995) and subsequent leaf proliferation. It increases leaf count and stem diameter by aiding protein synthesis and cellular division.Studies conducted by Muhammad *et al*. (2014) in chili, Samreen *et al*. (2013) in Mungbean and Prasad and Subbarayappa (2018) in tomatoes also highlighted the positive impact of Zn application on enhancing growth parameters.

3.2 Chlorophyll content

Chlorophyll a, b and total chlorophyll content were significantly different across different varieties, whereas it was non-significant among Zn levels. The highest chlorophyll a, b and total chlorophyll content among varieties was recorded in VTLCH-4 (Fig 1). Even though Zn levels did not show any significant effect, chlorophyll b and total chlorophyll content increased with increasing Zn levels, while chlorophyll a content showed a decreasing trend with increasing Zn levels (Fig 2). The diversity in chlorophyll content among varieties is attributed to their genetic composition. In response to the limited availability of Zn, VTLCH-4 might have upregulated(undefined) specific pathways associated with chlorophyll synthesis as a protective measure or to compensate for nutrient deficiency. This response could have led to a higher chlorophyll accumulation to optimize photosynthesis and maintain essential metabolic processes despite the stressor? (Alloway, 2008).

3.3 Biomass allocation

Distinct responses to varying Zn levels were observed among different cocoa varieties in relation to the shoot-to-root and root-to-shoot ratios (Table 2). As Zn levels increased, the shoot-to-root ratio generally decreased, with the highest ratio (6.03) at low Zn level. Conversely, the root-to-shoot ratio increased with higher Zn levels, with the highest ratio (0.19) observed at high Zn level. Notably, variety VTLCS-1 showed the highest shoot-to-root ratio (8.74) at low zinc level. Conversely, the highest root-to-shoot ratio was recorded in VTLCH-4 and VTLCS-1 under high Zn level (0.25).

Diverse genetic compositions among various plant varieties are responsible for the distinct ways they distribute biomass across different parts of the plant (Poorter *et al.*, 2012). The genetic variability in biomass allocation was also reported by Jahn *et al*. (2011) in rice. To compensate for the limited nutrient availability, plants may allocate more resources to the shoot for increased photosynthetic activity, which is a survival strategy to maximize the capture of sunlight and optimize the production of carbohydrates, which results in a higher shoot-to-root ratio at a low Zn level. Zhang *et al*. (2013) reported a significant decrease in shoot-to-root ratio with increasing Zn application in maize which might have occurred due to the substantial increase in root biomass relative to shoot biomass. Paivoke (1983) opined that a high Zn supply suppresses shoot growth more than root growth, decreasing the shoot-to-root ratio. The results obtained contradict the conclusions drawn by Sudhalakshmi *et al*. (2007) in rice who reported a synergistic effect of Zn on shoot-to-root ratio.

Plant height (cm)				Number of leaves				Stem diameter (mr		
Z1	Z2	Z3	Mean A	Z1	Z2	Z3	Mean A	Z1	Z2	Z3
80.67	83.67	103.50	89.28	40.00	45.33	52.33	45.89	10.00	9.77	10.97
96.07	88.33	101.13	95.18	41.33	52.67	53.67	49.22	10.23	9.77	10.43
93.00	98.97	102.07	98.01	52.33	52.33	53.33	52.67	10.43	11.60	11.20

110.33	82.33	90.00	94.22	46.00	45.67	43.33	45.00	9.90	9.17	9.80
74.50	63.00	68.67	68.72	49.67	44.67	47.33	47.22	10.30	10.57	10.00
119.93	138.73	127.03	128.57	63.33	61.67	70.33	65.11	11.07	11.40	10.87
70.17	103.40	93.90	89.16	49.00	54.33	54.00	52.44	6.57	10.07	11.10
100.57	89.13	108.47	99.39	42.33	38.67	50.67	43.89	9.60	9.53	10.43
93.15	93.45	99.35		48.00	49.42	53.13		9.76	10.23	10.6
A=3.99	B=2.44	A+B=6.91		A=3.31	B=2.03	A+B=5.74		A=0.46	B=0.28	A+B=0.8

Table 1. Growth parameters of cocoa varieties as influenced by varied Zn levels

Table 2. Shoot to root and root to shoot ratio of cocoa varieties as influenced by varied Zn levels

	Shoot: Root				Root: Shoot			
Varieties	Z1	Z2	Z3	Mean A	Z1	Z2	Z3	Mean A
V1	5.45	6.34	6.33	6.04	0.18	0.16	0.16	0.17
V2	4.47	6.42	5.58	5.49	0.22	0.16	0.18	0.19
V3	5.60	5.00	5.20	5.27	0.18	0.2	0.19	0.19
V4	6.57	6.09	4.03	5.56	0.15	0.16	0.25	0.19
V5	5.69	5.32	8.08	6.36	0.18	0.19	0.12	0.16
V6	6.79	6.41	6.43	6.54	0.15	0.16	0.17	0.15
V7	8.74	4.82	4.05	5.87	0.12	0.21	0.25	0.19
V8	4.89	4.58	4.77	4.75	0.21	0.22	0.21	0.21
Mean B	6.03	5.62	5.56		0.17	0.18	0.19	
LSD at 5%	A=0.47	B=0.28	A+B=0.81		A=0.015	B=0.1	A+B=0.025	

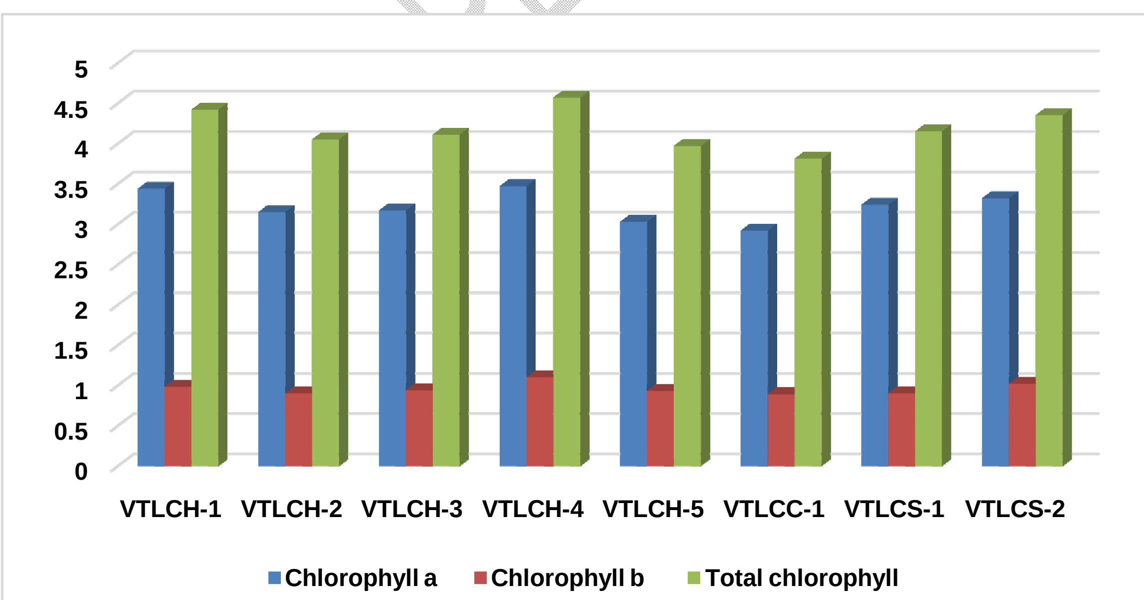

Fig 1. Varietal difference in chlorophyll a, b and total chlorophyll content in cocoa

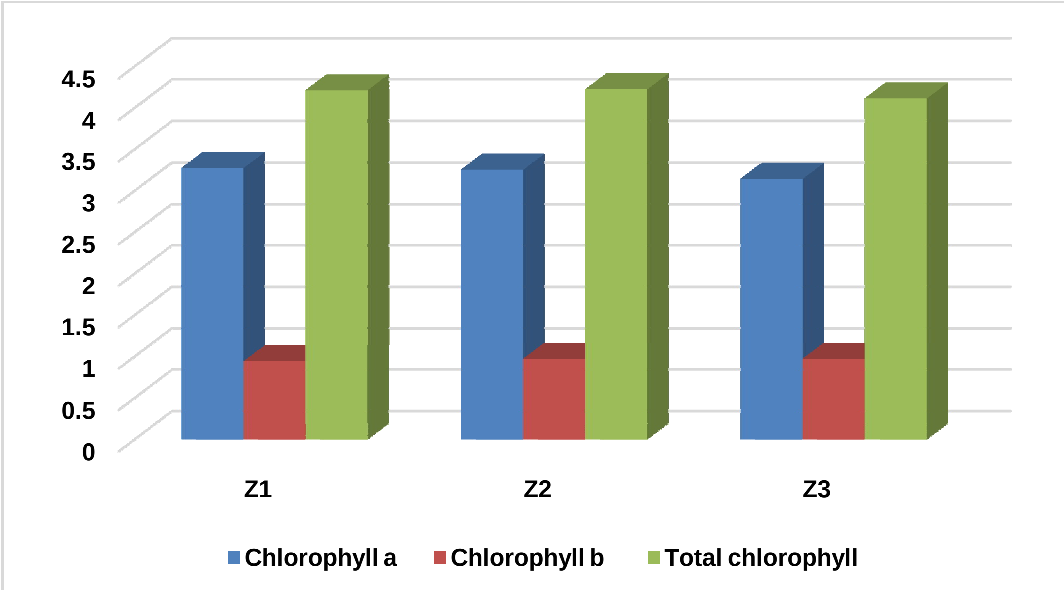

Fig 2. Chlorophyll a, b and total chlorophyll content in cocoa as influenced by varied Zn levels

4. CONCLUSION

The findings suggest that varying zinc levels exerted a significant positive influence on growth parameters in cocoa plants, notably enhancing plant height, leaf count, and stem diameter. Variety VTLCC-1 demonstrated exceptional growth performance, particularly when subjected to medium and high Zn levels, showcasing the variety's high responsiveness to Zn supplementation. Moreover, the observed variations in chlorophyll content among different cocoa varieties underscored the genetic diversity inherent in these plants. These results imply that genetic composition plays a crucial role in determining chlorophyll accumulation. Furthermore, distinct responses in biomass allocation were observed across cocoa varieties in relation to shoot-to-root and root-to-shoot ratios, highlighting the intricate interplay between genetic factors and Zn levels in shaping plant morphology and physiology. The findings underscore the significance of Zn supplementation in enhancing growth and optimizing biomass allocation in cocoa plants, with variety-specific responses highlighting the importance of considering genetic variability in cocoa cultivation.

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