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Impact of chelated zinc and seaweed extract on soil properties under guava cultivation

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Abstract
The field experiment was conducted at Fruit Orchard, Department of Horticulture, College of Agriculture, Gwalior (M.P.) during 2023-24 and 2024-25 to study the effect of Chelated Zinc and Seaweed extract on the Soil properties under guava (*Psidium guajava* L.) cv. G-27 cultivation. The results revealed a statistically significant improvement in all studied soil parameters *viz.*, electrical conductivity (EC), available nitrogen, phosphorus, potassium, cation exchange capacity (CEC), and organic carbon. Pooled data revealed that the application of chelated zinc at 0.4% (C_2) consistently enhanced nutrient availability, CEC and organic carbon over control, while seaweed extract at 6 ml (S_3) proved superior in improving all studied soil fertility indices. These findings suggest that integrating chelated zinc with seaweed extract application enhances soil health and nutrient dynamics in guava cultivation.

Keywords: Chelated zinc, seaweed extract, soil properties, organic carbon, soil health, CEC

Introduction

Guava (*Psidium guajava* L.) is a valuable and hardy fruit crop widely cultivated in tropical and subtropical regions around the world (Negi *et al.*, 1998) [9]. Belonging to the Myrtaceae family, guava is believed to have originated in Tropical America, specifically from Mexico to Peru, and possesses a chromosome number of 2n = 22 (Menzel, 1985; Boora, 2012) [8, 4]. However, seedless triploid guava varieties exhibit a chromosome number of 2n = 33 (Raman *et al.*, 1971). Often referred to as the “Apple of the Tropics” due to its versatility and widespread consumption, guava is primarily enjoyed as a fresh fruit (Webber, 1944; Menzel, 1985) [19, 8]. According to the National Nutrient Database of the United States Department of Agriculture (USDA, 2018), 100 g of guava fruit contains 14.3 g carbohydrates, 5.4 g total dietary fiber, 8.92 g sugar, and 2.55 g protein, along with high nutritional value in vitamins and minerals such as vitamin C (228 mg), vitamin A (31 µg), potassium (417 mg), phosphorus (40 mg), magnesium (22 mg), calcium (18 mg), and iron (0.26 mg) (Anonymous, 2018) [3]. Guava is also a rich source of pectin (0.78%), an important constituent in jelly preparation (Dhingra, 1979) [5]. Foliar application of micronutrients plays a vital role in enhancing plant growth by stimulating enzyme activity, protein synthesis, and physiological regulation (Alebidi and Zaman, 2020) [20]. Zinc deficiency, however, can adversely affect growth, yield, and fruit quality. Chelated zinc, owing to its superior bioavailability, has been reported to improve vegetative growth, fruit yield, and leaf nutrient status in guava (Singh and Singh, 2023) [15]. Similarly, seaweed extract has gained attention in sustainable agriculture for its organic and biodegradable nature, making it a preferred input in organic farming systems (Shaji *et al.*, 2021) [13]. Rich in bioactive compounds such as auxins, cytokinins, and gibberellins, along with essential nutrients and polysaccharides, seaweed extract promotes plant growth, improves nutrient uptake, and enhances stress tolerance (Alebidi and Zaman, 2024) [1].

Considering these benefits, the present study was conducted to evaluate the effect of chelated zinc and seaweed extract on soil properties under guava (*Psidium guajava* L.) cultivation, aiming to enhance nutrient dynamics and improve orchard productivity.

Materials and Methods

The field investigation was carried out at the Fruit Orchard, Department of Horticulture, College of Agriculture, Gwalior (M.P.) during the years 2022-23 and 2023-24. The study employed a factorial randomized block design comprising sixteen treatment combinations of chelated zinc and seaweed extract, replicated three times. The treatments were as follows: T_1- Control (water spray); T_2 - Seaweed extract 2 ml; T_3- Seaweed extract 4 ml; T_4 - Seaweed extract 6 ml; T_5 - Chelated Zinc 0.2%; T_6 - Chelated Zinc 0.2% + Seaweed extract 2 ml; T_7 - Chelated Zinc 0.2% + Seaweed extract 4 ml; T_8 - Chelated Zinc 0.2% + Seaweed extract 6 ml; T_9 - Chelated Zinc 0.4%; T_{10} - Chelated Zinc 0.4% + Seaweed extract 2 ml; T_{11} - Chelated Zinc 0.4% + Seaweed extract 4 ml; T_{12} - Chelated Zinc 0.4% + Seaweed extract 6 ml; T_{13} - Chelated Zinc 0.6%; T_{14} - Chelated Zinc 0.6% + Seaweed extract 2 ml; T_{15} - Chelated Zinc 0.6% + Seaweed extract 4 ml; and T_{16} - Chelated Zinc 0.6% + Seaweed extract 6 ml. Chelated zinc and seaweed extract were applied as a soil treatment before flowering, and the prepared solutions for each treatment were applied when fruits reached the pea stage of development. Available nitrogen in the soil was determined using the alkaline permanganate method as described by Subbiah and Asija (1956) [16]. Available phosphorus was estimated following Olsen's calorimetric method (Olsen *et al.*, 1954) [10] and Available potassium was measured using the flame photometer method (Hanway & Heidel, 1952) [6]. Electrical conductivity (EC) of the soil was measured using a digital conductivity meter following the method described by Jackson (1973) [7]. Cation exchange capacity (CEC) was calculated by determining the milliequivalents of hydrogen (H), potassium (K), magnesium (Mg), and calcium (Ca) per 100 g of soil (meq/100 g) using the following formulas: A)- H (meq/100 g soil) = 8 (8.00 - buffer pH) and B)- K (meq/100 g soil) = lbs/acre extracted K ÷ 782. Whereas soil organic matter was estimated using the wet oxidation method of Walkley and Black (1934) [18].

Results and Discussion

Table 1: Effect of Cheated Zinc and Seaweed extract on available N, P and K of soil in Guava field

A. Cheated Zinc	Available N (kg ha^{-1})			Available P (kg ha^{-1})			Available K (kg ha^{-1})		
	2023-24	2024-25	Pooled	2023-24	2024-25	Pooled	2023-24	2024-25	Pooled
C_0 - Control	154.68	159.16	156.92	8.31	9.67	8.99	174.03	176.99	175.51
C_1 - Cheated Zinc 0.2%	199.57	205.11	202.34	10.89	12.61	11.75	223.26	226.95	225.10
C_2 - Cheated Zinc 0.4%	215.57	221.44	218.51	11.83	13.63	12.73	240.83	244.75	242.79
C_3- Cheated Zinc 0.6%	208.70	214.44	211.57	11.44	13.19	12.32	233.45	237.23	235.34
S.Em±	3.53	3.62	3.57	0.199	0.240	0.217	3.86	3.92	3.89
CD (p=0.05)	10.20	10.45	10.32	0.575	0.692	0.628	11.16	11.33	11.24
B. Seaweed extract									
S_0 - Control	149.51	153.90	151.70	8.00	9.35	8.67	168.37	171.26	169.82
S_1 - Seaweed extract 2ml	182.36	187.45	184.91	9.90	11.46	10.68	204.25	207.68	205.96
S_2 - Seaweed extract 4ml	217.26	223.19	220.22	11.93	13.75	12.84	242.77	246.70	244.74
S_3 - Seaweed extract 6ml	229.39	235.63	232.51	12.63	14.55	13.59	256.18	260.29	258.23
S.Em±	3.53	3.62	3.57	0.20	0.24	0.22	3.86	3.92	3.89
CD (p=0.05)	10.20	10.45	10.32	0.57	0.69	0.63	11.16	11.33	11.24

Available nitrogen

Table. 1 revealed that both chelated zinc and seaweed extract significantly influenced the available nitrogen in guava soil based on pooled data. Among chelated zinc treatments, the highest nitrogen content was observed in C_2 (0.4%) with 218.51 kg ha^{-1}, followed by C_3 (0.6%) with 211.57 kg ha^{-1}, while the lowest was in control (C_0) with 156.92 kg ha^{-1}. In seaweed extract treatments, the maximum was recorded in S_3 (6 ml) with 232.51 kg ha^{-1}, followed by S_2 (4 ml) with 220.22 kg ha^{-1}, whereas the minimum was in control (S_0) with 151.70 kg ha^{-1}. Available nitrogen improved significantly with both chelated zinc and seaweed extract applications. The increase under zinc can be attributed to its role in promoting microbial mineralization and nitrate reductase activity, while seaweed extract stimulated nitrogen-fixing bacteria and provided amino acids that supported nitrogen cycling. Ujjwal *et al.* (2025) [17] similarly reported that zinc sulphate increased nitrogen availability in *Manilkara hexandra*, and Aly *et al.* (2021) [2] confirmed that seaweed extract enhanced nitrogen in guava cv. Maamoura.

Available phosphorus

Table. 1 revealed that both chelated zinc and seaweed extract significantly affected the available phosphorus in guava soil. Based on pooled data, the highest phosphorus content among chelated zinc treatments was recorded in C_2 (0.4%) with 12.73 kg ha^{-1}, followed by C_3 (0.6%) with 12.32 kg ha^{-1}, while the lowest was observed in control (C_0) with 8.99 kg ha^{-1}. Similarly, seaweed extract treatments showed maximum phosphorus in S_3 (6 ml) with 13.59 kg ha^{-1}, followed by S_2 (4 ml) with 12.84 kg ha^{-1}, whereas the minimum was recorded in control (S_0) with 8.67 kg ha^{-1}. Phosphorus availability also increased significantly. This improvement can be attributed to zinc-induced secretion of organic acids and phosphatases that mobilize bound phosphorus, and to chelating agents present in seaweed that release phosphorus from soil complexes. Singh *et al.* (2023) [14] reported similar increases in guava cv. Lalit under chelated zinc, and Aly *et al.* (2021) [2] noted enhanced phosphorus with seaweed extract application in guava soils.

Available potash

Table. 1 showed that chelated zinc and seaweed extract significantly influenced the available potassium in guava soil. In pooled data, the highest potassium among chelated zinc treatments was recorded in C_2 (0.4%) with 242.79 kg ha^{-1}, followed by C_3 (0.6%) with 235.34 kg ha^{-1}, while the lowest was in control (C_0) with 175.51 kg ha^{-1}. For seaweed extract, the maximum potassium was observed in S_3 (6 ml) with 258.23 kg ha^{-1}, followed by S_2 (4 ml) with 244.74 kg ha^{-1}, whereas the minimum was reported in control (S_0) with 169.82 kg ha^{-1}. The positive effect of zinc may be due to improved membrane permeability and absorption efficiency, while seaweed extract likely promoted root development and facilitated potassium transport. These findings are in line with Ujjwal *et al.* (2025) [17], who reported potassium increases with zinc sulphate in Manilkara hexandra, and Rana *et al.* (2023) [12], who found that seaweed extract application in kiwifruit improved potassium from 178.4 to 261.2 kg/ha.

Table 2: Effect of Cheated Zinc and Seaweed extract on EC, CEC and organic carbon of soil in Guava field

A. Cheated Zinc	Electrical conductivity (dS m^{-1})			CEC (meq $100g^{-1}$)			organic carbon		
	2023-24	2024-25	Pooled	2023-24	2024-25	Pooled	2023-24	2024-25	Pooled
C_0 - Control	0.29	0.31	0.30	35.19	35.49	35.34	0.35	0.37	0.36
C_1 - Cheated Zinc 0.2%	0.37	0.40	0.39	38.45	38.81	38.63	0.43	0.46	0.44
C_2 - Cheated Zinc 0.4%	0.39	0.42	0.41	39.61	40.00	39.80	0.45	0.49	0.47
C_3- Cheated Zinc 0.6%	0.41	0.45	0.43	39.13	39.51	39.32	0.44	0.47	0.46
S.Em±	0.009	0.009	0.009	0.256	0.262	0.259	0.006	0.007	0.007
CD (p=0.05)	0.025	0.026	0.026	0.741	0.756	0.748	0.019	0.020	0.019
B. Seaweed extract									
S_0 - Control	0.28	0.30	0.29	34.81	35.10	34.96	0.34	0.36	0.35
S_1 - Seaweed extract 2ml	0.33	0.36	0.34	37.19	37.52	37.35	0.39	0.42	0.41
S_2 - Seaweed extract 4ml	0.41	0.45	0.43	39.74	40.13	39.94	0.46	0.49	0.47
S_3 - Seaweed extract 6ml	0.44	0.48	0.46	40.63	41.04	40.84	0.48	0.51	0.50
S.Em±	0.009	0.009	0.009	0.256	0.262	0.259	0.006	0.007	0.007
CD (p=0.05)	0.025	0.026	0.026	0.741	0.756	0.748	0.019	0.020	0.019

Electrical conductivity (dS m^{-1})

Table. 2 revealed that both chelated zinc and seaweed extract had a significant effect on the electrical conductivity of guava soil. In pooled data, the highest electrical conductivity among chelated zinc treatments was recorded in C_3 (0.6%) with 0.43 dS m^{-1}, followed by C_2 (0.4%) with 0.41 dS m^{-1}, while the lowest was in control (C_0) with 0.30 dS m^{-1}. Similarly, seaweed extract treatments showed maximum conductivity in S_3 (6 ml) with 0.46 dS m^{-1}, followed by S_2 (4 ml) with 0.43 dS m^{-1}, whereas the minimum was reported in control (S_0) with 0.29 dS m^{-1}. This increase indicates greater ionic activity and nutrient solubility, which may be linked to zinc's role in stimulating root exudation and microbial activity, as well as the natural electrolytes and organic acids present in seaweed. These results align with Rakha *et al.* (2024) [11], who observed that chelated zinc and seaweed extract improved EC in Nemaguard peach rootstock.

CEC (meq 100 g^{-1})

Table. 2 revealed that both chelated zinc and seaweed extract significantly affected the cation exchange capacity (CEC) of guava soil. In pooled data, the highest CEC among chelated zinc treatments was recorded in C_2 (0.4%) with 39.80 meq $100g^{-1}$, followed by C_3 (0.6%) with 39.32 meq $100g^{-1}$, while the lowest was observed in control (C_0) with 35.34 meq $100g^{-1}$. Similarly, seaweed extract treatments showed maximum CEC in S_3 (6 ml) with 40.84 meq $100g^{-1}$, followed by S_2 (4 ml) with 39.94 meq $100g^{-1}$, whereas the minimum was recorded in control (S_0) with 34.96 meq $100g^{-1}$. This suggests enhanced soil colloidal activity and greater nutrient retention capacity. Chelated zinc likely stimulated root activity and humus formation, while seaweed extract contributed humic substances and polysaccharides that stabilized soil colloids. Rakha *et al.* (2024) [11] reported similar improvements in CEC with chelated zinc and seaweed extract in Nemaguard peach rootstock.

Organic carbon (%)

Table. 2 revealed that chelated zinc and seaweed extract significantly influenced the organic carbon content in guava leaves. Based on pooled data, the highest organic carbon among chelated zinc treatments was observed in C_2 (0.4%) with 0.47%, followed by C_3 (0.6%) with 0.46%, while the lowest was in control (C_0) with 0.36%. Similarly, seaweed extract treatments recorded the maximum organic carbon in S_3 (6 ml) with 0.50%, followed by S_2 (4 ml) with 0.47%, whereas the minimum was reported in control (S_0) with 0.35%. This enhancement may be linked to zinc's stimulation of microbial biomass and decomposition of residues, and seaweed's contribution of organic matter that promotes humus formation. Aly *et al.* (2021) [2] reported similar increases in organic carbon from 0.35% to 0.48% with chelated zinc in guava soils, while Rana *et al.* (2023) [12] confirmed seaweed extract increased organic carbon in kiwifruit soils from 0.36% to 0.52%.

Conclusion

Thus, it can be concluded that foliar application of chelated zinc (0.4%) and seaweed extract (6 ml) individually, as well as in combination, was found to be the most effective treatment for improving soil fertility parameters in guava cultivation, enhancing nutrient availability, cation exchange capacity, and organic carbon content.

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