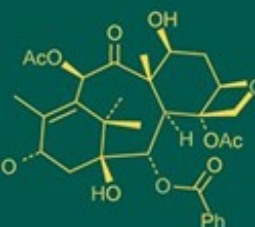
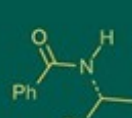
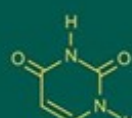


International Journal of Advanced Biochemistry Research



ISSN Print: 2617-4693
ISSN Online: 2617-4707
NAAS Rating (2026): 5.29
Indexing: Embase
IJABR 2026; SP-10(9): 1938-1942
www.biochemjournal.com
Received: 14-07-2026
Accepted: 14-08-2026
Published: 24-09-2026

Anasuya Sil

Ph.D. Scholar, Department of
Plantation, Spices, Medicinal
and Aromatic Crops, Faculty
of Horticulture, Bidhan
Chandra Krishi
Viswavidyalaya, Mohanpur
(741252), West Bengal, India.

Jitesh Kumar Hore

Former Professor, Dean and
Dean PG Studies, BCKV
Department of Plantation,
Spices, Medicinal and
Aromatic Crops, Faculty of
Horticulture, Mohanpur
(741252), West Bengal, India.

Role of nano Zn and Mn on growth, productivity, quality, soil and leaf nutrient status of turmeric (*Curcuma longa* L.)

Anasuya Sil¹, Jitesh Kumar Hore²

DOI: <https://www.doi.org/10.33545/26174693.2026.v10.i9Sx.10141>

ABSTRACT

A field experiment was conducted at horticultural research station, Mondouri, Bidhan Chandra Krishi Viswavidyalaya, India, to assess the effect of nano and non nano micronutrients on turmeric. The whole experiment was laid out in randomized block design with twelve treatments and three replications containing three different levels (0.3, 0.4 and 0.5%) of nano and non nano zinc and manganese along with full recommended dose of fertilizers (N: P₂O₅: K₂O @ 150:60:150 kg ha⁻¹) at 45 and 90 days after planting. Foliar application of 0.5% nano-Zn and 0.4% nano-Mn (T11) recorded maximum plant height (112.68 cm), leaf length (56.53 cm) and breadth (14.35 cm) at 120 DAP, projected yield (30.84 t ha⁻¹), dry recovery (23.28%) and total curcumin yield (433.27 kg ha⁻¹). In contrast T2 (RDF + 0.4% ZnSO₄ and MnSO₄) recorded minimum projected yield (25.54 t ha⁻¹), dry recovery (20.91%) and total curcumin content (267.36 kg ha⁻¹). Plants grown under nano micronutrients recorded better leaf NPK and available soil nutrient status also. The study demonstrated that nano-micronutrient application effectively improves growth, productivity, quality, and soil and leaf nutrient status of turmeric.

Keywords: Dry recovery, Nano zinc, Nano manganese, Total curcumin, Turmeric, Yield

Introduction

Turmeric (*Curcuma longa* L.), a perennial rhizomatous herb belongs to the family Zingiberaceae, originated from Southeast Asia. It is widely recognized as **Herbal Gold** owing to significant medicinal, nutritional and economic value. The crop is cultivated primarily for its underground modified stem (rhizome), which contain several bioactive constituents, including curcumin, oleoresin, essential oils and phenolic compounds. Among these, curcumin imparts the characteristic yellow colour and possesses diverse medicinal properties such as antioxidant, anti-inflammatory, antimicrobial, anticancer, hepatoprotective and immunomodulatory activities (Nguyen *et al.*, 2024) [1]. Turmeric is extensively utilized in traditional medicine, pharmaceutical formulations, nutraceutical products, food preservation, cosmetics and as a natural colorant. India is the leading producer, consumer and exporter of turmeric (Sil *et al.*, 2026) [2]. Despite its commercial importance, sustaining high productivity and superior quality remains challenging due to inefficient nutrient management practices.

Being a long duration crop, turmeric requires heavy and balanced nutrition for optimal growth and productivity. While considerable emphasis has been placed on primary nutrients, the importance of micronutrients has often been overlooked. Among various micronutrients zinc and manganese regulate key enzymatic, photosynthetic and metabolic processes. The efficiency of conventional micronutrient is frequently constrained by fixation, leaching, precipitation, and other soil related losses, limiting nutrient availability to plants. Nanotechnology offers a promising alternative through the development of nano-fertilizers possessing high surface area, enhanced reactivity, controlled nutrient release, and improved nutrient use efficiency while reducing environmental losses. However, information regarding the combined effects of nano zinc and nano manganese on turmeric is limited. Therefore, the present study was undertaken to evaluate the influence of nano Zn and Mn on growth, productivity, quality, soil and leaf nutrient status in turmeric.

Materials and Methods

The experiment was carried out during 2022-23 and 2023-24 at the Horticultural Research Station, Mondouri, under the Faculty of Horticulture, Bidhan Chandra Krishi Viswavidyalaya, West Bengal. The site is situated at 23°05' N latitude and 89°00' E longitude, with an altitude of 9.75 m above MSL. The experimental soil belongs to the Gangetic New Alluvial Plains and possesses a sandy clay loam texture with pH of 6.62 (Jackson, 1967) [3], organic carbon 0.67% (Walkey and Black, 1934) [4], containing 229.71 kg ha⁻¹ available N (by modified Kjeldahl's method), 18.53 kg ha⁻¹ available P (Olsen *et al.*, 1954) [5] and 210.65 kg ha⁻¹ available K (by flame photometer). The experiment was laid out in randomized block design

Corresponding Author:
Anasuya Sil

Ph.D. Scholar, Department
of Plantation, Spices,
Medicinal and Aromatic
Crops, Faculty of
Horticulture, Bidhan
Chandra Krishi
Viswavidyalaya, Mohanpur
(741252), West Bengal,
India.

with 12 treatments and 3 replications (Table 1) containing 3 different levels (0.3, 0.4 and 0.5%) of non-nano and nano zinc and manganese at 45 and 90 DAP. Seed rhizomes (25-30 g) of variety Suguna were planted in a raised bed of 15 cm with a diameter of $3.0 \text{ m} \times 1.0 \text{ m}$ at a spacing of $30 \text{ cm} \times 25 \text{ cm}$ which accommodate 40 plants per bed altogether 1440 plants in total 36 plots. In both years, planting was done in the middle of June, while harvesting was completed by the end of January. Before planting seed rhizomes were treated with blitox @ 4 g L^{-1} for 30 minutes followed by shade drying to avoid any fungal infection. Full recommended fertilizer dose of NPK @ 150:60:150 kg ha^{-1} (Medda *et al.*, 2003) [6] was supplied through urea, single super phosphate and muriate of potash to all the treatments. 40% nitrogen along with the full dose of phosphorus were applied as a basal along with FYM @ 25 t ha^{-1} , while the remaining nitrogen and potassium were applied in two split doses at 45 and 90 DAP. The irrigation was done immediately after planting and rest of other irrigations were given based on soil moisture availability. Mulching was done with paddy straw @ 10 t ha^{-1} just after planting and additional mulching was provided at 45 and 90 DAP using paddy straw at 5 t ha^{-1} and earthing up was carried out prior to the second and third mulching operations.

$$\text{Total curcumin (kg ha}^{-1}\text{)} = \text{Dry recovery} \times \text{Projected yield} \times \text{curcumin percentage}$$

Available nitrogen, phosphorus and potassium were estimated using the alkaline permanganate, Olsen's extraction and flame photometric methods respectively and expressed as kg ha⁻¹. For leaf nutrient analysis, the third fully expanded leaf was sampled at 120 DAP, washed in distilled water, oven-dried at 55-65 °C and ground. Nitrogen content was determined by the Kjeldahl method, while phosphorus and potassium were analysed by using colorimeter and flame photometer respectively and was expressed in percentage (Jackson, 1967) [3].

Data analysis

Recorded data was analysed by ANOVA using Microsoft Excel 2016 and OPSTAT online as outlined by [Gomez *et al.* \(1984\)](#) [8]. The treatment significance and critical differences assessed at 5% probability following the procedure described in the statistical tables of [Fisher *et al.* \(1953\)](#) [9] for comparison of treatment means.

Results and Discussions

The data presented in Table 3 and 4 revealed a significant variations among the treatments due to application of nano micronutrients.

Growth parameters

The foliar application of nano-Zn @ 0.5% and Mn @ 0.4% (T₁₁) recorded maximum plant height (112.68 cm), which is statistically *at par* with T₈ (111.91 cm). The plants grown under treatment combinations of RDF + 0.4% ZnSO₄ and MnSO₄ (T₂) showed the shortest (93.09 cm) plant height. Tiller numbers increased markedly across all treatments at 120 days after planting, with the values ranging from 1.08 to 1.92. Treatment receiving 0.5% nano-Zn and Mn at 45 and 90 DAP (T₁₂) produced maximum number of tillers (1.92) followed by T₁₀ (1.83) and T₉ (1.83), whereas T₂ recorded minimum number of tillers per plant (1.08). The data presented in Table 3 reported that maximum leaf length (56.53 cm) and breadth (14.35 cm) were recorded under T₁₁ which is statistically *at par* with T₉ and T₈. Treatment combinations of 0.4% ZnSO₄ and MnSO₄ (T₂) recorded the shortest leaf length (50.04 cm) whereas minimum breadth (11.92 cm) was recorded under foliar application of 0.3% ZnSO₄ and MnSO₄ (T₁). It is clearly observed from Table 4 that at 120 DAP the maximum number of leaves (12.07) was recorded under T₁₂ which is statistically *at par* with T₁₁ (12.05) and T₉ (11.85) in contrast to T₁ that recorded minimum leaf numbers (8.57).

Foliar spray of nano and non-nano Zn and Mn (Table 2) were prepared freshly by dissolving the required quantity of nano and non nano micro nutrients in distilled water according to the treatments. During this time 2-3 drops of sticker (balanstick) were added in the solution to enhance leaf retention. Spraying was uniformly done during morning hours until near runoff to ensure efficient nutrient uptake while minimizing drift and environmental losses.

Observations

Growth attributes such as plant height (cm), number of tillers and leaves per plant, leaves length (cm) and breadth (cm) were recorded at 120 DAP from 5 randomly selected plants of each plot. Projected yield was estimated from the total harvested plot yield, considering 75% effective cropped area and 25% area occupied by pathways and irrigation channels, using the formula: Projected yield (t ha^{-1}) = plot yield (kg 3 m^{-2}) $\times$ 2500 (Anonymous, 1995) [7].

Dry recovery was determined by drying 100 g of freshly chopped rhizomes in a mechanical dryer at 55 °C until constant weight and expressed as a percentage. Total curcumin yield was computed by following the formula:

Projected yield

The projected yield per hectare followed the similar trend, with values ranging from 25.54 t ha⁻¹ to 30.84 t ha⁻¹ presented in Table 4. The maximum projected yield (30.84 t ha⁻¹) was recorded in T₁₁ which is statistically *at par* with T₁₂ (30.72 t ha⁻¹) and T₁₀ (30.08 t ha⁻¹). The lowest projected yield (25.54 t ha⁻¹) was observed in T₂ (RDF + 0.4% ZnSO₄ and MnSO₄ at 45 and 90 DAP).

Quality attributes

The data presented in Table 4 revealed that maximum dry recovery (23.28%) and total curcumin content ($433.27 \text{ kg ha}^{-1}$) were recorded in the plants treated with 0.5% nano Zn and 0.4% nano Mn (T_{11}) as compare to T_2 (0.4% ZnSO_4 and MnSO_4) which recorded minimum dry recovery (20.91%) and total curcumin content ($267.36 \text{ kg ha}^{-1}$). The treatments combined nano Zn and Mn application at 45 and 90 DAP (T_{11}) showed better results for most of the vegetative parameters, projected yield and quality attributes suggests that split application of nano micronutrients may ensures better nutrient supply during critical vegetative growth phases rather than conventional. Similar findings have been reported in turmeric by Khattab *et al.*, 2023 [10] where application of nano-Zn @ 10 mg L^{-1} significantly improved plant height, leaf numbers and yield as compare to control. In another study Alkhlefawi, (2022) [11] observed application of nano-Mn @ 2 g L^{-1} significantly enhanced plant height, number of leaves per plant and leaf area in fenugreek compared to conventional fertilizers. Nano-Zn and nano-Mn exhibit high surface to volume ratios, increased reactivity and greater solubility compared to bulk fertilizers. Their nanoscale size facilitates enhanced penetration through leaf cuticles and stomatal openings in foliar application, rapid mobility within apoplastic and symplastic pathways, controlled nutrient release synchronized with crop demand (Semenova *et al.*, 2024) [12]. In a study Sharma *et al.* (2013) [13] reported that Zn enhances yield through activation of carbonic anhydrase, improving CO_2 assimilation efficiency, stimulation of tryptophan synthesis, a precursor of IAA, promoting cell division and elongation, improved synthesis of nucleic acids and proteins, supporting vigorous vegetative growth where nano-Mn improves yield by strengthening photolysis of water and electron transport activity, increasing chlorophyll stability and light-harvesting efficiency, enhancing photosynthetic carbon fixation and assimilate accumulation (Pradhan *et al.*, 2013). The findings of present experiment are closely related to Poornima *et al.* (2019) [14] who reported that foliar application of nano- ZnO at 500 ppm significantly influenced plant height, leaf area, leaf area index and total dry matter compared with 1000 ppm bulk ZnSO_4 .

Soil nutrient status

Data presented in table 5 revealed that the highest available soil nitrogen ($238.41 \text{ kg ha}^{-1}$) was recorded under T_{12} (0.5% nano-Zn and Mn), followed by T_{10} ($237.68 \text{ kg ha}^{-1}$) as compared to T_1 which recorded minimum available nitrogen content ($223.09 \text{ kg ha}^{-1}$) after harvesting. In case of available phosphorus maximum value (20.57 kg ha^{-1}) was recorded in T_4 which is statistically *at par* with T_9 (20.21 kg ha^{-1}). The minimum phosphorus content (17.48 kg ha^{-1}) was observed in T_{10} . The soil available potassium content ranged from $223.25 \text{ kg ha}^{-1}$ to $232.85 \text{ kg ha}^{-1}$. T_{11} showed the highest value followed by T_8 ($230.74 \text{ kg ha}^{-1}$) while T_1 recorded the lowest available potassium ($223.25 \text{ kg ha}^{-1}$). The results demonstrate that nano-formulated micronutrients integrated with commercial fertilizers significantly improved soil nitrogen and phosphorus availability, while potassium content remained largely unaffected. Treatments T_{12} , T_{11} , T_{10} and T_9 performed better in maintaining higher soil nutrient status, suggesting that nano micronutrient based nutrient management can enhance soil fertility and sustainability in turmeric cultivation.

Leaf nutrient status

Leaf NPK content is a key indicator of plant nutritional status and photosynthetic capacity. Maximum leaf nitrogen was recorded under T_8 (1.58%), leaf phosphorus was recorded under T_{12} (0.43%) where T_6 recorded highest potassium content (3.13%) at 120 DAP. In contrast the lowest nitrogen was recorded under T_4 , while T_2 showed lowest leaf phosphorus (0.33%) and potassium (2.34%). The improved leaf nutrient status under nano-fertilizer treatments may be due to enhance metabolic activity due to application of nano micronutrients which ultimately contributed to improved growth, yield, and quality attributes observed in the study.

Conclusion

The findings of the present investigation established that considering the projected yield, total curcumin content and growth attributes, T_{11} (0.5% nano-Zn and 0.4% nano-Mn) emerged as the most effective treatment, followed by T_{12} (0.5% nano-Zn and Mn). Overall, the study demonstrates that foliar application of nano-formulated micronutrients in combination with commercial fertilizers represents a promising strategy for optimizing micronutrient use efficiency and maximizing turmeric productivity and quality under the Gangetic New Alluvial Plains of West Bengal.

Table 1. Treatment details

Sl. No.	Treatment combination
T_1	RDF + 0.3% ZnSO_4 and MnSO_4
T_2	RDF + 0.4% ZnSO_4 and MnSO_4
T_3	RDF + 0.5% ZnSO_4 and MnSO_4
T_4	RDF + 0.3% Nano Zn and Mn
T_5	RDF + 0.3% Nano-Zn and 0.4% Nano-Mn
T_6	RDF + 0.3% Nano-Zn and 0.5% Nano-Mn
T_7	RDF + 0.4% Nano-Zn and 0.3% Nano-Mn
T_8	RDF + 0.4% Nano Zn and Mn
T_9	RDF + 0.4% Nano-Zn and 0.5% Nano-Mn
T_{10}	RDF + 0.5% Nano-Zn and 0.3% Nano-Mn
T_{11}	RDF + 0.5% Nano-Zn and 0.4% Nano-Mn
T_{12}	RDF + 0.5% Nano Zn and Mn

[RDF: 40% N+100% P (Basal)→ 30% N+50% K (45 and 90 DAP). Nano and non nano zinc and manganese were applied at 45 and 90 DAP]

Table 2. Characterization of nano and non nano micronutrients

Name	Source	Nutrient content	Particle size	Formulation type	Solubility
Nano-Zn	Geolife	30% as Zn-EDTA chelate	25-50 nm	White powder	Highly water soluble
Nano-Mn	Geolife	26.6% as Mn-EDTA chelate	-Do-	-Do-	-Do-
$\text{ZnSO}_4 \cdot \text{H}_2\text{O}$	Local market	33% Zn, 15% S, Non-chelated	> 100 nm	White crystalline powder	-Do-
$\text{MnSO}_4 \cdot \text{H}_2\text{O}$	-Do-	31–32% Mn, 17–18% S, Non-chelated	-Do-	Pale pink crystalline powder	-Do-

Table 3. Effect of nano micronutrients on growth parameters at 120 DAP

Treatments	Plant height (cm)			Tiller number			Leaf length (cm)			Leaf breadth (cm)		
	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled
T_1	91.28	96.58	93.93	1.10	1.13	1.11	50.89	49.57	50.23	11.53	12.31	11.92
T_2	91.16	95.02	93.09	1.03	1.12	1.08	49.53	50.55	50.04	11.73	12.52	12.13
T_3	96.45	95.96	96.21	1.19	1.21	1.20	52.67	51.91	52.29	12.27	12.79	12.53
T_4	104.39	103.39	103.89	1.46	1.51	1.49	51.24	52.52	51.88	12.87	13.24	13.05
T_5	104.23	106.60	105.42	1.43	1.56	1.50	51.83	54.12	52.97	13.08	13.48	13.28
T_6	107.28	104.25	105.77	1.51	1.59	1.55	52.95	53.49	53.22	13.41	13.32	13.37
T_7	109.69	108.69	109.19	1.57	1.60	1.58	53.21	56.89	55.05	13.55	14.29	13.92
T_8	108.83	114.98	111.91	1.59	1.65	1.62	54.07	57.09	55.58	13.89	14.19	14.04
T_9	107.16	110.06	108.61	1.76	1.89	1.83	53.36	57.38	55.37	13.78	14.63	14.21
T_{10}	105.40	109.59	107.50	1.71	1.94	1.83	55.75	54.21	54.98	14.07	13.91	13.99
T_{11}	110.13	115.23	112.68	1.76	1.73	1.75	54.47	58.59	56.53	14.13	14.57	14.35
T_{12}	103.89	108.60	106.25	1.80	2.03	1.92	53.63	56.69	55.16	13.76	14.05	13.90
S.E.m.(±)	1.503	1.528	1.504	0.021	0.024	0.022	0.806	0.828	0.823	0.198	0.207	0.199
C.D.(P = 0.05)	4.437	4.510	4.441	0.063	0.070	0.066	2.379	2.444	2.428	0.585	0.612	0.588

(continued on next page)

Table 4. Effect of nano micronutrients on number of leaves at 120 DAP, projected yield and quality attributes

Treatments	Leaf number			Projected yield (t ha ⁻¹)			Dry recovery (%)			Total curcumin (kg ha ⁻¹)		
	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled
T ₁	8.73	8.40	8.57	24.08	27.47	25.77	19.68	22.36	21.02	245.48	328.61	287.04
T ₂	9.37	9.43	9.40	23.28	27.81	25.54	21.14	20.67	20.91	249.02	285.69	267.36
T ₃	9.65	9.98	9.82	23.64	28.14	25.89	20.69	21.23	20.96	251.40	347.10	299.25
T ₄	10.63	10.91	10.77	24.11	29.73	26.92	22.81	20.39	21.60	289.27	336.44	312.86
T ₅	10.86	11.01	10.94	24.56	30.21	27.38	20.55	23.16	21.86	258.92	394.61	326.76
T ₆	11.08	11.13	11.11	25.06	30.81	27.94	23.37	22.41	22.89	327.38	336.94	332.16
T ₇	11.10	11.24	11.17	25.54	30.63	28.08	21.82	22.42	22.12	319.88	399.67	359.78
T ₈	11.21	11.30	11.26	26.90	30.18	28.54	22.68	23.68	23.18	347.14	433.09	390.11
T ₉	11.75	11.95	11.85	27.19	31.10	29.14	23.12	22.95	23.04	377.18	411.83	394.51
T ₁₀	11.47	11.53	11.50	28.53	31.64	30.08	23.76	22.15	22.96	389.10	417.69	403.40
T ₁₁	11.81	12.29	12.05	29.91	31.77	30.84	23.09	23.46	23.28	408.16	458.37	433.27
T ₁₂	11.88	12.25	12.07	30.15	31.30	30.72	22.77	23.34	23.06	383.08	459.51	421.29
S.Em.(±)	0.163	0.164	0.158	0.384	0.431	0.401	0.323	0.308	0.313	5.093	5.856	5.365
C.D.(P = 0.05)	0.481	0.484	0.467	1.132	1.273	1.185	0.954	0.909	0.924	15.034	17.287	15.837

Table 5. Effect of nano micronutrients on soil nutrient status (kg ha⁻¹)

Treatments	Nitrogen			Phosphorus			Potassium		
	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled
T ₁	219.01	227.16	223.09	17.23	18.57	17.90	220.14	226.36	223.25
T ₂	220.54	238.78	229.66	19.03	20.36	19.70	228.39	222.75	225.57
T ₃	229.30	236.43	232.87	16.79	19.26	18.03	221.17	226.43	223.80
T ₄	235.15	230.26	232.71	19.36	21.78	20.57	227.63	230.17	228.90
T ₅	234.79	236.17	235.48	16.75	22.15	19.45	228.02	220.20	224.11
T ₆	233.36	239.52	236.44	16.21	20.83	18.52	219.28	230.49	224.89
T ₇	235.28	239.3	237.29	15.06	21.76	18.41	232.56	223.61	228.09
T ₈	238.59	235.37	236.98	19.89	18.58	19.24	229.11	232.36	230.74
T ₉	236.26	232.69	234.48	22.53	17.89	20.21	230.61	221.23	225.92
T ₁₀	235.75	239.61	237.68	19.41	15.55	17.48	231.40	227.26	229.33
T ₁₁	238.98	234.45	236.72	16.29	21.87	19.08	229.91	235.78	232.85
T ₁₂	237.43	239.39	238.41	17.27	21.08	19.18	220.46	229.14	224.80
S.Em.(±)	3.233	3.282	3.305	0.264	0.289	0.273	3.181	3.210	3.274
C.D.(P = 0.05)	9.545	9.687	9.757	0.780	0.853	0.805	9.388	9.475	NS

Table 6. Effect of nano micronutrients on leaf nutrient status (%)

Treatments	Nitrogen			Phosphorus			Potassium		
	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled
T ₁	1.34	1.41	1.38	0.31	0.35	0.33	2.60	2.63	2.62
T ₂	1.35	1.41	1.38	0.33	0.32	0.33	2.36	2.31	2.34
T ₃	1.49	1.32	1.41	0.34	0.36	0.35	2.87	2.85	2.86
T ₄	1.35	1.37	1.36	0.35	0.37	0.36	3.07	3.06	3.07
T ₅	1.46	1.37	1.42	0.40	0.37	0.39	2.95	2.97	2.96
T ₆	1.42	1.38	1.40	0.37	0.39	0.38	3.10	3.15	3.13
T ₇	1.36	1.40	1.38	0.38	0.39	0.39	2.79	2.85	2.82
T ₈	1.59	1.56	1.58	0.38	0.42	0.40	2.58	2.57	2.58
T ₉	1.38	1.54	1.46	0.42	0.4	0.41	2.73	2.75	2.74
T ₁₀	1.41	1.44	1.43	0.36	0.4	0.38	2.64	2.63	2.64
T ₁₁	1.53	1.50	1.52	0.4	0.41	0.41	2.77	2.78	2.78
T ₁₂	1.39	1.45	1.42	0.42	0.43	0.43	2.77	2.84	2.81
S.Em.(±)	0.020	0.020	0.020	0.005	0.005	0.005	0.039	0.039	0.039
C.D.(P = 0.05)	0.060	0.060	0.060	0.015	0.015	0.015	0.117	0.117	0.117

Acknowledgements

The authors express their sincere appreciation to the Department of Plantation, Spices, Medicinal and Aromatic Crops, Horticultural Research Station, Faculty of Horticulture, BCKV for all the necessary facilities that helps in smooth conduct of the research work.

Author's contribution

Field experiment, laboratory analysis, preparation of manuscript and manuscript edit (AS).

Conceptualization of research work and methodology, manuscript reviewed (JKH).

Declaration

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgement

The authors express their sincere appreciation to the Department of Plantation, Spices, Medicinal and Aromatic Crops, Horticultural Research Station, Faculty of Horticulture, BCKV for all the necessary facilities that helps in smooth conduct of the research work.

Author's contribution

Field experiment, laboratory analysis, preparation of manuscript and manuscript edit (AS). Conceptualization of research work and methodology, manuscript reviewed (JKH).

Conflict of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The data that support the findings of this study are included within the article (and its supplementary materials).

References

1. Nguyen L, Govindasamy R, Mentreddy SR. Turmeric trends: analyzing consumer preferences and willingness to pay. *Front Sustai Food Syst.* 2024;8:1-18.
2. Sil A, Mondal T, Swarnalatha A, Hembram S, Hore JK. Biodiversity and characterization of Indian spices: a review. *Plant Arch.* 2026;26(1):151-163.
3. Jackson ML. *Soil Chemical Analysis*. New Delhi: Prentice Hall of India Private Limited; 1967.
4. Walkley A, Black IA. An examination of the Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. *Soil Sci.* 1934;37(1):29-38.
5. Olsen SR, Cole CV, Watanabe FS, Dean LA. Estimation of available phosphorus in soils by extraction with sodium bicarbonate. *USDA Circular No. 939*. 1954.
6. Medda PS, Hore JK. Effect of N and K on growth and yield of turmeric in alluvial plains of West Bengal. *Indian J Hortic.* 2003;60(1):84-88.
7. Anonymous. *IISR Annual Report, 1995-96*. Indian Institute of Spices Research; Calicut; 1995. p. 45.
8. Gomez KA, Gomez AA. *Statistical Procedures for Agricultural Research*. John Wiley and Sons. 1984;1-657.
9. Fisher RA, Yates F. *Statistical Tables for Biological, Agricultural and Medical Research*. Hafner Publishing Company. 1953;1-124.
10. Khattab S, Alkuwayti MA, Yap YK, Meligy AM, Bani Ismail M, *et al.* Foliar spraying of ZnO nanoparticles on *Curcuma longa* had increased growth, yield, expression of curcuminoid synthesis genes, and curcuminoid accumulation. *Horti.* 2023;9(3):1-12.
11. Alkhlefawi AMK. Impact of nano-manganese and siapton on the growth of fenugreek. *Al-Qadisiyah J Agri Sci.* 2022;12(2):49-57.
12. Semenova NA, Burmistrov DE, Shumeyko SA, Gudkov SV. Fertilizers based on nanoparticles as sources of macro and microelements for plant crop growth: A review. *Agronomy.* 2024;14(8):1-48.
13. Sharma A, Patni B, Shankhdhar D, Shankhdhar SC. Zinc—an indispensable micronutrient. *Physiol Mol Biol Plants.* 2013;19(1):11-20.
14. Poornima R, Koti RV. Effect of nano zinc oxide on growth, yield and grain content of sorghum (*Sorghum biococor*). *J Pharmacogn Phytochem.* 2019;8(4):727-731.
15. Pradhan S, Patra P, Das S, Chandra S, Mitra S, *et al.* Photochemical modulation of biosafe manganese nanoparticles on *Vigna radiata*: a detailed molecular, biochemical, and biophysical study. *Environ Sci Technol.* 2012;47(22):13122-13131.

How to cite this article: Sil A, Hore JK. Role of nano Zn and Mn on growth, productivity, quality, soil and leaf nutrient status of turmeric (*Curcuma longa* L.). *International Journal of Advanced Biochemistry Research.* 2026;SP-10(9):1938-1942. doi: <https://www.doi.org/10.33545/26174693.2026.v10.i9Sx.10141>