



Assessment of nano NPK integrated nutrient management on growth, productivity and economics of turmeric cv. Suguna

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ABSTRACT

Modern agriculture increasingly emphasizes smart nutrient management to enhance productivity and sustainability. In this context, a two-year field experiment (2022–23 and 2023–24) was conducted at the Horticultural Research Station, Mondouri, Bidhan Chandra Krishi Viswavidyalaya (BCKV), to evaluate the effect of nano NPK in combination with conventional fertilizers on turmeric cv. Suguna. The experiment comprised eight treatments and three replications, involving different combinations of nano NPK at 0.4% along with conventional fertilizers (N:P₂O₅:K₂O @ 150:60:150 kg ha⁻¹). Among the treatments, the application of 40% N + 75% P (basal) along with foliar sprays of 0.4% nano-NPK at 45 DAP and nano-NK at 90 DAP (T₈) recorded the maximum plant height (152.63 cm), tiller production (2.33), and leaf production (16.85) at 150 days after planting. The same treatment also recorded the highest plot yield (13.98 kg 3 m⁻²), gross return (Rs. 6,29,190/-), net return (Rs. 4,30,549/-), and benefit–cost ratio (2.17), followed by T₄ (B:C ratio 2.02), compared with T₁ (1.13). Based on total yield and benefit–cost ratio, T₈ was identified as the best treatment for enhancing productivity and profitability. Therefore, it can be concluded that integrated application of nano NPK with reduced conventional fertilizers holds promise as a sustainable and economically viable nutrient management strategy for improving productivity in turmeric cv. Suguna.

Key words: B: C ratio, integrated nutrient management, nano fertilizers, turmeric, yield.

INTRODUCTION

Turmeric (*Curcuma longa* L.), often termed Indian saffron, is a major export-oriented crop of India, mainly cultivated for its yellow underground rhizome. Since antiquity, turmeric rhizomes have been widely used as a spice, natural dye, flavouring substance, and an important ingredient in cosmetic and medicinal preparations (Bairagi, 3). Beyond its economic importance, turmeric also holds a significant place in several cultural, religious, and traditional practices (Anuradha *et al.*, 2). India is the largest producer, consumer, and exporter of turmeric, contributing 80% of its total production. Indian turmeric is highly valued in the global market because of its superior quality and rich curcumin content, the key bioactive compound associated with numerous medicinal and therapeutic benefits. Despite its high economic potential, turmeric cultivation in India often suffers from poor nutrient use efficiency, declining soil fertility, and increasing dependence on chemical fertilizers. Continuous use of high doses of chemical fertilizers results in reduced soil health, increased production costs, and limited sustainable productivity, which ultimately reduces farmers' economic returns (Seleiman *et al.*, 14). In recent years, nano fertilizers

have attracted considerable attention because of their small particle size (<100 nm), high surface area, precise delivery, and higher nutrient use efficiency (Semenova *et al.*, 15).

Turmeric, being a long-duration and nutrient-exhaustive crop, responds remarkably to balanced nutrition throughout its growth cycle (Sil and Hore, 16). An adequate supply of nitrogen promotes vegetative growth, phosphorus supports root and rhizome development, while potassium plays a vital role in the translocation of photosynthates, quality improvement, and stress tolerance (Preetha and Balakrishna, 13). However, the challenge lies not merely in supplying nutrients, but in improving their availability and utilization efficiency within the plant–soil system. Application of nano NPK in combination with conventional fertilizers offers a practical solution for sustaining higher productivity with better economic returns. Although nano-fertilizers have demonstrated beneficial effects in various crops, limited information is available on their integrated use with conventional fertilizers in turmeric cultivation. With these considerations, the present investigation was undertaken to evaluate the impact of nano NPK integrated nutrient management on the growth, productivity, and economics of turmeric cv. Suguna.

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MATERIALS AND METHODS

The investigation was undertaken at Horticultural Research Station, Mondouri, Bidhan Chandra Krishi Vishwavidyalaya, during the year 2022–23 and 2023–24. The research field was located at 23°05' N latitude and 89°00' E longitude with an altitude of 9.75 m MSL under subtropical climatic region with an annual mean temperature of 25.99 °C. The soil of the experimental site was sandy clay loam with adequate moisture retention along with efficient drainage. The experiment was laid out in randomized block design comprising eight treatments with three replications, altogether there was 24 plots. Turmeric variety Suguna was planted during the middle of June in a raised bed of 3.0 m × 1.0 m with a height of 15 cm at a spacing of 30 cm × 25 cm, which accommodate 40 plants per plot. Before planting, seed rhizomes (25-30 g) were treated with blitox @ 4 g L⁻¹ for 30 minutes towards the protection from fungal attack. The recommended dose of conventional fertilizer *i.e.* NPK @ 150:60:150 kg ha⁻¹ (Medda and Hore, 12) was supplied through urea, single super phosphate and muriate of potash. The 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. Mulching was done immediately after planting with paddy straw @ 10 t ha⁻¹. 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. Foliar application of three nano-macronutrients (N, P and K) were done @ 0.4% at 45 and 90 days after planting (DAP) along with reduced recommended dose of conventional fertilizers as per treatment schedule including control (Table 1). The spray solutions were prepared at the required quantity and 2-3 drops of a suitable sticker (Balanstick) was added per litre of solution to enhance leaf adherence

and improve nutrient absorption efficiency. Spraying was done on the upper surface of the leaf until runoff condition during morning hours.

The growth parameters like plant height, tiller number and leaf characteristics (number, length and breadth) were recorded from five randomly selected plants at 90 and 150 DAP. All plants from the net plot area were harvested, separated from the pseudo-stem, cleaned thoroughly to remove adhering soil and extraneous matter and shade dried to remove surface moisture. The fresh weight of rhizomes obtained from each net plot was recorded to assess the effect of treatments on rhizome yield of turmeric. Projected yield was calculated based on plot yield considering 75% area occupied by turmeric (Anonymous, 1). Formula for calculating projected yield was – plot yield × 2500.

The economic outcome of the various treatments was carried out by estimating the cost of cultivation, gross income, and net income, taking into account the expenditure on inputs and the prevailing market price of the produce during the experimental period. Inputs included FYM at Rs.2000 t⁻¹, urea at Rs.5.92 kg⁻¹, SSP at Rs.10.00 kg⁻¹, MOP at Rs.34.00 kg⁻¹, nano nitrogen at Rs.258.00 lit⁻¹, nano phosphorus at Rs.587.40 lit⁻¹, nano potash at Rs.719.6 kg⁻¹, turmeric seed rhizome at Rs.30.00 kg⁻¹, man power @ Rs.363.00 day⁻¹, tractor rate Rs.1000.00 hr⁻¹, irrigation cost 50 hour⁻¹ and turmeric selling price was Rs.18.00 kg⁻¹ average market price. Gross return (GR) was calculated by multiplying the projected yield with turmeric selling price while net return (NR) was calculated as the difference between gross return (GR) and cost of production (COP). The benefit cost ratio was calculated by using the formula:

$$\text{Benefit cost ratio} = \frac{\text{Net return}}{\text{Cost of production}}$$

The recorded observations for different parameters were statistically analysed following

Table 1: Overview of treatment details and combinations.

Sl. No.	Treatment combination
T ₁	40% N+100% P (B)→ 30% N + 50% K (45 and 90DAP)
T ₂	40% N+100% P (B)→ 0.4% Nano N + 50% K (45 and 90DAP)
T ₃	40% N+100% P (B)→ 30% N + 0.4% Nano K (45 and 90DAP)
T ₄	40% N+100% P (B)→ 0.4% Nano N + K (45DAP) → 0.4% Nano N + K (90DAP)
T ₅	40% N+75% P (B)→ 0.4% Nano P (45DAP) + 30% N and 50% K (45 and 90DAP)
T ₆	40% N+75% P (B)→ 0.4% Nano P (45DAP) + 0.4% Nano N and 50% K (45 and 90DAP)
T ₇	40% N+75% P (B)→ 0.4% Nano P (45DAP) + 30% N and 0.4% Nano K (45 and 90DAP)
T ₈	40% N+75% P (B)→ 0.4% Nano N,P and K (45DAP) + 0.4% Nano N and K (45 and 90DAP)

B: Basal, DAP: days after planting

the method described by Gomez and Gomez, 7. Treatment effects were evaluated using Fisher's F-test at the 5% significance level. The critical difference (CD) values at 5% probability were determined according to the tables provided by Fisher and Yates, 6.

RESULTS AND DISCUSSION

The data presented in Table 2 clearly indicated significant variations in plant height and tiller number among the treatments at 90 and 150 DAP during both the years and pooled analysis. The plants grown under T_8 recorded the highest plant height (90.25 cm and 152.63 cm) and maximum number of tillers (1.20 and 2.33) per plant. While treatment combinations of T_1 showed lowest plant height (63.89 cm and 117.02 cm) and minimum tillers (0.79 and 1.39) per plant at 90 and 150 DAP. The findings of the present investigation are in close conformity with Chavan *et al.* (4) who reported that integration of nano urea (50%) and nano potash (50%) along with conventional fertilizer treatment recorded maximum plant height in white onion (*Allium cepa*). Nano-fertilizers enhance nutrient assimilation by increasing chlorophyll synthesis and photosynthetic efficiency which help in better plant growth and supports the emergence of more tiller buds. Additionally, nano fertilizers improve the availability of amino acids and proteins required for rapid shoot development and enhanced root activity, leading to increased tiller number and tiller vigour (Kottegoda *et al.*, 9).

The various leaf characters *i.e.* number, length and breadth at 90 and 150 DAP varied significantly due to application of nano-NPK integrated with

commercial fertilizers (Table 3 and 4). In case of leaf length, the maximum value *i.e.* 35.30 cm and 70.13 cm at 90 and 150 DAP was obtained under T_8 whereas the minimum leaf length (30.90 cm and 60.69 cm at 90 and 150 DAP) was observed in T_1 . Data presented in Table 3 revealed that plants treated with 0.4% nano-NPK at 45 DAP and 0.4% nano-NK at 90 DAP along with 40% N and 75% P as basal (T_8) recorded the highest leaf breadth (9.11 cm and 14.85 cm) at 90 and 150 days after planting as compared to minimum breadth (7.99 cm and 13.57 cm) under control treatment (T_1).

At 90 DAP the plants grown under treatment T_7 recorded the highest leaf number (7.12), where at 150 DAP T_8 showed the maximum number of leaves (16.85) which was statistically *at par* with T_4 (16.70). The sole application of conventional fertilizers (T_1) recorded the lowest number of leaves per plant at 90 and 150 DAP (5.96 and 13.30 respectively). The results are in close conformity with Dubey *et al.* (5) who revealed that foliar application of 0.4% nano urea in combination with non-nano NPK @ 75:50:50 kg ha⁻¹ resulted in maximum number of leaves in *Allium cepa* L. The improvement in leaf attributes under integrated nutrient management and nano-fertilizer treatments could be associated with a steady and efficient nutrient supply during the active vegetative stage of crop growth. The gradual release of nutrients reduced losses through leaching and volatilization while enhancing nutrient uptake and translocation within the plant, which subsequently promoted cell enlargement and proper leaf lamina development. Sufficient availability of nitrogen and potassium is known to stimulate chlorophyll

Table 2: Effect of nano NPK on plant height and tiller number.

Treatment	Plant height (cm)						Tiller number					
	90 DAP			150 DAP			90 DAP			150 DAP		
	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled
T_1	65.02	62.75	63.89	118.87	115.17	117.02	0.71	0.87	0.79	1.30	1.47	1.39
T_2	72.82	78.05	75.44	135.10	138.81	136.96	1.09	1.15	1.12	1.63	2.04	1.84
T_3	63.88	71.18	67.53	128.32	137.47	132.90	1.03	1.05	1.04	1.44	1.69	1.57
T_4	84.23	78.56	81.40	146.78	150.05	148.42	1.13	1.21	1.17	1.92	2.29	2.11
T_5	69.40	81.39	75.40	136.75	142.77	139.76	0.96	1.14	1.05	1.66	1.72	1.69
T_6	91.41	77.21	84.31	147.58	148.15	147.87	1.09	1.20	1.15	2.11	2.21	2.16
T_7	79.47	85.28	82.38	141.23	145.69	143.46	1.10	1.23	1.17	1.97	1.90	1.94
T_8	89.19	91.31	90.25	148.71	156.55	152.63	1.21	1.19	1.20	2.29	2.36	2.33
S.Em. ($\pm$)	1.020	1.268	0.992	2.343	1.835	1.827	0.013	0.019	0.016	0.030	0.032	0.032
C.D. ($p=0.05$)	3.123	3.883	3.037	7.176	5.621	5.595	0.040	0.057	0.049	0.091	0.097	0.097

Table 3: Effect of nano NPK on leaf dimension.

Treatment	Leaf length (cm)						Leaf breadth (cm)					
	90 DAP			150 DAP			90 DAP			150 DAP		
	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled
T ₁	31.26	30.53	30.90	58.76	62.62	60.69	7.69	8.30	7.99	13.24	13.90	13.57
T ₂	30.86	32.60	31.73	64.91	65.33	65.12	8.46	9.00	8.73	14.26	14.14	14.20
T ₃	31.92	33.71	32.82	62.76	66.04	64.40	8.32	8.56	8.44	14.54	14.37	14.45
T ₄	35.31	33.99	34.65	65.59	69.37	67.48	8.93	9.19	9.06	14.71	14.95	14.83
T ₅	30.85	35.70	33.27	63.03	65.37	64.20	9.07	8.47	8.77	14.65	14.52	14.58
T ₆	35.47	34.75	35.11	67.69	65.25	66.47	8.54	8.90	8.72	14.23	15.18	14.70
T ₇	34.14	32.89	33.52	64.82	67.20	66.01	9.12	9.02	9.07	14.80	14.69	14.74
T ₈	35.10	35.50	35.30	72.05	68.21	70.13	8.90	9.32	9.11	14.37	15.33	14.85
S.Em. (±)	0.545	0.550	0.558	1.061	1.124	1.125	0.140	0.148	0.142	0.246	0.245	0.239
C.D. (p=0.05)	1.668	1.684	1.708	3.249	3.443	3.445	0.430	0.454	0.436	0.752	0.751	0.731

formation, leaf tissue expansion and photosynthetic efficiency, thereby contributing to increased leaf size, greater photosynthetic surface area (Magen, 10) and improved overall leaf growth.

The data presented in Table 4 clearly indicated significant variations in both plot and projected yield of turmeric. Treatment T₈ recorded the maximum plot (13.98 kg 3 m⁻²) and projected yield (34.95 t ha⁻¹) followed by T₄ (plot yield: 13.34 kg 3 m⁻² and projected yield: 33.34 t ha⁻¹) while the lowest plot (9.73 kg 3 m⁻²) and projected yield (24.31 t ha⁻¹) were observed under control (T₁). The improvement in yield under integrated nutrient management may be due to enhanced nutrient availability, improved physiological

efficiency, better source–sink relationship, increased vegetative parameters and rhizome growth. Nitrogen plays a critical role in chlorophyll synthesis and vegetative growth, phosphorus in root development and energy transfer, and potassium in carbohydrate transport and storage in rhizomes. The synergistic effect of these nutrients results in increased sink strength and higher rhizome yield (Marschner, 11; Havlin *et al.*, 8).

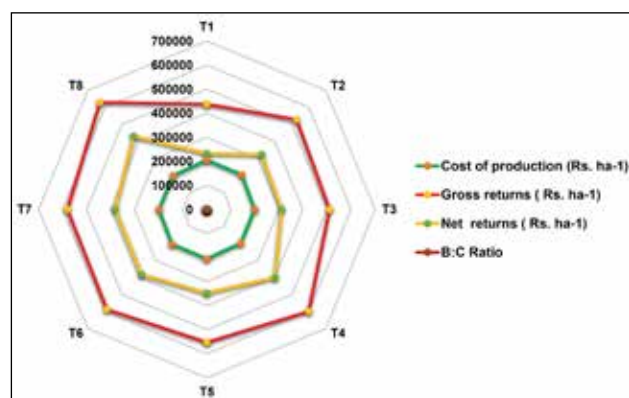
Based on mean data of economic analysis of turmeric under integrated nano NPK treatments (Table 5 and Fig. 1), it was observed that the highest cost of production, amounting Rs.205605/- was observed under T₁, followed by T₅ (Rs.205380/-) as

Table 4: Effect of nano NPK on leaf number and yield.

Treatment	Leaf number (cm)						Yield per plot (kg 3 m ⁻²)			Projected yield (t ha ⁻¹)		
	90 DAP			150 DAP								
	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled
T ₁	5.87	6.05	5.96	12.33	14.26	13.30	9.13	10.32	9.73	22.83	25.80	24.31
T ₂	6.47	6.84	6.66	14.72	16.49	15.61	11.40	12.07	11.74	28.50	30.18	29.34
T ₃	6.15	5.99	6.07	13.29	15.06	14.18	11.18	11.52	11.35	27.95	28.79	28.37
T ₄	6.84	7.01	6.93	15.75	17.65	16.70	12.58	14.09	13.34	31.45	35.23	33.34
T ₅	6.05	6.19	6.12	12.92	15.81	14.37	11.43	13.15	12.29	28.58	32.87	30.72
T ₆	6.61	6.95	6.78	15.83	16.60	16.22	12.11	14.03	13.07	30.28	35.09	32.68
T ₇	6.96	7.27	7.12	14.28	16.51	15.40	12.31	13.48	12.90	30.78	33.71	32.24
T ₈	7.08	6.92	7.00	16.07	17.63	16.85	13.45	14.51	13.98	33.63	36.28	34.95
S.Em. (±)	0.110	0.117	0.113	0.240	0.281	0.264	0.184	0.214	0.201	0.487	0.536	0.510
C.D. (p=0.05)	0.337	0.358	0.347	0.736	0.859	0.808	0.564	0.655	0.616	1.491	1.641	1.561

Table 5: Effect of nano NPK on economics of turmeric cultivation.

Treatment	Cost of production (Rs. ha ⁻¹)			Gross returns (Rs. ha ⁻¹)			Net returns (Rs. ha ⁻¹)			B:C Ratio		
	2022-23	2023-24	Mean	2022-23	2023-24	Mean	2022-23	2023-24	Mean	2022-23	2023-24	Mean
T ₁	202880	208330	205605	410940	464400	437670	208060	256070	232065	1.03	1.23	1.13
T ₂	202286	207736	205011	513000	543240	528120	310714	335504	323109	1.54	1.62	1.58
T ₃	196735	202185	199460	503100	518220	510660	306365	316035	311200	1.56	1.56	1.56
T ₄	196141	201591	198866	566100	634140	600120	369959	432549	401254	1.89	2.15	2.02
T ₅	202655	208105	205380	514440	591660	553050	311785	383555	347670	1.54	1.84	1.69
T ₆	202061	207511	204786	545040	631620	588330	342979	424109	383544	1.70	2.04	1.87
T ₇	196510	201960	199235	554040	606780	580410	357530	404820	381175	1.82	2.00	1.91
T ₈	195916	201366	198641	605340	653040	629190	409424	451674	430549	2.09	2.24	2.17

**Fig. 1.** Effect of integrated nano NPK management on turmeric economics.

compared to T₈ (Rs.198641/-). In respect to gross and net return, the maximum value (Rs. 629190/- and Rs. 430549/-) were observed in T₈, followed by T₄ (Rs. 600120/- and Rs. 401254/-). The lowest of gross and net return were recorded under control (Rs. 437670/- and Rs. 232065/-). Highest benefit: cost ratio was noticed in T₈ (2.17) followed by T₄ (2.02). The lowest was observed in untreated control (1.13). The maximum profitability under T₈ was primarily attributed to its higher rhizome yield and improved quality. Moreover, partial substitution of conventional fertilizers with nano fertilizers reduced the cost of cultivation owing to lower fertilizer requirement, while maintaining balanced nutrient availability throughout the crop growth period.

Considering all of the facts, the present study demonstrated that integration of nano-formulated N, P, and K with commercial fertilizers significantly enhanced the growth, yield, and economic performance of turmeric. The combined application of nano fertilizers with reduced doses of conventional

fertilizers proved more effective than the sole use of conventional fertilizers, indicating the potential of nano formulations to improve nutrient use efficiency and reduce fertilizer dependency. Based on growth parameters at 90 and 150 DAP, yield, and benefit–cost ratio, T₈ (40% N + 75% P as basal + 0.4% nano-NPK at 45 DAP and 0.4% nano-NK at 90 DAP) emerged as the most effective treatment, followed by T₄ (40% N + 100% P as basal → 0.4% nano N and K at 45 DAP → 0.4% nano N and K at 90 DAP). The superior performance of these treatments can be attributed to the precise and sustained nutrient delivery facilitated by nano formulations, which enhanced nutrient uptake, promoted vegetative growth, and improved rhizome development and yield. The higher net returns and benefit–cost ratio obtained under T₈ further confirm its economic viability and practical applicability for turmeric growers. Thus, the study confirms that nano fertilizers can partially substitute conventional fertilizers, thereby reducing the quantity of chemical fertilizers applied without compromising productivity. This integrated nutrient management approach can be effectively used as a sustainable strategy for turmeric cultivation, offering a promising pathway to improve soil health, enhance farmers' profitability, and support environmentally responsible agriculture. However, further multi-location and multi-season trials are recommended to validate these findings and to develop location-specific nano fertilizer recommendations for wider adoption.

AUTHOR'S CONTRIBUTION

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

DECLARATION

Authors of this manuscript declare that they do not have any conflict of interest.

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