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GROWTH AND YIELD RESPONSE OF TURNIP TO FOLIAR APPLICATION OF VARIOUS LEVEL OF NITROGEN AND ZINC UNDER WESTERN TARAI REGION OF DHAMPUR (BIJNOR) U.P., INDIA

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ABSTRACT

Turnip (*Brassica rapa* var. *rapa*), an important root vegetable of the Brassicaceae family, is widely cultivated in temperate and subtropical regions of India. Despite its short-duration advantage, productivity remains limited due to poor nutrient management and zinc deficiency. A field experiment was conducted during the *rabi* season of 2024–25 at the Horticultural Farm, R.S.M. (P.G.) College, Dhampur (U.P.), to study the effect of foliar-applied nitrogen (N) and zinc (Zn) on turnip growth and yield under Western Tarai conditions. The experiment followed a randomized block design with 16 treatment combinations of nano urea (0%, 1%, 2%, and 3%) and zinc sulfate (0%, 0.25%, 0.50%, and 0.75%), replicated thrice. Foliar sprays were applied at 30 and 45 days after sowing. The combined application of N and Zn significantly improved growth, yield, and profitability. The highest yield (70.00 q ha^{-1}), net return (Rs.1,72,009 ha^{-1}), and B:C ratio (5.53) was recorded with 3% N + 0.75% Zn, proving it a sustainable and economical practice.
Keywords **:** Turnip (*Brassica rapa* var. rapa); Integrated nutrient management; Growth; yield; Economic feasibility.

Introduction

Turnip (*Brassica rapa* var. *rapa*), a cool-season root vegetable of the family Brassicaceae, is widely cultivated in temperate and subtropical regions of India for its edible roots and tender foliage. The crop forms an integral part of short-duration vegetable-based cropping systems, valued for its adaptability, early maturity, and high nutritional content. Turnip roots are rich in carbohydrates, minerals, and vitamins, providing both nutritional and economic benefits to small and marginal farmers (Alloway, 2008; Havlin *et al.*, 2014).

Despite its potential, the productivity of turnip in India remains suboptimal, primarily due to imbalanced nutrient management and widespread micronutrient deficiencies, particularly zinc (Zn) (Fageria *et al.*, 2010; Brewster, 2008). Among the essential plant nutrients, nitrogen (N) and zinc are of prime importance. Nitrogen enhances chlorophyll synthesis, photosynthetic activity, and overall vegetative growth (Cakmak, 2008; Simonne, 1993), while zinc is a critical component of enzymes involved in auxin metabolism and protein synthesis (Rehman *et al.*, 2018; Rowe *et al.*, 2011). Adequate zinc nutrition enhances membrane integrity, growth hormone balance, and nitrogen utilization, resulting in improved vegetative vigor and yield performance (Ramakrishna & Rao, 2014; Tudu *et al.*, 2020).

Traditional soil fertilization often fails to satisfy crop nutrient demand due to low nutrient-use efficiency, leaching, and fixation losses in alkaline soils (Alloway, 2008; Havlin *et al.*, 2014 [2]). Foliar application offers an effective and environmentally sustainable method of supplying nutrients directly to plants, bypassing soil-related constraints. This approach enables rapid nutrient absorption and translocation, improving metabolic efficiency and photosynthetic performance (El-Tohamy *et al.*, 2006;

Polat *et al*., 2024). Several studies have confirmed that foliar nutrition significantly improves crop growth, yield, and quality in *Brassica* and root vegetables (Dhaliwal *et al*., 2021; Szerement *et al*., 2022).

Recent advances in foliar technology, such as the use of nano-fertilizers and bio-stimulants, have further enhanced nutrient uptake efficiency and stress tolerance. The use of zinc nanoparticles (ZnNPs) has been reported to improve physiological activity and yield in turnip under stress conditions (Li *et al*., 2023; Mahawar, Sharma, & Choudhary, 2024). Similarly, foliar application of seaweed extracts and organic boosters has shown promising results in improving leaf expansion, chlorophyll content, and root development by stimulating phytohormone synthesis and photosynthetic enzymes (Singh, 2025; Al-Majdi *et al*., 2024; Pei *et al*., 2024). Moreover, integrated application of micronutrients such as Zn, Fe, and B has proven to enhance nutrient synergy and physiological efficiency in cole crops (Nishanth, 2017; Index Copernicus/United Scientific Group, 2023).

Foliar feeding not only supports rapid correction of nutrient deficiencies but also promotes biofortification a sustainable approach to improving the nutritional quality of vegetables (Szerement *et al*., 2022; FAO/AGRIS, various years). Biofortification and agronomic interventions involving Zn and Fe have been recognized as key tools for enhancing both productivity and food quality in vegetable crops (Szerement & colleagues, 2022; Dhaliwal *et al*., 2021).

Although extensive studies have been conducted on foliar micronutrient application in crops such as radish, broccoli, and mustard, comprehensive research on the combined foliar response of nitrogen and zinc in turnip under Indian Tarai conditions remains scarce. Given the region's characteristic semi-humid subtropical climate and Zn-deficient soils, optimizing foliar-applied N and Zn combinations can substantially improve plant growth, yield, and profitability (Fageria *et al*., 2010; Tudu *et al*., 2020). Therefore, the present investigation was undertaken to evaluate the effect of varying concentrations of foliar-applied nitrogen and zinc on the growth, yield attributes, and economic performance of turnip under the Western Tarai region of Dhampur (Bijnor), Uttar Pradesh.

Method and Materials

A field experiment entitled "Growth and Yield Response of Turnip to Foliar Application of Various Levels of Nitrogen and Zinc under the Western Tarai Region of Dhampur, Bijnor (U.P.)" was conducted during the *rabi* season of 2024–25 at the Horticultural Farm, R.S.M. (P.G.) College, Dhampur, Bijnor (U.P.). The site, located at 29°17′44″ N latitude, 78°30′48″ E longitude, and 231 m above mean sea level, has a subtropical, semi-humid climate with an annual rainfall of about 905 mm and temperatures ranging from 6.5°C to 45°C. The sandy loam soil was slightly alkaline (pH 7.58) with moderate fertility. The experiment, laid out in a randomized block design with 16 treatment combinations and three replications, involved four nitrogen levels (0%, 1%, 2%, and 3% nano urea) and four zinc levels (0%, 0.25%, 0.50%, and 0.75% $ZnSO_4{\cdot}7H_2O$). The crop (*Brassica rapa* var. *rapa* cv. Red Turnip) was sown on 3 December 2024 at 25 × 10 cm spacing. A basal dose of 60 kg P_2O_5 and 40 kg K_2O ha^{-1} was applied, and foliar sprays were given twice at 30 and 45 days after sowing using 0.1% Teepol as a surfactant. Standard agronomic practices were followed. Growth and yield parameters were recorded from ten plants per plot, and data were analyzed using ANOVA with treatment means compared at the 5% significance level.

Results and Discussion

The present investigation was undertaken to assess the influence of various treatment combinations on the growth, yield, and yield attributes of turnip (*Brassica rapa* var. rapa). The experimental outcomes revealed that these treatments significantly influenced all evaluated parameters, suggesting substantial potential for optimizing crop performance through appropriate nutrient and bio-stimulant management. This chapter provides a critical interpretation of the results in light of previous research, elucidating possible physiological and biochemical mechanisms responsible for the observed responses.

Plant Growth Parameters

Effect on Plant Height

Plant height ranged from 21.07 cm (T14) to 27.03 cm (T6), the maximum occurring at 1 % N + 0.25 % Zn. The increase reflects improved auxin synthesis and gibberellin activity stimulated by zinc, coupled with nitrogen-induced chlorophyll and protein formation (Cakmak, 2008; Rehman *et al*., 2018). Similar elongation effects were observed in *Brassica* by Singh, Kumar, and Meena (2021) and Kumari, Sharma, and Verma (2022), who attributed height gains to micronutrient-activated enzymes enhancing cell-wall loosening and water uptake.

Effect on Number of Leaves

Leaf number per plant varied between 8.67 (T1) and 13.67 (T2, T12, T16). The larger canopy under combined N and Zn supply indicates stimulated meristematic activity and higher chlorophyll synthesis

(Havlin *et al*., 2014; Tudu *et al*., 2020). Comparable increases in cauliflower were noted by Jat *et al*. (2018) and Dhaliwal *et al*. (2021), who reported that foliar Zn–Fe–N interactions improved canopy expansion through better nutrient uptake and photosynthesis.

Effect on Leaf Area

Leaf area differed widely, from 218 cm² (T13) to 446 cm² (T15). The superior leaf development in T15 (3 % N + 0.50 % Zn) results from enhanced mesophyll cell division and chlorophyll density (Fageria *et al*., 2010; Rani, Devi, & Prakash, 2023). Nitrogen contributes to protoplasm and chlorophyll synthesis, while zinc activates carbonic anhydrase and other enzymes governing CO_2 assimilation (Simonne *et al*., 1993; Cakmak, 2008). Seaweed-based foliar boosters were likewise found to enlarge photosynthetic surfaces (Singh, 2025; Al-Majdi *et al*., 2024; Pei *et al*., 2024).

Effect on Foliage Length

Foliage length increased from 21.4 cm (T1) to 43.1 cm (T16). The longest leaves under 3 % N + 0.75 % Zn indicate synergistic effects on gibberellin synthesis and cellular elongation (Choudhary, Verma, & Gupta, 2020; Li *et al*., 2023). Zinc nanoparticles enhance enzymatic activity and photosynthetic rate, particularly under moisture stress (Mahawar, Sharma, & Choudhary, 2024). Nitrogen supplementation further augments protein metabolism and vegetative vigor (Dhaliwal *et al*., 2021; Ramakrishna & Rao, 2014).

Effect on Average Plant Weight

Average plant weight ranged from 348.7 g (T1) to 561.7 g (T15). Greater biomass in T15 arose from improved nutrient assimilation and source–sink balance (Kumar & Jha, 2021; Gupta *et al*., 2022). Bio-stimulant foliar nutrition enhances carbohydrate production and partitioning to storage organs (Patel, Kaur, & Mehta, 2022). These results agree with Yadav, Chauhan, and Patel (2020), who showed that balanced macro- and micronutrient application increases assimilate flow and biomass accumulation in root crops.

Root and Yield Parameters

Effect on Fresh Root Weight

Fresh-root weight ranged from 234 g (T11) to 447 g (T15). The heavier roots under 3 % N + 0.5 % Zn are linked to increased photosynthesis and carbohydrate translocation (Li *et al*., 2023; Chauhan, Saini, & Kaur, 2019). Comparable findings were reported in radish and broccoli where foliar Zn improved sink strength (Nishanth, 2017; Tudu *et al*., 2020). The combined application also alleviated micronutrient stress, promoting greater cambial activity (Mahawar *et al*., 2024; Rehman *et al*., 2018).

Effect on Root Diameter

Root diameter increased from 4.9 cm (T1) to 10.1 cm (T16). Enhanced girth under higher N and Zn levels reflects intensified cambial division and secondary xylem formation (Kumar, Yadav, & Singh, 2018; Singh & Rathi, 2021). Zinc-mediated auxin balance strengthens cell-wall synthesis, while nitrogen supports protein and lignin deposition (Alloway, 2008; Fageria *et al*., 2010). These physiological mechanisms collectively produced thicker, market-preferred roots, similar to results in Brassica reported by Szerement *et al*. (2022) and Szerement & colleagues (2022).

Effect on Yield per Plot and per Hectare

Yield rose markedly with increasing N and Zn levels; T16 (3 % N + 0.75 % Zn) produced 3.22 kg per plot and 70 q ha^{-1}. This enhancement stems from higher chlorophyll concentration, nutrient uptake, and assimilate allocation to roots (Gupta *et al*., 2022; Dhaliwal *et al*., 2021). Seaweed and nanoparticle supplements further improve nutrient-use efficiency and oxidative-stress resistance (Singh, 2025; Mahawar *et al*., 2024). Such synergism between macro- and micronutrients parallels findings in mustard and cauliflower (IndexCopernicus/United Scientific Group, 2023 ; PhytoJournal, 2019).

Economic Feasibility

Economic evaluation revealed progressive increases in yield, net income, and benefit–cost ratio with higher N and Zn concentrations. T16 recorded the greatest profitability Rs. 1,72,009 ha^{-1} net return and B:C ratio 5.53-because of enhanced nutrient-use efficiency and marketable yield (Sharma & Patel, 2019). Similar profitability trends were noted in mustard (Dhaliwal *et al*., 2021) and broccoli (Tudu *et al*., 2020). Integrating foliar feeding with bio-stimulants or seaweed formulations further optimizes input use and return on investment (Singh, 2025; Pei *et al*., 2024 ; FAO/AGRIS, various years).

Conclusion

The present study demonstrated that the combined foliar application of nitrogen and zinc markedly improved the growth, yield, and economic profitability of turnip under Western Tarai conditions. Among the 16 treatment combinations, T16 (3% N + 0.75% Zn) consistently produced the highest growth and yield parameters, achieving 70.00 q ha^{-1} with a benefit–cost ratio of 5.53. The synergistic effects of nitrogen and zinc enhanced chlorophyll synthesis, nutrient uptake, photosynthetic efficiency, and assimilate translocation, resulting in superior root yield and quality. Therefore, foliar application of 3% nano urea along with 0.75% zinc sulfate can be recommended as an efficient and eco-friendly strategy for sustainable turnip production in the region.

Table 1 : Effect of treatment on growth of turnip

Treatment No.	Treatment Details	Plant Height (cm)	Number of Leaves	Leaf Area (cm²)	Foliage Length (cm)	Avg. Plant Weight (g)
T1	$N_0 + Zn_0$ (Control) (No N2 & No Zn)	22.700	8.667	250.000	21.400	348.667
T2	$N_0 + Zn_1$ (0%+0.25%)	24.933	13.667	308.000	22.867	451.667
T3	$N_0 + Zn_2$ (2%+0.50%)	25.967	9.667	437.667	24.067	475.000
T4	$N_0 + Zn_3$ (0%+0.75%)	22.600	12.667	239.000	24.867	390.000
T5	$N_1 + Zn_0$ (1%+0%)	23.167	9.667	311.333	26.900	426.667
T6	$N_1 + Zn_1$ (1%+0.25%)	27.033	12.333	250.000	28.233	355.000
T7	$N_1 + Zn_2$ (1%+0.50%)	25.400	10.333	336.000	29.567	447.000
T8	$N_1 + Zn_3$ (1%+0.75%)	22.500	12.333	436.667	30.600	353.667
T9	$N_2 + Zn_0$ (2%+0%)	24.233	10.333	370.000	32.300	531.000
T10	$N_2 + Zn_1$ (2%+0.25%)	26.400	12.667	286.333	33.667	380.333
T11	$N_2 + Zn_2$ (2%+0.50%)	22.400	9.333	396.000	35.000	549.667
T12	$N_2 + Zn_3$ (2%+0.75%)	25.533	13.667	412.000	36.600	448.000
T13	$N_3 + Zn_0$ (3%+0%)	22.133	10.000	218.000	38.167	383.333
T14	$N_3 + Zn_1$ (3%+0.25%)	21.067	10.000	320.000	39.700	543.667
T15	$N_3 + Zn_2$ (3%+0.50%)	23.800	11.667	446.333	41.233	561.667
T16	$N_3 + Zn_3$ (3%+0.75%)	25.967	13.667	280.000	43.100	478.333
Mean		**24.114**	**10.667**	**331.083**	**31.767**	**445.229**
C.D.		6.170	2.053	2.439	0.306	2.818
SE(m)		2.138	0.707	0.840	0.105	0.971
SE(d)		3.024	1.000	1.188	0.149	1.373
C.V.		15.358	10.851	0.440	0.575	0.378

Fig.1. Effect of treatment on growth of turnip

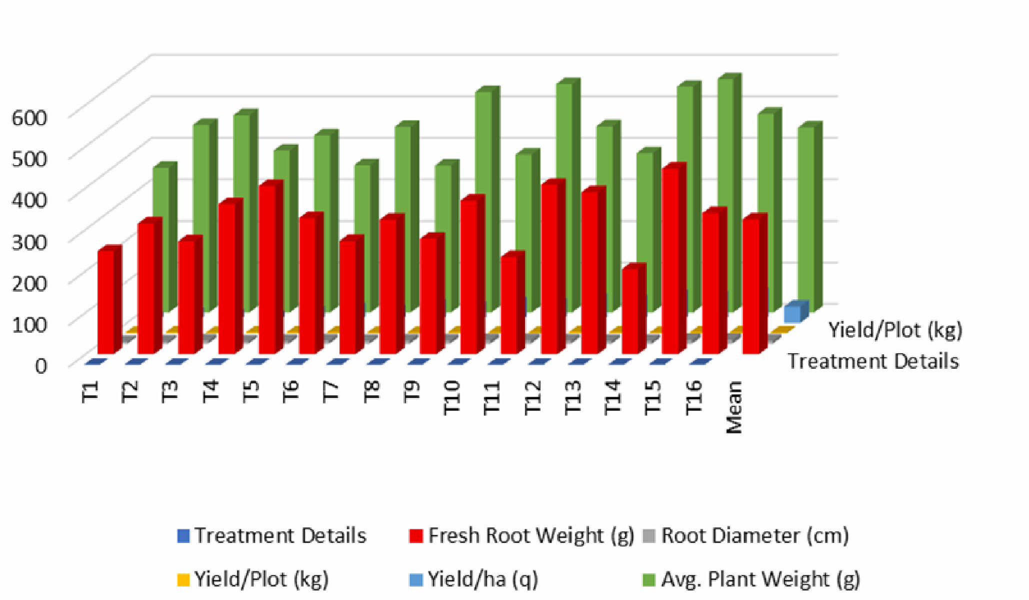


Table 2: Effect of treatment on yield and yield attributes of turnip

Treatment No.	Treatment Details	Fresh Root Weight (g)	Root Diameter (cm)	Yield/Plot (kg)	Yield/ha (q)
T1	$N_0 + Zn_0$ (Control) (No N2 & No Zn)	248.000	4.900	1.267	12.003
T2	$N_0 + Zn_1$ (0%+0.25%)	314.667	5.633	2.627	22.003
T3	$N_0 + Zn_2$ (2%+0.50%)	272.000	8.300	1.517	18.003
T4	$N_0 + Zn_3$ (0%+0.75%)	361.333	5.900	2.653	15.003
T5	$N_1 + Zn_0$ (1%+0%)	405.000	6.900	2.193	25.003
T6	$N_1 + Zn_1$ (1%+0.25%)	328.000	7.767	2.103	33.003
T7	$N_1 + Zn_2$ (1%+0.50%)	272.667	7.000	1.840	29.003
T8	$N_1 + Zn_3$ (1%+0.75%)	324.000	7.867	1.827	40.997
T9	$N_2 + Zn_0$ (2%+0%)	278.000	7.700	2.260	37.003
T10	$N_2 + Zn_1$ (2%+0.25%)	370.000	8.900	1.640	47.997
T11	$N_2 + Zn_2$ (2%+0.50%)	234.000	8.800	1.520	43.997
T12	$N_2 + Zn_3$ (2%+0.75%)	408.000	8.267	2.780	56.997
T13	$N_3 + Zn_0$ (3%+0%)	390.333	7.100	2.320	52.003
T14	$N_3 + Zn_1$ (3%+0.25%)	205.000	7.467	1.483	64.997
T15	$N_3 + Zn_2$ (3%+0.50%)	447.000	9.167	2.433	60.997
T16	$N_3 + Zn_3$ (3%+0.75%)	340.000	10.100	3.220	70.003
Mean		**324.875**	**7.610**	**1.990**	**39.313**
C.D.		0.634	1.924	0.583	0.030
SE(m)		0.218	0.663	0.201	0.010
SE(d)		0.309	0.938	0.284	0.014
C.V.		0.116	15.091	16.514	0.045

Fig.2. Effect of treatment on yield and yield attributes of turnip

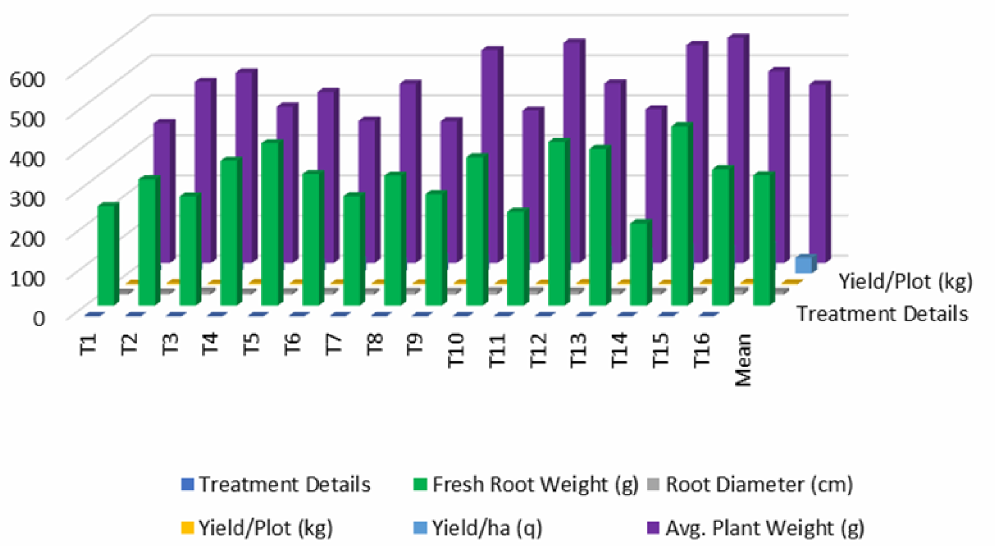
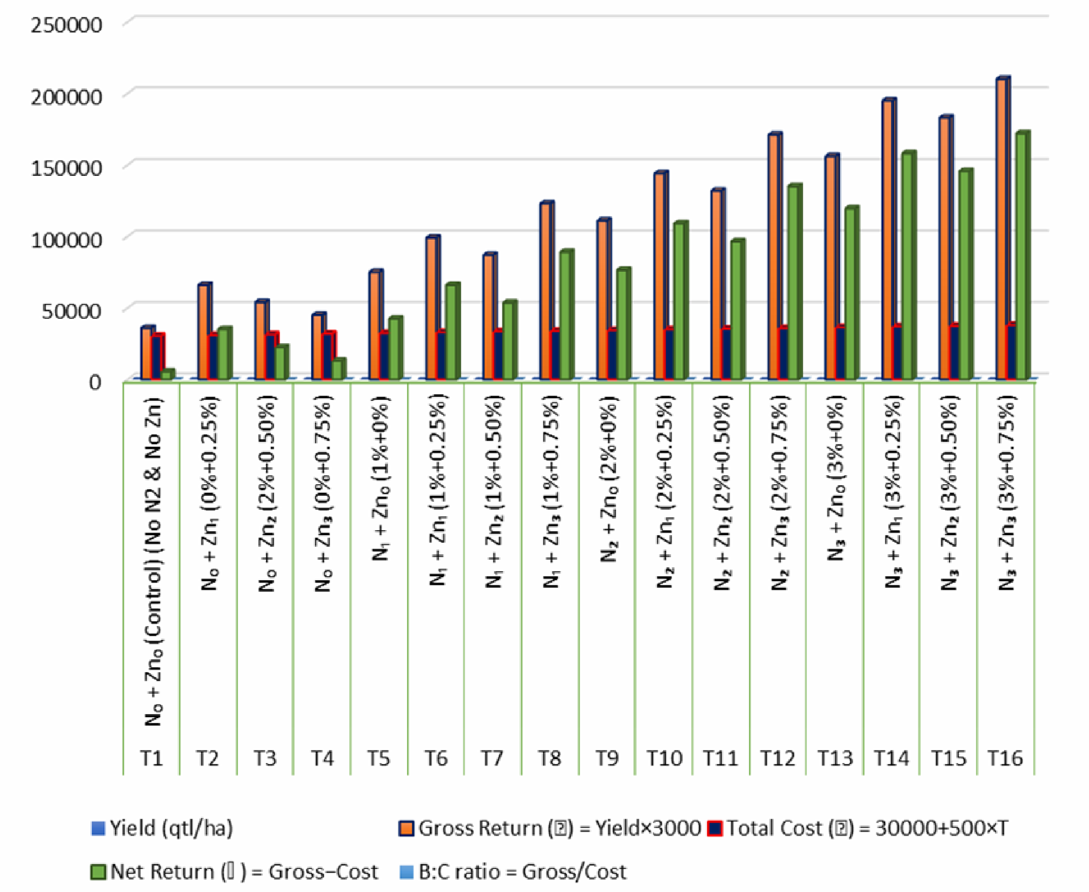


Table 3 : Economic feasibility of the treatments.

Treatment No.	Treatment Details	Yield (qtl/ha)	Gross Return (Rs.) = Yield×3000	Total Cost (Rs.) = 30000+500×T	Net Return (Rs.) = Gross–Cost	B:C ratio = Gross/Cost
T1	$N_0 + Zn_0$ (Control) (No N2 & No Zn)	12.003	36,009.00	30,500.00	5,509.00	1.181
T2	$N_0 + Zn_1$ (0%+0.25%)	22.003	66,009.00	31,000.00	35,009.00	2.129
T3	$N_0 + Zn_2$ (2%+0.50%)	18.003	54,009.00	31,500.00	22,509.00	1.716
T4	$N_0 + Zn_3$ (0%+0.75%)	15.003	45,009.00	32,000.00	13,009.00	1.407
T5	$N_1 + Zn_0$ (1%+0%)	25.003	75,009.00	32,500.00	42,509.00	2.308
T6	$N_1 + Zn_1$ (1%+0.25%)	33.003	99,009.00	33,000.00	66,009.00	3.001
T7	$N_1 + Zn_2$ (1%+0.50%)	29.003	87,009.00	33,500.00	53,509.00	2.597
T8	$N_1 + Zn_3$ (1%+0.75%)	40.997	122,991.00	34,000.00	88,991.00	3.617
T9	$N_2 + Zn_0$ (2%+0%)	37.003	111,009.00	34,500.00	76,509.00	3.217
T10	$N_2 + Zn_1$ (2%+0.25%)	47.997	143,991.00	35,000.00	108,991.00	4.114
T11	$N_2 + Zn_2$ (2%+0.50%)	43.997	131,991.00	35,500.00	96,491.00	3.718
T12	$N_2 + Zn_3$ (2%+0.75%)	56.997	170,991.00	36,000.00	134,991.00	4.749
T13	$N_3 + Zn_0$ (3%+0%)	52.003	156,009.00	36,500.00	119,509.00	4.276
T14	$N_3 + Zn_1$ (3%+0.25%)	64.997	194,991.00	37,000.00	157,991.00	5.270
T15	$N_3 + Zn_2$ (3%+0.50%)	60.997	182,991.00	37,500.00	145,491.00	4.880
T16	$N_3 + Zn_3$ (3%+0.75%)	70.003	210,009.00	38,000.00	172,009.00	5.527

Fig.3. Economic feasibility of the treatments



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