Plant Archives Vol. 26, No. 2, 2026 pp. 2223-2235 e-ISSN:2581-6063 (online), ISSN:0972-5210

Plant Archives

Journal homepage: http://www.plantarchives.org

DOI Url : https://doi.org/10.51470/PLANTARCHIVES.2026.v26.no.2.305

NANO UREA AND NPK CONSORTIA REDUCED CONVENTIONAL FERTILIZERS REQUIREMENT IN TORIA (*Brassica campestris* var. *toria*)

Gurdev Singh[1], Prabhjot Kaur[1], Lakhmir Singh[2], A.H. Reddy[1] and Anju Pathania[1*]

[1]Faculty of Agricultural Sciences, DAV University, Jalandhar, Punjab, India.

[2]Department of Biotechnology, DAV University, Jalandhar, Punjab, India.

*Corresponding author E-mail : anju_pathania@rediffmail.com

(Date of Receiving-24-07-2026; Date of Revision-14-10-2026; Date of Acceptance-19-10-2026)

ABSTRACT

Today, we are focussing on sustainable agricultural practices to minimize the impact of conventional, chemical intensive cultivation practices which has been used since decades. Integrating biofertilizers and nano fertilizers with conventional fertilizers can offer an alternative option to reduce use of chemical fertilizers without compromising yield. A study was done to identify sustainable integration of nano- urea and NPK consortia with conventional chemical fertilizers in toria, a major catch crop grown between *Kharif* and *Rabi* season crops in various parts of India. Ten treatments comprising different combinations of nano and biofertilizers with varying levels of recommended fertilizers dose (RDF) replicated thrice in randomized complete block design were evaluated using TL-17 variety of toria. Treatments T_3 (75% RDF + Nano urea spray at 30 DAS @ 4mL L^{-1} water), T_6 (75% RDF + NPK consortia @ 5mL kg^{-1} seed + Nano urea spray at 30 DAS @ 4mL L^{-1} water + sulphur @ 20 kg ha^{-1}) and T_{10} (50% RDF + NPK consortia @ 5mL kg^{-1} seed + Nano urea spray at 30 DAS @ 4mL L^{-1} water + Nano urea spray at 45 DAS @ 4mL L^{-1} water + sulphur @ 20 kg ha^{-1}) were statistically similar to the control treatment (100% RDF) based on observations recorded on various growth, yield, quality and economic parameters. However, treatment T_{10} was identified as a more sustainable option, reducing RDF use by half while maintaining agronomic and economic performance comparable to RDF.

Key words : Biofertilizer, Crop productivity, Nano urea, Microbial consortia, Sulphur, Toria.

Introduction

Toria (*Brassica campestris* var. *toria*) belongs to the rapeseed and mustard group, which has a significant contribution to the total oilseed production globally. The majority of information and data pertains to crops included in this group. The seeds contain oil rich in unsaturated fatty acids, making it desirable for consumption.

India's foreign reserves are under strain due to import of edible oils to meet the domestic needs, and achieving self reliance in edible oil production is immediate priority. Oilseeds crops belonging to rapeseed and mustard group can contribute significantly through productivity enhancement, expansion in non conventional areas and by adopting sustainable cultivation practices. Fertilizers play a pivotal role in enhancing the productivity of toria, with nitrogen (N), phosphorus (P) and sulphur (S) being the key nutrients influencing crop growth, yield, and quality (Famda *et al*., 2017). Among these, nitrogen is often the most limiting nutrient in agricultural systems and is essential for the synthesis of chlorophyll, amino acids, proteins, and nucleic acids (Pattam *et al*., 2017). Its application significantly contributes to vegetative growth, plant height, branching, and canopy development. However, nitrogen use efficiency (NUE) in conventional agriculture remains below 50%, largely due to losses through volatilization, leaching, and denitrification, leading to both economic losses and environmental degradation. Urea, a widely used nitrogen source, supports the development of leaves, stems and branches.

Recent advances in nanotechnology offer innovative solutions to overcome the limitations of conventional

fertilizers. Nano fertilizers, typically 30 - 40 nm in size, possess high surface area and nutrient-holding capacity, allowing for slow and controlled nutrient release aligned with crop demand. Their enhanced foliar absorption and efficient translocation within the plant improve nutrient uptake, photosynthetic activity, and yield. Additionally, they reduce nutrient losses and environmental contamination, thereby contributing to sustainable intensification (Rohitha *et al*., 2023).

In addition to chemical and nano fertilizers, biofertilizers play a significant role in sustainable nutrient management. The application of microbial inoculants such as *Azotobacter*, phosphate-solubilizing bacteria (PSB), and potash-mobilizing bacteria often formulated as NPK consortia improves nutrient availability by converting insoluble forms of N, P and K into plant-accessible forms (Shahwar *et al*., 2023). Similarly, nano- fertilizers are important for promoting efficient nutrient utilization by crop plants.

In the prevailing agro-climatic conditions of Punjab, where soils are becoming increasingly deficient in organic matter and micronutrients, there is a growing need to identify efficient, cost-effective, and environmentally sustainable nutrient management practices suitable for the region. Collectively, the judicious use of diverse nutrient sources chemical, nano and biological can significantly influence the growth, yield components, oil content and economic returns of toria. The integration of these nutrient sources not only ensures balanced nutrition, but also promotes soil health, resource-use efficiency and environmental sustainability in toria-based cropping systems, particularly in intensive agricultural regions like Punjab. Therefore, the present study was carried out to evaluate the influence of different combinations of conventional fertilizers along with foliar application of nano urea and seed treatment with NPK consortium. The study aimed to identify the sustainable combination of conventional, nano and biofertilizers to enhance the growth, yield and quality parameters in toria besides soil health.

Methods and Materials

Experiment site

The research trial was conducted at DAV University, Jalandhar, in 2024. The site was located at 31.42°N and 75.62°E, at 229 m above sea level. The climate was subtropical, and the average minimum and maximum temperatures during the crop period (42nd 2024 to 10th 2025 standard metrological week (SMW)) were 12.27°C (4.29°C - 20.25°C) and 23.56°C (15.42°C - 31.71°C), respectively. The rainfall during the crop season was recorded 46.82 mm. The average relative humidity was recorded as 88.87% (79.57% - 98.17%) and 73.39% (55.50% - 91.28%) in the morning and evening, respectively. The texture of soil was sandy loam, having 7.21 pH and 0.61dS m^{-1} electrical conductivity (EC). The soil organic carbon (0.31%) was low, available nitrogen (272.16 kg ha^{-1}) and phosphorus (15.21 kg ha^{-1}) was medium. The available potassium (83.45 kg ha^{-1}) and sulphur (12.50 kg ha^{-1}) were also low in the soil of experimental plot.

Experimental details

Ten treatments were evaluated in a randomized complete block design (RCBD) with three replications (Table 1). To ensure optimal seed germination, pre-sown irrigation was applied in the experimental field. The soil was ploughed to fine tilth by disc plough followed by rotavator; the recommended fertilizers dose (RDF) was applied at 62.5 kg ha^{-1} N: 20 kg ha^{-1} P_2O_5: 15 kg ha^{-1} K_2O, through urea (46% N), single superphosphate (16% P_2O_5), and muriate of potash (60% K_2O), respectively. Bentonite sulphur (90% S) was used as source of sulphur in the treatments.

Table 1 : Details of different nutrient sources used in the treatments.

S. no.	Treatments
T_1	100% RDF (N: 62.5 kg ha^{-1}, P_2O_5: 20 kg ha^{-1} and K_2O: 15 kg ha^{-1})
T_2	75% RDF + NPK consortia @ 5mL kg^{-1} seed
T_3	75% RDF + Nano urea spray at 30 DAS @ 4mL L^{-1} water
T_4	75% RDF + sulphur @ 20 kg ha^{-1}
T_5	75% RDF + NPK consortia @ 5mL kg^{-1}seed + sulphur @ 20 kg ha^{-1}
T_6	75% RDF + NPK consortia @ 5mL kg^{-1} seed + Nano urea spray at 30 DAS @ 4mL L^{-1} water + sulphur @ 20 kg ha^{-1}
T_7	50% RDF + Nano urea spray at 30 DAS @ 4mL L^{-1} water + Nano urea spray at 45 DAS @ 4mL L^{-1} water
T_8	50% RDF + NPK consortia @ 5mL kg^{-1} seed + Nano urea spray at 30 DAS @ 4mL L^{-1} water
T_9	50% RDF + NPK consortia @ 5mL kg^{-1} seed + Nano urea spray at 30 DAS @ 4mL L^{-1} water + sulphur @ 20 kg ha^{-1}
T_{10}	50% RDF + NPK consortia @ 5mL kg^{-1} seed + Nano urea spray at 30 DAS @ 4mL L^{-1} water + Nano urea spray at 45 DAS @ 4mL L^{-1} water + sulphur@20kg ha^{-1}

Note: RDF- Recommended dose of fertilizers, DAS- Days after sowing.

Fertilizers were applied at different rates, as per the treatment. Application of urea, single superphosphate (SSP), muriate of potash (MOP) and sulphur was done at time of sowing. NPK consortia (5 mL kg^{-1} seed) were used as seed treatment with in recommended treatments. Nano urea was applied as foliar spray (4 mL L^{-1} water) as per the treatment at 30 days and 45 days after sowing (DAS). Seeds of toria variety 'TL-17' procured from Punjab Agricultural University, Ludhiana, were inoculated with SAAF (Carbendazim 12% + Mancozeb 63% W.P.) @ 2g kg^{-1} seed and NPK consortia (*Azotobacter* + *Pseudomonas* + *Bacillus*) @ 5mL kg^{-1} seed as per treatments (https://www.iffco.in/en/liquid-consortia).For sowing, the line sowing was done and spacing between rows was kept 30 cm. To maintain 10cm spacing between plants, thinning was done after 15 days of sowing.

Observation recorded on various parameters

A random selection and tagging of five plants was done in each plot to measure different parameters related to growth and yield. Data for days to 50% flowering were recorded on a plot basis in each replication of different treatments. Growth parameters were observed at 30, 60 and 90 DAS, and at harvest. The data on parameters related to yield and quality were recorded at maturity, and relative economics have been worked out after the harvesting and threshing of the treatments. The growth parameters recorded in different treatments included plant height, number of branches and leaves per plant, leaf area index, and dry matter accumulation. Yield parameters comprised of number of siliquae per plant, length of siliquae (cm), number of seeds per siliquae, biological yield (q/ha), stover and seed yield (q/ha), harvest index (%), and test weight. Quality parameters like oil content (%), oil yield (q/ha) and protein content (%) were also estimated for each treatment in each replication. After completion of the trial, soil sampling was done in each treatment plot to study the physico- chemical characteristics of the soil such as, pH, EC (ds m^{-1}), organic carbon (%), and available N, P, K, and S after use of different combinations of nutrient sources. To find out the relative economics of each treatment studied, the cost of production, gross returns, net returns, and benefit cost ratios were estimated.

After weighing each plot yield, seed samples were collected from produce and 1000 grains were counted and weighed in grams. To estimate percent oil content, seed samples weighing 5 grams each from all the plots were taken, and oil extraction was done following the method given by Association of Official Analytical Chemists (AOAC, 1970) for the extraction of oil. The formula used for calculation of percent oil content in seeds was as follows:

$$\text{Oil content (\%)} = \frac{\text{Weight of oil}}{\text{Weight of sample}} \times 100$$

The formula given below was used to estimate oil yield per hectare:

Oil yield (q ha^{-1}) = Oil content (%) × Seed yield (q ha^{-1})

To determine the protein content in toria seeds, the method given by Piper (1966) was used. Nitrogen uptake was determined by the modified micro- Kjeldahl method (Jackson, 1973). Phosphorus uptake was determined by using the Vanado-molybdo-phosphoric yellow colour method (Jackson, 1973). The potassium content in plants was determined using triacid (mixture composed of nitric acid, sulfuric acid, and perchloric acid in the ratio of 10:4:1) digestion followed by flame photometry analysis (Jackson, 1973). To determine soil pH and electrical conductivity (EC), digital pH meter and EC meter were used following the process given by Chesnin and Yien (1951) for sample preparation. The soil organic carbon content was determined by wet oxidation method (Walkley and Black, 1934). In soil samples, available nitrogen and phosphorus were determined by following alkaline potassium permanganate method (Subbiah and Asija,1956) and method given by Olsen (1954), respectively. The method given by Jackson (1973) was used to estimate exchangeable potassium in soil. To estimate available sulphur in the soil, the turbidimetric method given by Chesnin and Yien (1951) was used.

The total cost of cultivation (Rs. ha^{-1}) of each treatment was calculated by including the labour wages, amount spent on machinery used for different operations, and cost of inputs such as seed, fertilizers, farmyard manure, etc. based on the prevailing respective market prices of various operations/inputs. The seed yield obtained in different treatments was multiplied with their respective sale prices to estimated gross returns and then presented in Rs. ha^{-1}.

Gross returns (Rs. ha^{-1}) = Grain yield (kg ha^{-1}) × Price (Rs. kg^{-1})

The cost of cultivation was deducted from the gross returns (Rs. ha^{-1}) to estimate net returns.

Net returns (Rs. ha^{-1}) = Gross returns (Rs. ha^{-1}) – Cost of cultivation (Rs. ha^{-1})

To calculate the benefit cost ratio, following formulae was used:

$$\text{B : C ratio} = \frac{\text{Net returns } \left(\text{Rs. ha}^{-1}\right)}{\text{Total cost of cultivation } \left(\text{Rs. ha}^{-1}\right)}$$

Statistical analysis

The observations recorded from field experiment and laboratory analyses were analysed (Gomez and Gomez, 1984) to study the impact of treatments. OPSTAT software was used for the analysis of variance. To test statistical significance, a F test was done and to compare the effects of the treatments; the least significant differences were estimated for those parameters where the F test was significant.

Results and Discussion

Influence of different nutrient combinations on days to 50% flowering

Differences among different treatments were found significant for days to 50% flowering (Table 2). Treatments T_3 (75% RDF + nano urea spray at 30 DAS @ 4mL L^{-1}water) and T_7 (50% RDF + nano urea spray at 30 DAS @ 4mL L^{-1} water + nano urea spray at 45 DAS @ 4mL L^{-1} water) took a statistically similar number of days to flower as taken by the control treatment T_1 (100% RDF). The remaining treatments displayed early flowering and a significantly lesser number of days were taken to flower when compared with control treatment. The treatments T_2 (75% RDF + NPK consortia @ 5mL kg^{-1} seed), T_6 (75% RDF + NPK consortia @ 5mL kg^{-1} seed + Nano urea spray at 30 DAS @ 4mL L^{-1} water + sulphur @ 20 kg ha^{-1}), T_9 (50% RDF + NPK consortia @ 5mL kg^{-1} seed + Nano urea spray at 30 DAS @ 4mL L^{-1} water + sulphur @ 20 kg ha^{-1}) and T_{10} (50% RDF + NPK consortia @ 5mL kg^{-1} seed + Nano urea spray at 30 DAS @ 4mL L^{-1} water + Nano urea spray at 45 DAS @ 4mL L^{-1} water + sulphur @ 20 kg ha^{-1}) took significantly minimum and statistically at par days to 50% flowering. The results showed that the days to 50% flowering were observed prior to the use of nano urea. This trait was influenced by the dose of fertilizers, NPK consortia and sulphur. The NPK consortia improve microbial activity of soil and nutrient solubilization, while sulphur is crucial for enzyme activity and protein synthesis and may have further accelerated physiological processes leading to earlier flowering. Biofertilizers such as *Azotobacter*, phosphorus solubilizing bacteria (PSB) and potassium solubilizing bacteria (KSB), besides nutrient fixation, synthesize and secrete many amino acids that influence flowering (Patel *et al.*, 2017). Inoculation of seeds with *Azotobacter* resulted in earlier 50% flowering being equivalent to phosphate- solubilizing microorganism (PSMO) treatment. The varying levels of fertilizer doses

Table 2 : Impact of different nutrient sources on phenological and growth parameters of toria.

S. no.	DAS to 50% flowering	Plant height (cm)				Branches per plant			Leaves per plant			Leaf area index			Dry matter accumulation			
		30 DAS	60 DAS	90 DAS	At harvest	30 DAS	60 DAS	90 DAS	At harvest	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS	At harvest
T_1	31.33	48.57	83.65	122.89	124.21	3.87	6.57	12.80	12.80	6.57	19.33	23.40	0.44	1.35	2.28	5.07	31.43	50.05	42.32
T_2	29.67	39.25	85.07	110.59	113.79	3.20	5.40	10.60	10.60	6.10	18.67	19.47	0.27	1.20	1.62	4.37	29.00	40.45	36.67
T_3	31.67	48.41	89.77	118.98	119.31	3.13	6.33	12.93	12.93	5.80	19.53	23.93	0.34	1.21	2.14	5.16	31.47	46.54	41.01
T_4	30.33	43.33	76.17	107.48	110.19	3.20	5.90	10.13	10.13	6.07	16.40	18.87	0.31	1.03	1.52	4.08	29.57	40.41	34.37
T_5	30.33	45.99	84.65	112.97	115.37	3.67	6.23	11.53	11.53	6.33	18.13	21.33	0.32	1.16	2.02	4.90	27.77	39.70	36.77
T_6	29.00	47.18	99.59	127.29	127.47	3.53	6.67	13.10	13.10	6.70	21.20	24.73	0.42	1.49	2.50	5.24	32.77	53.69	44.35
T_7	32.33	31.74	80.69	119.69	120.93	2.67	6.10	11.67	11.67	5.20	18.73	22.40	0.18	1.22	2.00	3.63	27.60	46.94	41.56
T_8	30.00	37.29	74.70	116.80	118.66	2.80	5.93	10.87	10.87	5.40	16.93	20.53	0.22	1.14	1.75	2.97	28.17	42.17	35.24
T_9	29.33	38.17	87.08	115.20	117.83	3.00	5.93	11.87	11.87	5.27	17.27	21.93	0.20	1.18	1.85	3.37	29.87	48.05	39.72
T_{10}	29.67	37.52	92.09	131.24	134.46	2.87	6.77	13.80	13.80	5.90	20.83	25.13	0.32	1.41	2.51	3.79	32.20	53.47	43.84
SE m (±)	**0.32**	**2.41**	**2.67**	**2.98**	**2.79**	**0.26**	**0.18**	**0.48**	**0.48**	**0.21**	**0.67**	**0.84**	**0.03**	**0.05**	**0.14**	**0.35**	**0.63**	**1.46**	**1.05**
CD (5%)	**0.97**	**7.22**	**8.00**	**8.92**	**8.34**	**NS**	**0.54**	**1.43**	**1.43**	**0.63**	**2.02**	**2.53**	**0.10**	**0.15**	**0.42**	**1.03**	**1.90**	**4.37**	**3.13**

(RDF) and different biofertilizers resulted early flowering and physiological maturity in mustard plots with application of full dose (100%) and 75% RDF (Prajapati *et al*., 2024). Application of 50% RDN as a basal dose led to earlier 50% flowering over 100% RDN. It is known that nitrogen enhances the photosynthetic activity in plants and results in the production of photosynthate for longer period, a higher dose of nitrogen leading to more vegetative growth and delayed flowering (Harode *et al*., 2024). However, studies on integrated nutrient management (INM) by (Kumar *et al*., 2025) in mustard reported non-significant impact of different treatments for days to 50% flowering.

Effect of different nutrient treatments on growth parameters of toria

The perusal of data presented in Table 2 revealed significant differences among treatments for various growth parameters at different time intervals. Plant height recoded at different growth stages was found significantly different among treatments. At 30 DAS, significant decrease in plant height was recorded under treatments T_2 (75% RDF + NPK consortia @ 5mL kg^{-1} seed), T_7 (50% RDF + Nano urea spray at 30 DAS @ 4mL L^{-1} water + Nano urea spray at 45 DAS @ 4mL L^{-1} water), T_8 (50% RDF + NPK consortia @ 5mL kg^{-1} seed + Nano urea spray at 30 DAS @ 4mL L^{-1} water), T_9 (50% RDF + NPK consortia @ 5mL kg^{-1} seed + Nano urea spray at 30 DAS @ 4mL L^{-1} water + sulphur @ 20 kg ha^{-1}), and T_{10} (50% RDF + NPK consortia @ 5mL kg^{-1} seed + Nano urea spray at 30 DAS @ 4mL L^{-1} water + Nano urea spray at 45 DAS @ 4mL L^{-1} water + sulphur @ 20 kg ha^{-1}), when compared with control treatment, which was recommended dose of fertilizers. The height of the plants increased significantly under treatments T_6 (75% RDF + NPK consortia @ 5mL kg^{-1} seed + Nano urea spray at 30 DAS @ 4mL L^{-1} water + sulphur @ 20 kg ha^{-1}) and T_{10} (50% RDF + NPK consortia @ 5mL kg^{-1} seed + Nano urea spray at 30 DAS @ 4mL L^{-1} water + Nano urea spray at 45 DAS @ 4mL L^{-1} water + sulphur @ 20 kg ha^{-1}) when recorded at 60 DAS. Similarly at 60 DAS, 90 DAS and at harvest, the height of toria plants were recorded significantly high under treatments T_6 (75% RDF + NPK consortia @ 5mL kg^{-1} seed + Nano urea spray at 30 DAS @ 4mL L^{-1} water + sulphur @ 20 kg ha^{-1}) and T_{10} (50% RDF + NPK consortia @ 5mL kg^{-1} seed + Nano urea spray at 30 DAS @ 4mL L^{-1} water + Nano urea spray at 45 DAS @ 4mL L^{-1} water + sulphur @ 20 kg ha^{-1}) among all the treatments including control treatment T_1. It was observed that the plant height were significantly increased in the treatments where lower doses of nitrogen through urea and DAP were used along with seed treatment with NPK consortium, foliar spray of nano urea and soil application of sulphur was done. Branches per plant were found similar under all the treatments at 30 DAS, however significant differences were recorded at 60 DAS, 90 DAS and harvest among treatments for this trait. Treatments T_6 (75% RDF + NPK consortia @ 5mL kg^{-1} seed + Nano urea spray at 30 DAS @ 4mL L^{-1} water + sulphur @ 20 kg ha^{-1}) and T_{10} (50% RDF + NPK consortia @ 5mL kg^{-1} seed + Nano urea spray at 30 DAS @ 4mL L^{-1} water + Nano urea spray at 45 DAS @ 4mL L^{-1} water + sulphur @ 20 kg ha^{-1}) resulted significantly higher number of branches among all treatments at 60 DAS, 90 DAS and at harvest. Like plant height, number of branches per plant was also recorded significantly more in plots where combination of lower doses of RDF, seed treatment with NPK consortia, soil application of sulphur and foliar application of nano urea were used. Leaves per plant and leaf area index were recorded significantly high in control treatment T_1 at 30 DAS, however significant increase in both the traits was observed as the plant growth advances. At 60 DAS, 90 DAS and harvest, statistically similar number of leaves and leaf area index was recorded in treatments T_6 (75% RDF + NPK consortia @ 5mL kg^{-1} seed + Nano urea spray at 30 DAS @ 4mL L^{-1} water + sulphur @ 20 kg ha^{-1}) and T_{10} (50% RDF + NPK consortia @ 5mL kg^{-1} seed + Nano urea spray at 30 DAS @ 4mL L^{-1} water + Nano urea spray at 45 DAS @ 4mL L^{-1} water + sulphur @ 20 kg ha^{-1}), which was significantly higher among all the treatments. Dry matter accumulation were significantly high in toria plants under treatments T_3 (75% RDF + nano urea spray at 30 DAS @ 4mL L^{-1}water) and T_6 (75% RDF + NPK consortia @ 5mL kg^{-1} seed + Nano urea spray at 30 DAS @ 4mL L^{-1} water + sulphur @ 20 kg ha^{-1}) at 30 DAS and was recorded significantly high under treatments T_6 (75% RDF + NPK consortia @ 5mL kg^{-1} seed + Nano urea spray at 30 DAS @ 4mL L^{-1} water + sulphur @ 20 kg ha^{-1}) and T_{10} at 60 and 90 DAS and at harvest. It has been observed that at early growth period, the treatments with high RDF performed well, however as growth period advances, the combined application of NPK consortium, spray of nano urea and soil application sulphur with reduced RDF levels outperformed the control treatment. The seeds inoculation with *Azotobacter* @ 10 mL kg^{-1} helped seed in fixing the atmospheric nitrogen, which resulted in more nitrogen available for the plants and influenced the plant height in a positive way (Hadiyal *et al*., 2017). The larger surface area of nano particles in nano urea enhanced nutrient penetration that of conventional urea, boosted the uptake of the nutrients efficiently, resulting in better development

and increased plant height (Prasad *et al.*, 2017).

The influence of various test treatments was not significant at 30 DAS, whereas significant differences were observed at later between the control and test treatments for number of branches per plant (Table 2). At 60 DAS, 90 DAS and harvest, significant reduction in branches per plant was noted in treatments T_2, T_4 and T_8 in comparison to the control treatment T_1 (Table 2). The present study has shown that treatments with 100% and 75% RDF at 30 DAS showed higher growth parameters due to readily available major nutrients and the crop responded well to inorganic fertilizers. The physiological capacity of the plant to absorb and utilize high amounts of nutrients was still limited at 30 DAS. Fifty percent (50%) reduction in major nutrients, *i.e.*; NPK and without sulphur, could be the reason for significant decrease in the height of the plants in treatment T_8. Significant increase in height and branches of plants was reported in mustard (*B. juncea* L.) when nitrogen and sulphur were used together (@120 kg ha^{-1} and 45 kg ha^{-1}, respectively (Islam *et al*., 2018).

Non-significant differences among treatments were reported for number of branches per plant in mustard [*B. juncea* (L.) Czern. & Coss] at 40 DAS, while studied the impact various biofertilizers along with varying levels of sulphur (Meena *et al*., 2018). The results of the present study showed similar number of branches per plant at 90 DAS and the harvesting. The number of branches in rapeseed was also reported similar in a study at 75 DAS and harvesting when nano urea was used in integrated nitrogen management (Kalita *et al*., 2024).

Control treatment displayed significantly high dry matter accumulation at 60 DAS compared to test treatments T_2, T_5, T_7 and T_8, while remaining treatments resulted in statistically on par dry matter accumulation with the control treatment (Table 2). It has been reported that accumulation of dry matter in plants started 10 days after flowering and continued till 40 days after flowering and, after that no further increase in dry matter was observed (Fazli *et al*., 2005). The response of growth and yield parameters of gobhi sarson to conventional NPK fertilizers and their combination with farm yard manure (FYM), and primary and secondary nutrients was investigated in an earlier study (Deekshith *et al*., 2023). The results revealed non-significant differences among treatments at early growth stages, but the at later growth stages (90, 120, 150 DAS and harvest), the use of 100% NPK exhibited high dry mater accumulation which was further increased at higher dose of NPK (150% NPK). The impact of various levels of recommended dose of nitrogen (RDN) along with nano urea on various parameters related to growth of Indian mustard were assessed and it was found that the growth of mustard in terms of plant height and number of branches per plant enhanced significantly when 75% RDN and nano urea 6mL L^{-1} were applied (Acharya *et al*., 2024). In Indian mustard, plant height and number of branches per plant increased significantly in plots where 100% recommended dose of fertilizers was applied along with two foliar sprays of nano urea @ 0.4% at 30 and 45 DAS (Bhedela *et al*., 2024). In an experiment to study the influence of different doses of sulphur and nano urea on the growth of mustard plants, it was observed that height and dry weight of the plants in plots treated with sulphur @ 30 kg ha^{-1} and nano urea @ 4 mL L^{-1} increased significantly among different treatments (Gouri *et al*., 2024). When NPK @120:60:40 kg ha^{-1} and sulphur @40 kg ha^{-1} were applied in mustard, non significant differences were observed for leaves and branches number per plant at 30, 60 and 90 DAS, but increased significantly at 120 DAS (Dhruw *et al*., 2017). The influence of varying levels of chemical fertilizers along combined with biofertilizers and FYM was studied on the growth of mustard plants. The results revealed that the height and branches of mustard plants increased significantly when 75% NPK was applied and seeds were treated with *Azotobacter* and phosphorus solublizing bacteria (PSB) at 40g per kg seed (Kalita *et al*., 2019).

When conventional urea was applied in mustard along with foliar spray of nano urea, significantly more height, leaf area index and accumulation of dry matter in plants was reported in plots where 100% RDN (recommended dose of nitrogen), and one spray of nano urea @ 1250 mL ha^{-1} before flowering -with 50% RDN as basal dose were applied (Navya *et al*., 2022). A significant and similar increase in various growth parameters of mustard such as plant height, branches per plant and leaf area index was reported in plots supplemented with 125% and 100% RDF, when various levels of RDF (NPK) and S were used. The application of sulphur significantly enhanced the growth of mustard plants with increase in its dose from 0 to 20 kg ha^{-1} and the maximum increase in growth parameters was recorded when sulphur was applied at 20 kg ha^{-1} (Basumotary *et al*., 2020).

When 0%, 75%, 100% RDN (recommended dose of nitrogen) and different rates (0, 20 ppm, 40 ppm, 60 ppm, 80 ppm) of nano urea were applied at 30 and 60 DAS, a significant effect of 75% RDN in combination with two sprays of nano urea (applied @ 40 ppm) was reported on growth parameters like plant height, branches

Table 3 : Influence of different nutrient sources on yield and yield attributes of toria.

S. no.	Number of Siliquae	Siliqua length (cm)	Seeds per siliqua	Test weight (g)	Biological yield(q ha^{-1})	Seed yield (q ha^{-1})	Stover yield (q ha^{-1})	Harvest Index (%)
T_1	156.77	4.14	13.17	3.81	52.22	15.34	36.88	29.39
T_2	130.44	3.43	11.89	3.60	43.34	11.95	31.39	27.51
T_3	157.84	4.16	12.47	3.86	54.16	16.41	37.74	30.30
T_4	137.31	3.57	11.70	3.55	41.48	10.96	30.52	26.37
T_5	151.67	3.68	11.15	3.63	43.62	12.31	31.31	28.22
T_6	158.89	4.19	13.04	3.98	53.99	16.83	37.17	31.10
T_7	151.23	4.07	11.22	3.74	51.88	15.31	36.57	29.43
T_8	137.94	3.65	12.60	3.69	43.88	11.88	32.01	27.07
T_9	146.50	3.93	12.84	3.75	48.97	13.71	35.26	27.96
T_{10}	160.41	4.21	13.40	3.95	55.74	17.17	38.57	30.73
SEm (±)	**3.43**	**0.09**	**0.37**	**0.06**	**1.08**	**0.83**	**0.59**	**1.17**
CD (5%)	**10.28**	**0.27**	**1.10**	**0.18**	**3.22**	**2.49**	**1.77**	**NS**

and functional leaves per plant and dry matter accumulation at 40, 60 and 80 DAS (Pandav *et al*., 2022).

Effect of different treatments on yield attribute and yield of toria

The effects of different treatments were recorded significant for various yield attributes and yield in toria (Table 3). Number of siliquae per plant were found significantly high in T_{10} (50% RDF + NPK consortia @ 5mL kg^{-1} seed + Nano urea spray at 30 DAS @ 4mL L^{-1} water + Nano urea spray at 45 DAS @ 4mL L^{-1} water + sulphur @ 20 kg ha^{-1}) and statistically similar in plants under treatments T_3 (75% RDF + nano urea spray at 30 DAS @ 4mL L^{-1} water) and T_6 (75% RDF + NPK consortia @ 5mL kg^{-1} seed + Nano urea spray at 30 DAS @ 4mL L^{-1} water + sulphur @ 20 kg ha^{-1}). The length of siliqua was recorded significantly high in treatment T_{10} (50% RDF + NPK consortia @ 5mL kg^{-1} seed + Nano urea spray at 30 DAS @ 4mL L^{-1} water + Nano urea spray at 45 DAS @ 4mL L^{-1} water + sulphur @ 20 kg ha^{-1}). Seeds per siliquae were recorded statistically same in all the treatments except treatments T_2, T_4, T_5 and T_7. The test weight of seeds harvested from treatments T_6 (75% RDF + NPK consortia @ 5mL kg^{-1} seed + Nano urea spray at 30 DAS @ 4mL L^{-1} water + sulphur @ 20 kg ha^{-1}) and T_{10} (50% RDF + NPK consortia @ 5mL kg^{-1} seed + Nano urea spray at 30 DAS @ 4mL L^{-1} water + Nano urea spray at 45 DAS @ 4mL L^{-1} water + sulphur @ 20 kg ha^{-1}) was recorded significantly high among all the treatments including control. However, biological yield per plant, stover yield and seed yield per plant were found significantly high and statistically same in treatments T_3 (75% RDF + nano urea spray at 30 DAS @ 4mL L^{-1}water), T_6 (75% RDF + NPK consortia @ 5mL kg^{-1} seed + Nano urea spray at 30 DAS @ 4mL L^{-1} water + sulphur @ 20 kg ha^{-1}) and T_{10} (50% RDF + NPK consortia @ 5mL kg^{-1} seed + Nano urea spray at 30 DAS @ 4mL L^{-1} water + Nano urea spray at 45 DAS @ 4mL L^{-1} water + sulphur @ 20 kg ha^{-1}). The differences among treatments were recorded non significant for harvest index.

Significant increase in yield parameters of Indian mustard was reported in plots where soil application of 75% RDN and foliar application of nano urea @ 6 mL L^{-1} was done (Acharya *et al*., 2024). The results were similar to those obtained with application of 100% RDN. However, for harvest index, non-significant differences among treatments were recorded.

The effects various rates of nano urea spray in combination with 100% RDF and 75% RDF on yield attributing traits of Indian mustard were studied (Bhedela *et al*., 2024). The results revealed that the increase in yield and yield attributing traits was statistically similar when 100% RDF was applied along with different doses of nano urea (0.2%, 0.4% and 0.6%) sprayed at 30 and 45 days after sowing.

Seed yield, stover yield, and test weight in mustard were significantly increased when sulphur and nano urea were applied @30 kg ha^{-1} and @ 4 mL L^{-1}, respectively, among treatments comprising varying levels of sulphur and nano urea used (Gouri *et al*., 2024).

Significant differences among treatments comprising combinations of varying levels of NPK and S in mustard were recorded. The application of NPK and S @120:60:40 kg ha^{-1} and 40 kg ha^{-1}, respectively, resulted a significant increase in yield attributes such as, number of siliquae per plant, number of seeds per siliqua, fresh weight and dry weight per plant, test weight, seed yield and straw

yield (Dhruw *et al*., 2017).

Mustard seeds treated with *Azotobacter* and phosphorus solubilizing bacteria in combination with 75% and 50% NPK significantly increased number of siliquae per plant, seeds per siliqua and 1000- seed weight compared to recommended NPK dose when the yield response of mustard plants to seed treatment with biofertilizers in combination with different rates of conventional chemical fertilizers and FYM were studied (Kalita *et al*., 2024). A similar and significant enhancement in yield attributing traits of mustard in plots was reported where recommended dose of nitrogen (100% RDN) and a half of the recommended nitrogen (50% RDN) along with nano N spray (1250 mL ha^{-1}) before flowering were applied (Navya *et al*., 2022). Significantly high increase in yield was reported when 100% and 125% of RDF and 20kg ha^{-1} sulphur were applied in mustard compared to lower doses of RDF and sulphur (Basumotary *et al*., 2020). In contrary to the present findings, in another study, siliqua length, number of seeds per siliqua, 1000-grain weight, seed yield and stover yield were increased significantly when 125% RDF along with biofertilizers (*Azotobacter* + PSB+ KMB) were applied in toria compared to 100% RDF and 75% RDF along with biofertilizers (Nitheesh *et al*., 2022).

A significant increase in siliquae per plant, seeds per siliqua and test weight was reported when nitrogen and sulphur were applied at higher rates (150 kg ha^{-1} nitrogen and 40 kg ha^{-1} sulphur), while studied the response of yield parameters of mustard to different rates of nitrogen and sulphur. However, different treatment combinations were found non-significant for harvest index (Godara *et al*., 2025).

The response of yield and yield attributes of mustard to different rates of nitrogen (0, 60, 120, 180 kg ha^{-1}) and sulphur (0, 15, 30, 45 kg ha^{-1}) was studied (Islam *et al*., 2018). The results of the study showed that siliquae per plant, siliqua length, seeds per siliqua, 1000 seed weight, seed yield, biological yield, and harvest index were increased significantly when nitrogen and sulphur were applied @ 120 kg ha^{-1} and 45 kg ha^{-1}, respectively.

Influence of different nutrient sources on seed quality parameters

The results pertaining to response of seed quality parameters such as protein content, oil content and oil yield per hectare to different nutrient sources are presented in Table 4. The results revealed significantly high protein content in treatments T_{10} (17.50%) and T_6 (17.40%), and significantly minimum seed protein content in treatment T_4 compared to the control treatment T_1. All test treatments were statistically at par with control treatment for oil content (%), except T_4, T_7 and T_8, with significantly low percent oil content compared to the control treatment T_1 (Table 3). Oil yield per hectare was significantly low in test treatments T_2, T_4, T_5, T_8, and the remaining treatments were statistically at par with treatment T_1 (control) for this trait (Table 3).

Sulphur enhanced amino acid formation that helped in improved nitrogen availability and higher protein production. The protein content in mustard seeds enhanced significantly with the use of sulphur could be due to its role as one of the important constituents of amino acids, cysteine and methionine, which play role in protein synthesis. The higher rates of sulphur may enhance the protein synthesis and facilitate the formation of protein bodies in the seeds, which subsequently leads to increased protein content of mustard seeds. A significantly high increase in oil content in the mustard seeds was observed when recommended dose of fertilizers (100% RDF) was applied, which was statistically similar to the oil content observed in higher doses of fertilizers (125% and 150% of RDF). It was suggested that the high seed protein content with higher nitrogen levels could be because of enhanced nitrogen uptake by the crop plants and its efficient translocation to developing seeds (Kumar, 2015).

It was reported that oil content and oil yield were significantly increased in mustard when full dose of NPK and S were applied together with spray of nano Zn (10 mL L^{-1}) in mustard (Verma *et al*., 2022).

Influence of different fertilizer treatments on nutrient uptake

The uptake of major nutrients namely Nitrogen (N), phosphorus (P) and potassium (K) by plants were estimated in stover harvested from different treatment plots. The content of N, P and K were recorded significantly high in test treatment T_{10} (50% RDF + NPK consortia @ 5mL kg^{-1} seed + Nano urea spray at 30 DAS @ 4mL L^{-1} water + Nano urea spray at 45 DAS @ 4mL L^{-1} water + sulphur @ 20 kg ha^{-1}) and low in treatments T_2, T_4, T_5 and T_8. N, P and K content present in stover were statistically similar to control treatment in the remaining test treatments (Table 4).

Nanofertilizers have particle size and surface area comparatively smaller to that of pore present on roots and leaves of the plants, resulting higher nutrient absorbance when applied on plant foliage. Enhanced nutrient uptake and accumulation in both straw and seeds were reported on application of nano fertilizers (González-

Table 4 : Impact of different nutrient sources on quality parameters and nutrient uptake by stover of toria.

S. no.	Protein content (%)	Oil content (%)	Oil yield (q ha^{-1})	N in stover (kg ha^{-1})	P in stover (kg ha^{-1})	K in stover (kg ha^{-1})
T_1	17.07	36.00	552.08	33.99	12.37	26.43
T_2	17.00	34.67	416.34	28.25	10.04	22.63
T_3	17.13	36.33	595.97	35.22	12.83	27.30
T_4	16.70	32.67	359.39	27.06	9.36	22.27
T_5	17.03	34.67	425.74	28.42	10.44	22.70
T_6	17.40	36.67	616.34	35.06	13.01	27.63
T_7	16.87	33.67	518.12	32.79	11.70	25.84
T_8	16.73	33.33	396.00	29.14	9.93	22.51
T_9	17.17	34.00	466.51	31.83	11.16	25.27
T_{10}	17.50	35.67	613.69	36.77	13.75	28.32
SEm(±)	**0.10**	**0.62**	**31.82**	**0.76**	**0.45**	**0.63**
CD (5%)	**0.31**	**1.84**	**95.27**	**2.26**	**1.35**	**1.89**

Melendi *et al*., 2008). The results of a research suggested that use of 50 kg ha^{-1} P_2O_5, 40 kg ha^{-1} S and 30 g kg^{-1} seed PSB significantly increased P and S content in the straw of mustard (Yadav *et al*., 2010). The uptake of nutrient by toria crop plants (*B. campestris* var *toria*) was studied when different nutrient combinations were used and the results revealed the highest nutrient uptake on combined application of 100% RDF, vermicompost @ 2 t per ha, S @20 kg ha^{-1} and Zn @4 kg ha^{-1} and seeds treated with biofertilizer consortia (Bora *et al*., 2020). The higher uptake of major nutrients N, P, K and S was reported when higher doses of fertilizers (125% RDF and 150% RDF) were applied in toria (*B. rapa* var toria) (Prajapati *et al*., 2024). The higher nutrient uptake by mustard plants were reported in plots where 75 kg ha^{-1} nitrogen, 50 kg ha^{-1} phosphorus and 40 kg ha^{-1} sulphur were used (Chauhan *et al*., 2020). The nutrients uptake in mustard plants was assessed when conventional urea and nano urea were used by Meena *et al*. (2024). The results indicated that recommended rate of nitrogen (RDN 100%) and one foliar spray of nano urea at 30 DAS increased nitrogen, phosphorus and potassium uptake in both mustard seeds and stover (Meena *et al*., 2024).

Impact of different nutrient sources on chemical properties of toria field

The analysis of soil samples collected from each treatment plot was done to study any change in the physical and chemical properties of the soil after the use of different nutrient combinations. The differences among different treatments were recorded non significant for soil pH and electrical conductivity after the completion of the experiment (Table 5). However, the soil organic carbon was found significantly high in the plots of treatments T_6 (75% RDF + NPK consortia @ 5mL kg^{-1} seed + Nano urea spray at 30 DAS @ 4mL L^{-1} water + sulphur @ 20 kg ha^{-1}) and T_{10} (50% RDF + NPK consortia @ 5mL kg^{-1} seed + Nano urea spray at 30 DAS @ 4mL L^{-1} water + Nano urea spray at 45 DAS @ 4mL L^{-1} water + sulphur @ 20 kg ha^{-1}). The increase might be due to high biological yield and use of NPK consortium as seed treatment which increases the availability of nutrients, release of root exudates and higher activity of soil microbes to stabilize organic carbon. Available nitrogen and phosphorus were recorded significantly high under treatment T_6 (75% RDF + NPK consortia @ 5mL kg^{-1} seed + Nano urea spray at 30 DAS @ 4mL L^{-1} water + sulphur @ 20 kg ha^{-1}), whereas available potassium was recorded statistically similar and high in soil samples collected from plots of all treatments except T_2, T_7, T_9 and T_{10}. Significantly high available sulphur was recorded in soil samples collected from plots under treatments T_5 (75% RDF + NPK consortia @ 5mL kg^{-1}seed + sulphur @ 20 kg ha^{-1}--), T_6 (75% RDF + NPK consortia @ 5mL kg^{-1} seed + Nano urea spray at 30 DAS @ 4mL L^{-1} water + sulphur @ 20 kg ha^{-1}) and T_{10} (50% RDF + NPK consortia @ 5mL kg^{-1} seed + Nano urea spray at 30 DAS @ 4mL L^{-1} water + Nano urea spray at 45 DAS @ 4mL L^{-1} water + sulphur @ 20 kg ha^{-1}).

The use of nano fertilizers reduce pollution of natural resources like soil and water and ensure continuous supply of nutrients to plants by minimizing losses to environment. To study how different phosphorus and sulphur levels along with seed treatment with PSB affected the available major nutrients in the soil, a study was done (Solanki *et al*., 2018). They recorded A slight increase in soil organic carbon, available nitrogen, phosphorus, potassium, and sulphur in the soil and decrease in pH and EC was recorded, when phosphorus, sulphur and PSB were

Table 5 : Impact of different nutrient sources on chemical properties of soil in treatment plots of toria.

S. no.	pH	EC ($dS\ m^{-1}$)	OC (%)	Avail. N ($kg\ ha^{-1}$)	Avail. P ($kg\ ha^{-1}$)	Avail. K ($kg\ ha^{-1}$)	Avail. S ($kg\ ha^{-1}$)
T_1	7.37	0.15	0.32	294.75	16.77	91.51	12.61
T_2	7.33	0.14	0.33	287.33	15.49	83.60	13.15
T_3	7.30	0.14	0.32	282.97	15.00	91.70	12.93
T_4	7.33	0.15	0.33	281.59	15.45	92.20	14.24
T_5	7.34	0.13	0.33	286.33	15.52	86.44	15.14
T_6	7.36	0.16	0.35	304.57	16.48	92.57	16.53
T_7	7.29	0.15	0.31	270.09	13.49	80.39	11.59
T_8	7.19	0.14	0.31	267.22	14.29	91.52	12.92
T_9	7.26	0.16	0.32	272.97	14.45	76.90	14.37
T_{10}	7.22	0.15	0.34	275.84	14.67	79.72	16.21
SEm (±)	**0.06**	**0.01**	**0.01**	**4.12**	**0.49**	**2.62**	**0.49**
CD (5%)	**NS**	**NS**	**0.02**	**12.34**	**1.48**	**7.84**	**1.46**

applied either alone or in combination (Solanki *et al*., 2018).

Different levels of RDF along with FYM and biofertilizers were used in gobhi sarson (*B. napus* L.) to study their effect on soil properties (Ratanoo *et al*., 2021). The results revealed significant influence of 50% RDF along with FYM and consortium on various soil parameters. The pH of the soil decreased and soil electrical conductivity, soil organic carbon, available N, P, K and S increased significantly. Similar results were reported for different treatments of biofertilizers where seed inoculation with consortium resulted significant increase in soil fertility (Ratanoo *et al*., 2021).

A significant influence on soil characteristics was reported when applied nano N and Zn at 30 and 45 DAS in addition to recommended dose of fertilizers (Sharma *et al*., 2023). The availability of macro and micro nutrients along with microbial population was enhanced when 100% RDF was applied along with foliar sprays of nano fertilizers containing N and Zn were applied at 30 and 45 days after sowing (Sharma *et al*., 2023). The soil pH and EC was stabilized and organic carbon and available nitrogen and phosphorus were high in the soil of the mustard plots after harvesting where biofertilizers (*Azotobactor* and PSB) and vermicompost was used with 80% RDF (Vaiphei *et al*., 2025).

Relative economics of different treatments used in toria

To compare the economics of different treatments, benefit cost ratio was calculated. The gross returns, net returns and benefit cost ratio obtained under different treatments were found significantly different among treatments (Table 6). High gross and net returns and benefit cost ratios were recorded in treatments T_3 (75% RDF + nano urea spray at 30 DAS @ 4mL L^{-1} water), T_6 (75% RDF + NPK consortia @ 5mL kg^{-1} seed + Nano urea spray at 30 DAS @ 4mL L^{-1} water + sulphur @ 20 kg ha^{-1}) and T_{10} (50% RDF + NPK consortia @ 5mL kg^{-1} seed + Nano urea spray at 30 DAS @ 4mL L^{-1} water + Nano urea spray at 45 DAS @ 4mL L^{-1} water + sulphur @ 20 kg ha^{-1}). The variation in economic parameters could be due to differences among treatments for seed yield and cost of inputs used.

Khatkar *et al*. (2009) reported maximum net returns in treatment with higher doses of nitrogen (100 kg ha^{-1}), phosphorus (60 kg ha^{-1}) and sulphur (30 kg ha^{-1}). The use of an efficient biofertilizer strain serves as an eco-friendly and economical input, enhancing the availability of nutrients to crops while simultaneously reducing the overall cost of cultivation (Bhardwaj *et al*., 2014). Significant improvement in B: C ratio was observed in treatments in which seeds were inoculated with *Azotobacter* and PSB at 10mL each per kg of seed (Hadiyal *et al*., 2017). Similarly, it was demonstrated that a higher dose of nitrogen (120 kg ha^{-1}) along with sulphur (40 kg ha^{-1}) significantly increased the economic yield, which in turn contributed to higher net returns (Kumar *et al*., 2017). The economics of cultivation when biofertilizers (*Azotobacter* and PSB) were used with different doses of conventional fertilizers and FYM in toria (var. TS36) was worked out. It was found that the application of biofertilizers with 50% and 75% NPK over recommended dose of NPK yielded high net returns and benefit cost ratio (Kalita *et al*., 2024).

The application of 100% NPK and S along with nano Zn spray (10 mL L^{-1}) in mustard yielded significantly high net returns and benefit cost ratio when the impact of

Table 6 : Impact of different nutrient sources on relative economics of toria.

S. no.	Cost of production (` ha^{-1})	Gross returns (` ha^{-1})	Net returns (` ha^{-1})	B:C ratio
T_1	40412.03	92,041.27	51,629.24	1.28
T_2	39670.53	71,706.34	32,035.82	0.81
T_3	40635.62	98,485.71	57,850.09	1.42
T_4	42079.67	65,729.37	23,649.70	0.56
T_5	42285.81	73,828.57	31,542.76	0.75
T_6	43457.04	100,944.60	57,487.55	1.32
T_7	40843.81	91,857.94	51,014.13	1.25
T_8	39878.72	71,242.85	31,364.14	0.79
T_9	42494.00	82,253.17	39,759.17	0.94
T_{10}	43665.23	103,009.50	59,344.29	1.36
SEm(±)		**4,978.95**	**4,978.99**	**0.12**
CD (5%)		**14,907.84**	**14907.96**	**0.35**

novel nutrient sources, their dose and application methods on the profitability of Indian mustard were evaluated (Verma *et al*., 2022). A study conducted with four different doses of nitrogen and three different levels of sulphur to evaluate their effect on economic profitability of mustard cultivation revealed that the higher doses of nitrogen (150 kg ha^{-1}) and sulphur (40 kg ha^{-1}) significantly enhanced the gross returns, net returns and benefit cost ratio (Godara *et al*., 2025).

Conclusion

The results of the present study indicated that treatments with lower doses of RDF along with NPK consortia and nano urea showed almost similar influence on different growth, yield and quality parameters in toria to that of treatment with recommended fertilizer dose. Non-significant differences between control treatment and test treatments T_6 (75% RDF + NPK consortia @ 5mL kg^{-1} seed + Nano urea spray at 30 DAS @ 4mL L^{-1} water + sulphur @ 20 kg ha^{-1}), T_{10} (50% RDF + NPK consortia @ 5mL kg^{-1} seed + Nano urea spray at 30 DAS @ 4mL L^{-1} water + Nano urea spray at 45 DAS @ 4mL L^{-1} water + sulphur @ 20 kg ha^{-1}), and T_3 (75% RDF + nano urea spray at 30 DAS @ 4mL L^{-1} water), were recorded during vegetative growth stages. However, test treatment T_{10} showed better results for yield and quality attributes and treatment T_3 exhibited a higher B: C ratio. Among three alternative nutrient combinations, treatment T_{10} (50% RDF + NPK consortia @ 5mL kg^{-1} seed + nano urea spray at 30 DAS @ 4mL L^{-1} water + nano urea spray at 45 DAS @ 4mL L^{-1} water + sulphur bentonite @ 20 kg ha^{-1}) offered a sustainable combination of chemical, bio, and nano fertilizers compared to the recommended doses of conventional chemical fertilizers.

Acknowledgement

Financial assistance provided by DAV University, Jalandhar is duly acknowledged.

Conflict of interest : Authors declare no conflict of interest.

References

Acharya, P., Solanki N.S., Gehlot J.K., Rajwaniya A., Jaiswani S., Champawat T.S. and Panchal K. (2024). Effect of nano urea on growth and yield attributes of Indian mustard (*Brassica juncea* L). *Int J Res Agron.*, **7(12)**, 236-8.

Association of Official Analytical Chemists (AOAC) (1970). Official methods of analysis, 10th ed., Washington DC: AOAC; 1970. p. 154-170.

Basumotary, A., Ojha N.J. and Begum M. (2020). Growth and yield of rapeseed (*Brassica campestries* var. *toria*) influenced by NPK and sulphur under rainfed condition. *J. Oilseed Brassica*, **11(2)**, 121-125.

Bhardwaj, D., Ansari M.W., Sahoo R.K. and Tuteja N. (2014). Biofertilizers function as key player in sustainable agriculture by improving soil fertility, plant tolerance and crop productivity. *Microbial Cell Factories*, **13(1)**, 66.

Bhedela, S., Chhodavadia D.S., Zalavadiya R., Solanki D. and Usadadiya B. (2024). Effect of foliar application of nano urea on growth parameters, yield attributes and yield of mustard (*Brassica juncea* L.). *Int. J. Res. Agron.*, **7**, 432-435.

Bora, P., Ojha N.J. and Basumatary A. (2020). Effect of Integrated Nutrient Management on Nutrient Content and Uptake by Late Sown toria (*Brassica campestris* var *toria*) and availability of Nutrients in the Soil. *Int. J. Curr. Microbiol. Appl. Sci.*, **9(12)**, 920-928.

Chauhan, Z.Y., Patel D.K. and Bhabhor K. (2020). Effect of nitrogen, phosphorus and sulphur on yield, nutrient uptake and soil fertility after harvest of mustard (*Brassica juncea* L.). *Int. J. Curr. Microbiol. Appl. Sci.*, **9(6)**, 3506-3512.

Chesnin, L. and Yien C.H. (1951). *Turbidimetric determination of available sulfates*. 149-151.

Deekshith, H.N., Mankotia B.S. and Manuja S. (2023). Effect of Nutrients Management Management Practices on Growth and Yield Parameters of Gobhi sarson (*Brassica napus* spp. *napus*). *Int. J. Plant Soil Sci.*, **35(19)**, 1458-1466.

Dhruw, S.S., Swaroop N., Swamy A. and Upadhayay Y. (2017). Effects of different levels of NPK and sulphur on growth and yield attributes of Mustard (*Brassica juncea* L.) Cv. Varuna. *Int. J. Curr. Microbiol. Appl. Sci.*, **6(8)**, 1089-1098.

Famda, L., Singh D. and Jat B.L. (2017). Effect of phosphorus and sulphur nutrients on *Brassica campestris* L. variety toria under dry land condition. *Asian J. Environ. Sci.*, **12(1)**, 69-82.

Fazli, I.S., Abdin M.Z., Jamal A. and Ahmad S. (2005). Interactive effect of sulphur and nitrogen on lipid accumulation, acetyl-CoA concentration and acetyl-CoA carboxylase activity in developing seeds of oilseed crops (*Brassica campestris* L. and *Eruca sativa* Mill.). *Plant Science*, **168(1)**, 29-36.

Godara, V., Singh A., Singh M., Thakur S., Choudhary V., Sharma D. and Rana B.B. (2025). Response of mustard (*Brassica juncea* L.) to nitrogen and sulphur fertilization under semi-arid conditions. *J. Exp. Agricult. Int.*, **47(3)**, 339-348.

Gomez, K.A. and Gomez A.A. (1984). *Statistical procedures for agricultural research*. John wiley & Sons. p. 46-51

González-Melendi, P., Fernández-Pacheco R., Coronado M.J., Corredor E., Testillano P.S., Risueño M.C. and Pérez-de-Luque A. (2008). Nanoparticles as smart treatment-delivery systems in plants: Assessment of different techniques of microscopy for their visualization in plant tissues. *Annals of Botany*, **101(1)**, 187-195.

Gouri, P., Kumar P., Mehera B. and Kumar A. (2024). Effect of sulphur and nano urea on growth and yield of Indian mustard. *Int. J. Res. Agron.*, **7(8)**, 489-492.

Hadiyal, J.G., Kachhadiya S.P., Ichchhuda P.K. and Kalsaria R.N. (2017). Response of Indian mustard (*Brassica juncea* L.) to different levels of organic manures and bio-fertilizers. *J. Pharmacog. Phytochem.*, **6(4)**, 873-875.

Harode, M.N., Mankar D.D., Thakare S.S., Pagar P.C., Koytade G.G., Kubde K.J. and Nair B. (2024). Effect of nano-urea supplementation on growth and yield of linseed. *Int. J. Adv Biochem Res*., **8(10)**, 427-31.

Islam, R., Hossain H.T., Karim M.F. and Haque M.N. (2018). Yield and yield components of rapeseed as influenced by nitrogen and sulphur fertilization. *J. Oilseed Brassica*, **9(2)**, 84-95.

Jackson, M.L. (1973). *Soil Chemical Analysis*. New Delhi: Prentice Hall, Pvt. Ltd.; p. 239-41**.**

Kalita, N., Bhuyan S., Maibangsa S. and Saud R.K. (2019). Effect of biofertilizer seed treatment on growth, yield and economics of toria (*Brassica campestris* L.) under rainfed condition in hill zone of Assam. *Curr. Agricult. Res. J*., **7(3)**, 332.

Kalita, R., Luikham E., Devi T.S., Oinam T., Chakravarty J., Bhagat A.K. and Singh N.G. (2024). Integrating nano-urea in nitrogen management on growth and yield of rapeseed (*Brassica napus* L.) under rainfed condition in North east India. *Int. J. Res*., **7(9)**, 93-99.

Khatkar, Y., Dawson J., Zade K.K., Dixit P.M. and Khatkar R. (2009). Effect of nitrogen, phosphorus and sulphur fertilization on growth and yield of mustard (*Brassica juncea* L.). *Int. J. Agric. Sci*., **5(2)**, 396-398.

Kumar, M., Singh P.K., Yadav K.G., Chaurasiya A. and Yadav A. (2017). Effect of nitrogen and sulphur nutrition on growth and yield of Indian mustard (*Brassica juncea* L.) in western UP. *J. Pharmacog. Phytochem.*, **6(6S)**, 445-448.

Kumar, P., Nand V., Kumar D., Deepu, Mishra A., Suryabhan Kumar S. and Bagri J.P. (2025). Effect of integrated nutrient management on growth, yield and quality of Indian mustard (*Brassica juncea* L.). *Plant Archives*, **25(1)**, 1286-1292.

Kumar, R. (2015). Effects of NPKS on growth, yield and quality of late sown toria varieties (*Brassica rapa* L. var. toria) under rainfed condition of north-east India. *Bangladesh J. Bot.*, **44(4)**, 521-528.

Meena, J., Singh V., Kumar S. and Sagar A. (2018). Effect of biofertilizers and levelsof sulphur on growth and yield attributes of mustard [*Brassica juncea* (L.) Czern. & Coss]. *Int. J. Cur. Micro. App. Sci.*, **7(10)**, 2242-2249.

Meena, M.K., Singh H.V., Jat R.S., Dotaniya M.L., Meena M.D., Choudhary R.L. and Rai P.K. (2024). Effects of nano urea on Indian mustard (*Brassica juncea*) productivity and nutrient uptake in calcareous soils. *The Indian J. Agricult. Sci.*, **94(11)**, 1234-1239.

Navya, K., Sai Kumar R., Krishna Chaitanya A. and Sampath O. (2022). Effect of nano nitrogen in conjunction with urea on growth and yield of mustard (*Brassica juncea* L.) in Northern Telangana Zone. In : *Biol. Forum* (Vol. **14**, No. **3**, pp. 95-99).

Nitheesh, D.S., Jaswal A. and Singh A. (2022). Effect of Synthetic and Bio-fertilizers on the yield attributes of Toria. *Int. J. all Res. Educ. Scientific Methods*, **10(8)**, 863-867.

Olsen, S.R. (1954). *Estimation of available phosphorus in soils by extraction with sodium bicarbonate* (No. 939). US Department of Agriculture.

Pandav, D.M., Talathi M.S., Bodake P.S., Chavan V.G., More S.S., Pethe U.B. and Mote G.K. (2022). Response of nitrogen level and nano urea on mustard (*Brassica juncea* L.) under Konkan condition. *The Pharma Innov. J.*, **11(12)**, 2055-2061.

Patel, R.V., Pandya K.Y., Jasrai R.T. and Brahmbhatt N. (2017). A review: Scope of utilizing seaweed as a biofertilizer in agriculture. *Int. J. Adv. Res.*, **5(7)**, 2046-2054.

Pattam, K., Pannu R.K., Dhaka A.K. and Sharma K.D. (2017). Effect of dates of sowing and nitrogen levels on growth and yield of Indian mustard. *Int. J. Curr. Microbiol. Appl. Sci.*, **6**, 1029-1036.

Piper, C.S. (1966). *Soil and plant analysis*. Hans Publication, Bombay.

Prajapati, V., Mankotia B.S., Manuja S., Datt N. and Kumar P. (2024). Effect of biofertilizers and fertility levels on phenology, agronomic efficiency and crop recovery efficiency of gobhi sarson (*Brassica Napus* L.). *Himachal J. Agricult. Res.*, 57-61.

Prasad, R., Bhattacharyya A. and Nguyen Q.D. (2017). Nanotechnology in sustainable agriculture: Recent developments, challenges and perspectives. *Front. Microbiol.*, **8**, 264976.

Ratanoo, R., Walia S.S., Saini K.S. and Dheri G.S. (2021). Effect of biofertilizers, graded levels of chemical fertilizers and

FYM on soil properties and yield of Gobhi sarson (*Brassica napus* L.). *J Pharma Innov.*, **10(7)**, 10-17.

Rohitha, D.S., Mamatha B., Reddy K.S. and Desai N. (2023). Nano fertilisers on plant nutrition and soil microbial safety- A Review. *Mysore J. Agricult. Sci.*, **57(3)**, 44.

Shahwar, D., Mushtaq Z., Mushtaq H., Alqarawi A.A., Park Y., Alshahrani T.S. and Faizan S. (2023). Role of microbial inoculants as bio fertilizers for improving crop productivity: A review. *Heliyon*, **9(6)**.

Sharma, K., Meena R.H., Kumar K., Singh Y.V., Kumar P., Meena D. and Kumawat H. (2023). Impact of foliar application of nano nitrogen and nano zinc on soil properties of mustard (*Brassica juncea* L.) crop. *Int J Plant Soil Sci.*, **35(18)**, 1321-1334.

Solanki, R.L., Sharma M. and Indoria D. (2018). Effect of phosphorus, sulphur and PSB on yield of Indian mustard (*Brassica juncea* L.) and available macronutrients in soil. *J. Indian Soc. Soil Sci.*, **66(4)**, 415-419.

Subbiah, B.V. and Asija G.L. (1956). A rapid procedure for the estimation of available nitrogen in soils. **25**, 259-60.

Vaiphei, B., Rajput A., Thingbaijam S., Rajkumari D., Hanjabam R. and Konsam P. (2025). Growth and yield response of Indian mustard (*Brassica juncea* L.) to integrated nutrient management in Dehradun, Uttarakhand. *J. Adv. Biol. Biotechnol.*, **28(10)**, 455-466.

Verma, S.K., Rana N.S., Vivek B.P., Singh B., Verma A. and Maurya D.K. (n.d.). Effect of novel sources of nutrients, their dose and mode of application on yield, quality and profitability of Indian mustard [*Brassica juncea* (L.) Czern & Coss]. *Biolog. Forum - An Int. J.*, **14(3)**, 1385-90.

Walkley, A. and Black I.A. (1934). An examination of the Degtjareff method for determining soil organic matter, and a proposed modification of the chromic acid titration method. *Soil Science*, **37(1)**, 29-38.

Yadav, H.K., Thomas T. and Khajuria V. (2010). Effect of different levels of sulphur and biofertilizer on the yield of Indian mustard (*Brassica juncea* L.) and soil properties. *J. Agricult. Physics*, **10(1)**, 61-65.