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Effect of Integrated Nutrient Management on Soil Health and Quality Traits of Toria (*Brassica campestris* var. Toria)

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ABSTRACT

Background: Maintaining long-term soil health and achieving consistent crop quality requires a balanced supply of nutrients from diverse sources. The strategic combination of organic, inorganic and biological inputs - collectively termed integrated nutrient management (INM) - has emerged as a practical framework for addressing declining soil productivity under intensive cropping systems.

Methods: A field experiment was conducted during the *rabi* 2022-23 at Lovely Professional University, Punjab, using a randomized block design with three replications. Twelve treatments involving combinations of chemical fertilizers, vermicompost, FYM, biofertilizer (Azotobacter) and nano urea were evaluated.

Result: Application of 50% recommended dose of fertilizers (RDF) along with vermicompost recorded the highest oil content (42.75%) and oil yield (668.56 kg ha^{-1}). The highest protein content (22.72%) was observed under nano urea application, while maximum protein yield was obtained under 100% RDF. Integrated treatments improved nutrient uptake, whereas organic treatments with biofertilizers enhanced soil organic carbon (0.65%) and available N, P and K. Partial substitution of chemical fertilizers with vermicompost under INM improved crop quality, nutrient uptake and soil fertility, indicating a sustainable and efficient approach for toria production.

Key words: *Azotobacter*, Fym, Nano urea, Nitrogen, Quality, Vermi-compost.

INTRODUCTION

Toria (*Brassica campestris* var. toria) is an important oilseed crop cultivated during the rabi season due to its short duration and rapid growth habit. It is widely grown as a catch crop and contributes significantly to edible oil production. The seeds contain about 37-49% oil and also provide a considerable amount of protein with a balanced amino acid composition, making it valuable for both nutritional and industrial purposes (Kumar and Kumar, 2011).

In recent years, continuous and imbalanced use of chemical fertilizers has adversely affected soil health, resulting in declining productivity and nutrient-use efficiency. To address these challenges, integrated nutrient management (INM) has emerged as a sustainable approach that combines organic and inorganic nutrient sources to maintain soil fertility and ensure stable crop yields. The combined use of organic manures with fertilizers improves soil physical properties, enhances nutrient availability and supports long-term agricultural sustainability.

Biofertilizers such as Azotobacter play a crucial role in non-leguminous crops by fixing atmospheric nitrogen and improving rhizosphere activity. These microorganisms enhance nutrient availability and promote plant growth by synthesizing growth-promoting substances. Their application in combination with organic and inorganic sources can significantly improve nutrient-use efficiency (Saral *et al*., 2025).

Nitrogen is considered one of the most limiting nutrients in crop production systems and its inefficient use often leads to substantial losses to the environment. To improve nitrogen-use efficiency, innovative inputs such as nano fertilizers have been introduced. Among these, nano urea has gained attention due to its targeted nutrient

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delivery and reduced losses, thereby enhancing nutrient uptake and crop performance.

The integration of organic manures, chemical fertilizers, biofertilizers and nano fertilizers offers a balanced nutrient supply system that can improve soil health, crop productivity and quality parameters. However, limited information is available on the combined effect of these components, particularly nano urea with organic and biological inputs, in toria cultivation. Therefore, the present investigation was undertaken to evaluate the effect of integrated nutrient management on soil properties and quality traits of toria under the agro-climatic conditions of Punjab.

MATERIALS AND METHODS

Experimental site and soil characteristics

The experiment was conducted at the research farm of the Department of Agronomy, Lovely Professional University, Phagwara, Punjab, India, during the rabi season of 2022-23. The experimental location lies at 31°22′N latitude and 75°23′E longitude with an elevation of approximately 245 m above mean sea level. The soil of the site was sandy loam in texture, having 0.47% organic carbon, available nitrogen 183.7 kg ha^{-1}, available phosphorus 26.4 kg ha^{-1} and available potassium 192.3 kg ha^{-1}.

Climate

The experimental site falls within a subtropical climatic zone, typified by pronounced seasonal variation. Summers are marked by intense heat accompanied by dry, desiccating winds, while nights during this period remain warmer than in temperate regions. The area receives an annual precipitation of 500-800 mm, predominantly concentrated during the southwest monsoon period spanning July through September. The toria crop was established under rabi season conditions, with sowing carried out on 16 September 2022.

Experimental design and treatments details

The trial was laid out in a randomized block design (RBD), accommodating twelve treatment combinations each replicated three times, yielding thirty-six experimental units in total. Treatments spanned a spectrum from fully conventional to fully organic nutrient management: T_1 served as the inorganic benchmark, receiving the complete recommended dose of fertilizers (RDF: 62 kg N + 20 kg P_2O_5 ha^{-1}); T_2 and T_3 replaced half the nitrogen requirement with organically sourced nitrogen - through vermicompost and FYM, respectively - while retaining 50% RDF; T_4 paired 50% RDF with *Azotobacter* inoculation as a biological supplement. Nano urea treatments were structured to evaluate both full and partial substitution: T_5 received 100% nano urea as a 0.4% foliar spray administered at 25 and 45 DAS, whereas T_6 and T_7 applied a reduced nano urea dose (0.2% spray at 25 and 45 DAS) alongside 50% RDN supplied through vermicompost and FYM, respectively. T_8 combined the same reduced nano urea dose with *Azotobacter* inoculation. Treatments T_9 and T_{10} relied entirely on biological and organic inputs - vermicompost and FYM paired with *Azotobacter*, respectively - while T_{11} received *Azotobacter* alone and T_{12} was maintained as an unfertilized control. The improved toria variety TL-17 was dibbled at a row-to-plant spacing of 45 cm × 15 cm, with a seed rate of 5 kg ha^{-1}. Organic manures - FYM and vermicompost - were quantified on the basis of their nitrogen contribution and thoroughly incorporated into the soil approximately 15 days prior to sowing to allow partial decomposition. *Azotobacter* was administered as a seed biopriming treatment at 25 g kg^{-1} of seed, using a 10% jaggery solution as a sticking agent; inoculated seeds were subsequently shade-dried to preserve microbial viability before field sowing. Inorganic nitrogen, phosphorus and potassium were supplied through urea, single super-phosphate and muriate of potash, respectively.

Estimation of quality, nutrient uptake and soil fertility

The seed samples were first desiccated at 70°C to remove moisture for oil extraction, then ground into a fine powder using a pestle and mortar. The Soxhlet's extraction method (AOAC 1970) was utilized for the extraction of the oil.

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

Oil yield

Oil yield is calculated by multiplying the seed yield by the corresponding oil content, providing a quantitative estimate of the extractable oil from the seed sample:

$$\text{Oil yield (kg ha}^{-1}\text{)} = \frac{\text{Seed yield (kg ha}^{-1}\text{)} \times \text{Oil content (\%)}}{100}$$

Protein content

The nitrogen content in mustard seeds was initially determined using the Kjeldahl method (Snell and Snell, 1949). The protein content was then calculated by multiplying the nitrogen content by a factor of 6.25.

Protein yield

Protein yield (kg ha^{-1}) is calculated by multiplying the protein content (%) by the seed yield (kg ha^{-1}) and dividing the result by 100:

$$\text{Protein yield (kg ha}^{-1}\text{)} = \frac{\text{Seed yield (kg ha}^{-1}\text{)} \times \text{Protein content (\%)}}{100}$$

Nutrient uptake

The analysis for N, P and K were done in crop plants at harvest stage by adopting micro-Kjeldahl method (Kjeldahl, 1883) Venadomolybdate yellow colour method (Koenig and Johnson, 1942) and flame emission photometry method (Jackson, 1973), respectively. The uptake of these nutrients

was calculated as kg ha^{-1} by multiplying the contents with grain and stover yields in different treatments.

Nutrient uptake (kg ha^{-1}) =

$$\frac{\text{Nutrient content in seed (\%)} \times \text{Seed yield (kg ha}^{-1}\text{)} + \text{Nutrient content in stover (\%)} \times \text{Stover yield (kg ha}^{-1}\text{)}}{100}$$

Statistical analysis

The data were analysed using analysis of variance (ANOVA) suitable for randomized block design as prescribed by Cochran and Cox (1962).

RESULTS AND DISCUSSION

The results showed that the highest oil content (42.75%) and oil yield (668.56 kg ha^{-1}) was recorded in T_2 (50% RDF + 50% RDN through VC) which was statistically similar to treatment T_3 (50% RDF + 50% RDN through FYM), while the lowest was observed in the control plot *i.e.,* 30.56% and 183.87 kg ha^{-1}, respectively (Fig 1). The utilization of farmyard manure (FYM), vermicompost and chemical fertilizers potentially contributes to increase in oil concentration. This may be due to an augmented accessibility of sulphur, which is involved in the conversion process of initial fatty acid metabolites into the final products of fatty acid. These findings of Varma *et al*. (2021) and Kansotia *et al*. (2013) were in concurrence with the results.

However, in terms of protein content, the highest protein levels in seeds (22.72%) were observed in the treatment T_5 [100% Nano Urea (0.4% spray @ 25 and 45 DAS)], which was statistically similar to treatment T_1 (RDF 100%), T_2 (50% RDF + 50% RDN through VC), whereas the remarkable increase in protein yield (321.38 kg ha^{-1}) was attained in treatment T_1 (RDF 100%), which was statistically similar to treatments T_2 (50% RDF + 50% RDN through VC) and T_3 (50% RDF + 50% RDN through FYM). Control plot showed the lowest values of protein content (13.75%) as well as protein yield (82.65 kg ha^{-1}). The findings of Kumar *et al*. (2021); Raliya *et al*. (2022). Meena *et al*. (2024) and Yadav *et al*. (2025) revealed that the increased protein levels in seeds This improvement may be due to enhanced nitrogen metabolism and enzyme activity promoted by nano urea and initiates internal mechanisms and pathways within the plant, all aimed at attaining the desired nitrogen levels in amino acids and protein content.

The nitrogen content in the seed was found to be higher compared to the stover. Results indicated that Fig 2 indicated that T_5[100% Nano Urea (0.4% spray @ 25 and 45 DAS)] resulted in increased nitrogen content in both the seed (3.64%) and stover (0.74%) being statistically at par T_1 (RDF 100%), whereas significantly higher nitrogen uptake (51.42 kg N ha^{-1}) was recorded maximum under T_1 (RDF 100%) being statistically similar to T_2 (50% RDF + 50% RDN through VC) and T_3 (50% RDF + 50% RDN through FYM). However, treatment T_2 (50% RDF + 50% RDN through VC) recorded significantly highest value for stover yield (20.33 kg ha^{-1}) and total uptake (70.99 kg ha^{-1}), which was statistically similar to T_1 (RDF 100%) and T_3 (50% RDF + 50% RDN through FYM). Conversely, the lowest nitrogen content in the seed (2.20%) and stover (0.45%) and nitrogen uptake by seed (13.22 kg ha^{-1}) and stover (5.48 kg ha^{-1}) was observed in the control treatment. The study conducted by Kumar *et al.* (2021) stated that due to the precise and focused administration of nitrogen using the foliar application of liquid nano urea (nano nitrogen) reduce urea wastage while enhancing the efficiency of uptake of nitrogen.

Phosphorus and potassium content in seed (0.61% and 0.66%) and stover (0.28% and 1.58%) were maximum under T_1 (RDF 100%) which was statistically similar to T_2 (50% RDF + 50% RDN through VC) and T_3 (50% RDF + 50% RDN through FYM). Application of chemical fertilizers alone or in combination with organic manure can be attributed to its delivery of sufficient nutrients within the root zone and plant system which increases cellular metabolic activity and consequently, observed rise in phosphorus and

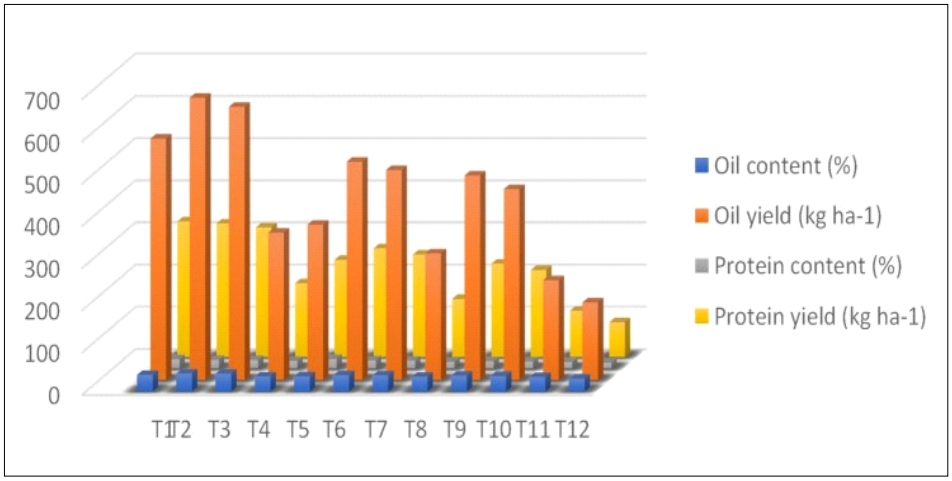


Fig 1: Influence of integrated nutrient management on quality parameters of toria.

potassium levels within both the seeds and the stover. These corroborate with the findings of Jat *et al*. (2019).

However, in terms of uptake of nutrients, T_2 (50% RDF + 50% RDN through VC) recorded significantly highest absorption of phosphorus and potassium by seed (9.28 kg ha^{-1} and 10.22 kg ha^{-1}) and stover (7.59 kg ha^{-1} and 44.81 kg ha^{-1}). Devi *et al*. (2025) in their study stated that the utilization of both vermicompost and nutrients resulted in significantly enhancement in nutrient absorption, primarily attributed to enhanced growth and increased seed yield. Moreover, nutritional balance further augmented the cooperative influence on the absorption of essential plant nutrients.

Results indicated that (Table 1) indicated the effect of various treatments on soil parameters revealed that the higher of organic carbon (0.65%) was observed under the T_{10} (100% RDN through FYM + *Azotobacter*) which was statistically similar to T_9 (100% RDN through VC + *Azotobacter*). This can be attributed to the optimistic impact of organic manure, which facilitates the decomposition of both natural and its own nutrient content, thus creating favourable conditions for microbial and chemical activities. These results align with Jat *et al*. (2012), Ratanoo *et al*. (2021) indicated that bioinoculants in the soil produce growth-enhancing substances, stimulating carbon release *via* root exudates and promoting rhizo deposition. They boost crop development, increasing root biomass and organic matter accumulation. However, Soil pH was not significantly influenced by different nutrient management treatments.

Results indicated that Table 1 clearly indicated that the T_9 (100% RDN through VC + *Azotobacter*) resulted in significantly highest available N (197.85 kg ha^{-1}) being statistically comparable to T_{10} (100% RDN through FYM + *Azotobacter*). On the other hand, the control plot recorded the lowest available N (165.72 kg ha^{-1}). The utilization of vermicompost, biofertilizer and chemical fertilizers, either individually or in combination, resulted in enhancement of available nitrogen. Also, it can be attributed to the increased

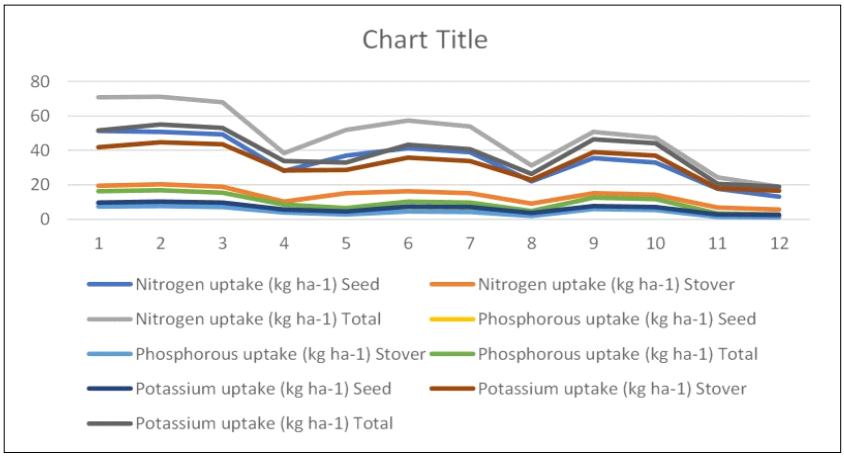


Fig 2: Influence of integrated nutrient management on N, P, K content and uptake of Toria.

Table 1: Effect of integrated nutrient management on chemical properties of soil.

Treatments	Organic carbon (%)	Soil pH	Available N (kg ha^{-1})	Available P_2O_5 (kg ha^{-1})	Available K_2O (kg ha^{-1})
T_1	0.58	7.60	194.26	30.07	200.89
T_2	0.61	7.58	194.96	30.83	205.39
T_3	0.61	7.58	194.67	30.69	201.38
T_4	0.58	7.60	187.82	27.11	196.27
T_5	0.56	7.60	183.85	20.50	180.82
T_6	0.60	7.58	190.91	28.44	198.14
T_7	0.61	7.58	190.35	27.70	196.61
T_8	0.58	7.60	184.39	21.04	181.15
T_9	0.64	7.51	197.85	33.73	208.26
T_{10}	0.65	7.51	197.63	33.56	207.71
T_{11}	0.57	7.60	178.80	20.73	180.94
T_{12}	0.55	7.60	165.72	20.06	180.57
Sem (±)	0.02	0.05	0.88	0.85	0.74
CD (5%)	0.04	NS	2.60	2.51	2.18
Initial					

microbial activity present in the nutrient management practices, which facilitated the conversion of organically bound nitrogen into an inorganic form (Kumukchum *et al*., 2020) and Oyege and Bhaskar (2023).

The available of phosphorous and potassium, recorded highest in T_9 (100% RDN through VC + *Azotobacter*), which was (33.73 kg ha^{-1} and 208.26 kg ha^{-1}) was statistically similar to T_{10} (100% RDN through FYM + *Azotobacter*). The control plot obtained the least (180.57 kg ha^{-1} and 20.06 kg ha^{-1}). Studies by Ratanoo *et al*. (2021), Kumukchum *et al*. (2020) and Mohankumar and Gowda (2010) concluded that the application of organic manures released organic acids and chelation effects which solubilize insoluble phosphorus into soluble forms, organic acids reduce potassium fixation and release non- exchangeable potassium by interacting with clay minerals thereby increasing its availability for plant uptake.

CONCLUSION

The study concludes that the combined application of 50% RDF and 50% RDN through vermicompost (VC) produced the highest oil content, oil yield and phosphorus and potassium uptake by seeds, stover and the overall crop. Protein content was maximized with 100% Nano Urea (0.4% spray) at 25 and 45 DAS, while maximum protein yield and nitrogen uptake were achieved with 100% RDF, showing comparable performance to treatments using 50% RDF + 50% RDN through VC or FYM. Thus, integrating organic and inorganic nutrient sources proved effective in optimizing crop quality and nutrient uptake.

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Informed consent

All experimental procedures and handling techniques were approved by the Division of Agronomy, Lovely Professional University, Phagwara.

Data availability statement

The data that support the findings of this study are available on request from the corresponding author.

Conflict of interest

The authors declare that there are no conflicts of interest related to the publication of this article. No funding or sponsorship influenced the study's design, data collection, analysis, decision to publish, or preparation of the manuscript.

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