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Response of integrated nutrient management on Growth and yield of radish (*Raphanus sativus* L.) CV. Kashi Sweta

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Abstract
The experiment was conducted during 2023-24 at the Horticulture Research Farm-1, Babasaheb Bhimrao Ambedkar University, Lucknow, India. This study evaluates the impact of Integrated Nutrient Management (INM) on the growth and root yield of radish (*Raphanus sativus* L.) cv. Kashi Sweta, following a Randomized Block Design (RBD) with nine treatments and three replications under the agro-climatic conditions of Lucknow. The treatments included varying combinations of inorganic fertilizers (Recommended Dose of Fertilizers - RDF), farmyard manure (FYM), and phosphate-solubilizing bacteria (PSB). Results indicated that treatment T_8 (50% RDF + 25% PSB + 25% FYM) significantly outperformed other treatments, achieving the highest germination rate (96.01%), plant height (37.20 cm), number of leaves (13.21), leaf length (29.65 cm), and fresh plant weight (98.26 g) at 60 days after sowing (DAS). Yield attributes such as root length (22.11 cm), root weight (194.36 g), root diameter (3.61 cm), root volume (226.30 cc), and root yield per plot (4.15 kg) were also maximized under T8. The control (T_0) consistently exhibited the lowest values across all parameters. These findings emphasize the efficacy of INM, particularly the integration of 50% RDF, 25% PSB, and 25% FYM, in enhancing the growth and productivity of radish.

Keywords: Radish, yield attributes, growth parameters, randomized block design (RBD)

Introduction
Radish (*Raphanus sativus* L.), belonging to the Brassicaceae family and having a chromosome count of 2n=2x=18, is an important root crop globally and probably originated from Europe and Western Asia. The herbaceous annual has fast growth and edible fleshy roots coming from the primary root and hypocotyl. Radish is eaten in different ways; it can be eaten raw as part of salad, cooked like any other vegetable, and fermented as pickles. Aside from its culinary purpose, the radish root was used traditionally in the treatment of stomach problems, piles, gastrodynia, splenomegaly, jaundice, and symptoms of the urinary system.

Radish is recognized for its sharp flavor due to volatile isothiocyanates, which is trans-4-methyl-thiobutenyl-isothiocyanate. In India, the country has a very large area covered by 208.55 thousand hectares of cultivation of radish, with the produce amounting to 3,061.29 Mt. Although radish is grown throughout the country, the major production centers are Punjab, Uttar Pradesh, Maharashtra, and Kashmir. West Bengal is the largest in terms of area and production. In Himachal Pradesh, radish is grown over 206 thousand hectares, with a production of 3,304 Mt.

Overuse of chemical fertilizers may degrade the soil health, decrease the quality of radish, and also create human health hazards. This not only improves radish production but also quality without harming the environment, thus an alternative sustainable measure (Chapagain *et al.*, 2010) [2]. Secondly, the increase in the prices of chemical fertilizers and, more importantly, their inability to provide all nutrient requirements of a crop from one source make necessary the use of INM approaches. INM includes the judicious use of inorganic fertilizers, organic amendments like FYM and vermicompost, and biological nutrient sources to optimize crop yields while maintaining soil health and the environment.

This approach is supposed to strike a balance between agronomic feasibility, economic viability, environmental sustainability, and long-term crop productivity (Kafle *et al.*, 2019) [4]. Organic amendments like FYM provide more than just nutrient supply. By enhancing soil aggregation through a binding effect, FYM significantly improves soil texture (Mengistu & Mekonnen, 2012) [10]. This leads to increased water-holding capacity and enhanced phosphate availability. Furthermore, the application of FYM has been shown to improve fertilizer use efficiency and stimulate microbial activity within the soil ecosystem. Notably, the slow-release nature of nutrients derived from FYM minimizes nitrogen losses, as observed in studies conducted by Khatri.

Biofertilizers, being the microbial inoculants of natural origin, are eco-friendly, cost-effective, and sustainable alternatives to synthetic fertilizers. These renewable and non-bulky resources provide essential nutrients to plants besides improving soil biological activity. Phosphate-Solubilizing Bacteria (PSB) is a biofertilizer that helps in the solubilization of bound phosphorus, making it available for plant uptake, thereby promoting root development and overall plant growth.

The present study evaluates the effects of organic amendments, inorganic fertilizers, and biofertilizers on the growth and yield parameters of radish (*Raphanus sativus*), which will give an insight into their role in sustainable crop production systems.

Materials and Methods

This study focused on the effects of Integrated Nutrient Management (INM) on the vegetative growth and yield traits of radish (*Raphanus sativus* L.) in the 2023-24 growing season. The experiment was conducted at Horticulture Research Farm-1 of Babasaheb Bhimrao Ambedkar University, Lucknow, India. The experiment was arranged in a Randomized Block Design (RBD) with three replications and twelve treatments. These treatments comprised a control (T_0), 100% recommended dose of fertilizers (RDF) (T_1), 100% farmyard manure (FYM) (T_2), 100% phosphate-solubilizing bacteria (PSB) (T_3), and various combinations of RDF, FYM, and PSB: T_4 75% RDF + 25% FYM, T_5 50% RDF + 50% FYM, T_6 75% RDF + 25% PSB, T_7 50% RDF + 50% PSB, and T_8 50% RDF + 25% PSB + 25% FYM.

The experimental field was meticulously prepared by double harrowing and single plowing, followed by leveling to ensure optimal seedbed conditions. Irrigation channels were established with 30 cm spacing between ridges. Fifteen days before sowing, the field was amended with the respective treatments, including organic and inorganic fertilizers.

The crop was irrigated 4-5 days after sowing (DAS) and subsequently as per crop water requirements. Regular cultural practices were implemented throughout the growing season. Data were collected on yield and yield-contributing traits. Data analysis was conducted following the standard procedures outlined by Panse and Sukhatme (1985) [12].

Results and Discussion

Response of INM on Growth Parameters

The present investigation demonstrated significant differences in vegetative growth parameters, including plant height, number of leaves, fresh leaf weight, and leaf length and width at 30, 45, and 60 DAS (Table 1 and Figure-1 and Figure-2).

Table 1: Response of Integrated Nutrient Management on Vegetative Growth parameters of Radish

Treatment	Germination %	Plant height (cm)			Number of leaves			Leaf length (cm)			Fresh leaves weight (g)	Dry matter of leaves (g)
		30DAS	45DAS	60DAS	30 DAS	45 DAS	60 DAS	30 DAS	45 DAS	60 DAS		
T0	77.82	9.29	19.02	29.42	4.23	8.10	10.58	6.22	16.43	20.65	69.28	6.22
T^1	90.27	10.29	21.46	33.49	4.76	8.87	11.03	7.86	19.56	22.23	94.23	7.23
T^2	84.72	10.64	20.41	31.13	4.60	8.55	10.86	6.83	19.02	22.19	86.18	6.45
T^3	83.32	13.66	23.17	33.98	4.63	8.23	10.95	7.65	18.56	22.01	82.24	6.40
T^4	93.05	10.28	21.55	31.62	4.95	9.11	11.43	9.21	21.28	28.98	90.23	8.20
T^5	86.10	10.32	22.22	30.26	5.12	9.32	11.95	8.56	20.74	24.60	87.16	7.11
T_6	91.66	13.15	21.58	32.26	5.31	10.07	12.47	9.89	21.87	28.63	88.47	7.51
T_7	87.74	15.10	22.52	34.35	4.97	8.70	10.74	8.97	20.88	23.53	85.83	8.03
T_8	96.01	16.25	26.16	37.20	5.65	11.09	13.21	10.28	21.57	29.65	98.26	8.55
S.E(,m)±	0.95	0.32	0.33	0.44	0.049	0.123	0.124	0.095	0.267	0.317	0.909	0.083
C.D. at 5%	2.87	0.98	0.99	1.33	0.147	0.371	0.376	0.288	0.806	0.959	2.748	0.250

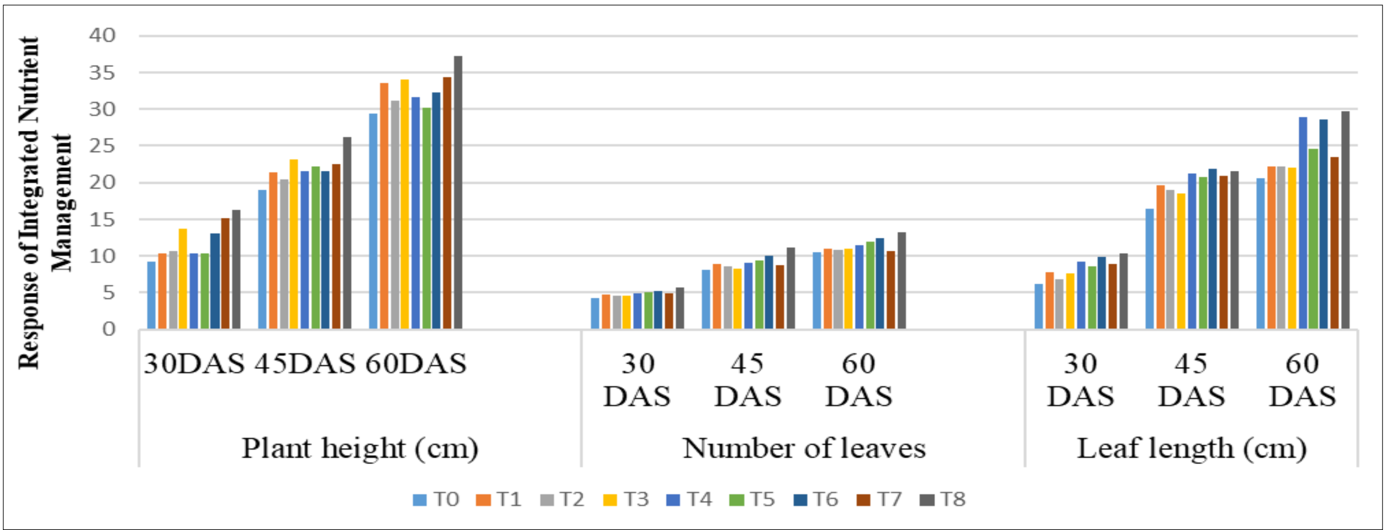

Fig 1: Response of Integrated Nutrient Management on Plant height (cm), Number of Leaves and Leaf Length (cm)

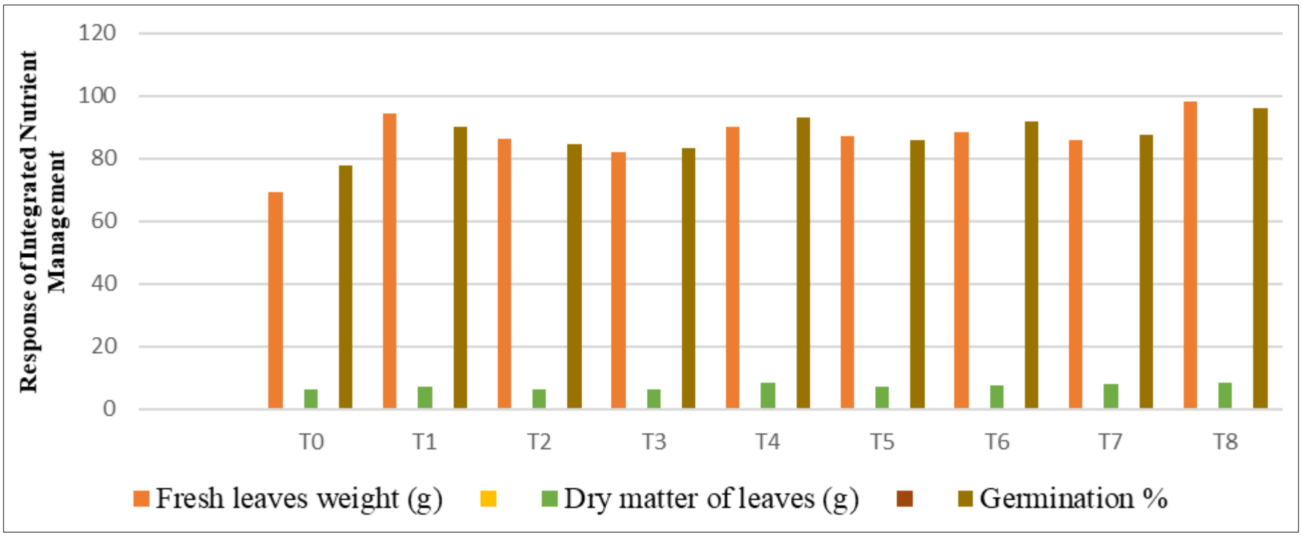

Fig 2: Response of Integrated Nutrient Management on Fresh leaves weight (g), Dry matter of leaves (g) and Germination %

Seed Germination

Treatment T_8 with a combination of 50% RDF + 25% PSB + 25% FYM showed the maximum germination percent (96.01%). Whereas, minimum seed germination (77.82%) was reported in control T_0.

Plant Height (cm)

Treatment T_8, the combination of 50% RDF + 25% PSB + 25% FYM, maintained higher plant height of 16.25 cm at 30, 26.16 cm at 45 and 37.20 cm at 60 DAS, respectively. However, the control treatment (T_0) recorded the lowest plant height at 9.29 cm, 19.02 cm, and 29.42 cm, respectively. This effect might be due to the influence of nutrients, which are the chief constituents of proteins and essential for the formation of protoplasm, leading to meristematic activity, cell division, and root development. The results are in accordance with the study of Mehwish *et al.* (2016) [9] and Kumar *et al.* (2014) [6].

Number of Leaves per Plant

At 30, 45, and 60 DAS, maximum number of leaves per plant was recorded as 5.65, 11.09, and 13.21 in treatment T_8 (50% RDF + 25% PSB + 25% FYM). The lowest number of leaves per plant was recorded in the control treatment (T_0) with 4.23, 8.23, and 10.58, respectively. The increase in the number of leaves may be due to the enhanced absorption of primary nutrients, which leads to increased synthesis of carbohydrates, proteins, and fats, which are used in the formation of new cells. These results are in accordance with the findings of Basnet *et al.* (2021) [1].

Leaf Length (cm)

Among the various INM treatments studied, T_8 with 50% RDF + 25% PSB + 25% FYM was the only treatment with maximum leaf length. The corresponding leaf lengths of treatment T_8 at 30, 45, and 60 DAS were 10.28 cm, 21.87 cm, and 29.65 cm, respectively. On the other hand, the control treatment (T_0) maintained the shortest leaf lengths, at 6.22 cm, 16.43 cm, and 20.65 cm at 30, 45, and 60 DAS, respectively. Uddain *et al.* (2010) [15], Subramani *et al.* (2011) [14], and Jadhav *et al.* (2014) [3] also observed similar results.

Fresh Weight of Plant (g)

The fresh weight of plants increased remarkably across all INM treatments. Treatment T_8 (50% RDF + 25% PSB + 25% FYM) recorded the highest fresh weight at 98.26 g, whereas the control treatment (T_0) exhibited the lowest fresh weight at 69.28 g. This could be due to the availability of nutrients from inorganic nitrogen and organic manures in adequate quantities, which are essential for plant growth and development. Nitrogen, being a constituent of protoplasm and having a favorable effect on the chlorophyll content of leaves, might have increased carbohydrate synthesis. Kumar *et al.* (2014) and Vijaya kumari *et al.* (2012) [16] also found similar results.

Dry Weight of Leaves (g)

The maximum dry weight of leaves was found in treatment T_8 with a value of 8.55 g, whereas the minimum dry weight was found in the control treatment T_0 with a value of 6.22 g.

Table 2: Response of Integrated Nutrient Management on yield parameters of Radish

Treatment	Root leaf ratio	Root length (cm)	Root weight (g)	Root diameter (cm)	Root volume (C^3)	Root yield/plot (kg)
T0	1:30	14.28	95.79	2.15	51.84	3.32
T1	1:49	16.28	140.67	2.79	99.52	4.09
T2	1:39	15.37	112.21	2.50	75.44	3.89
T3	1:71	16.95	138.84	2.55	86.54	3.49
T4	1:53	16.62	168.45	3.51	160.81	3.82
T5	1:44	16.16	129.51	2.27	66.40	3.70
T6	1:68	16.44	149.02	3.16	128.93	3.93
T7	1:73	16.94	147.29	3.25	137.94	3.90
T8	2:36	22.00	194.36	3.60	226.30	4.15
S.E(,m)±	0.021	1.166	1.388	0.036	1.134	0.054
C.D. at 5%	0.064	3.525	4.198	0.110	3.430	0.162

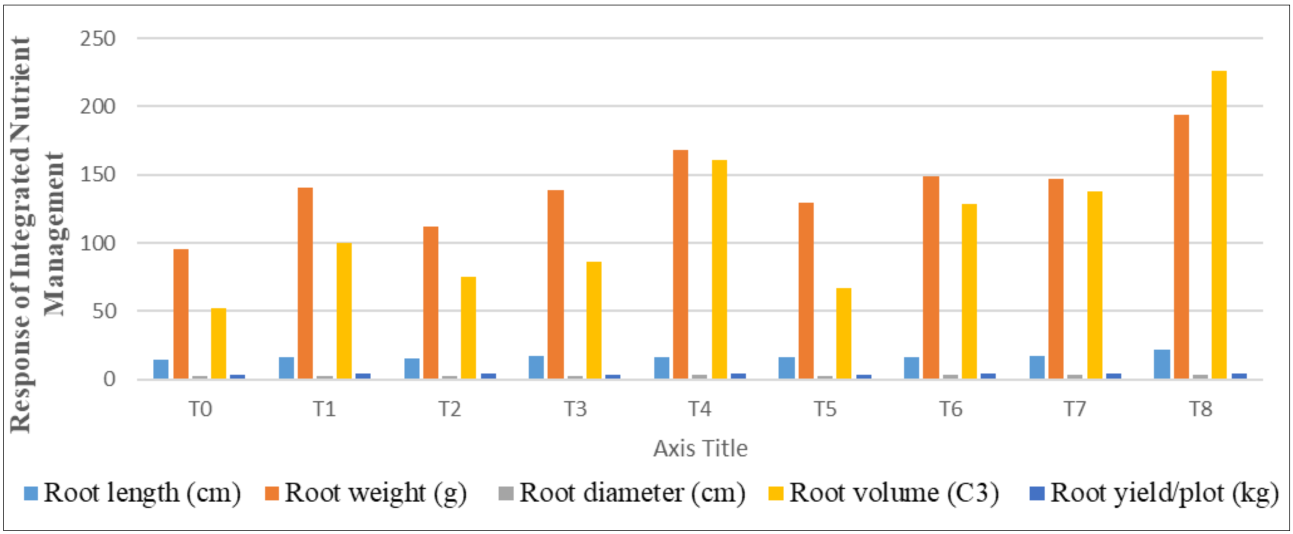

Fig 3: Response of Integrated Nutrient Management on Root Length (cm), Root Weight (g), Root Diameter (cm

INM at Yield Parameters

The present investigation demonstrated significant differences in vegetative growth parameters, including Root-Leaf Ratio, Root Length (cm), Root Weight (g), Root Diameter (cm) (Table 2 and Figure-3).

Root-Leaf Ratio

Highest significantly root-leaf ratio at 2.36, long length of the roots at 22.11 cm, high root weight at 194.36 g and a diameter at 3.61 cm, in T_8 50% RDF + 25% PSB + 25% FYM. In contrast, the lowest root-leaf ratio (1.30), shortest route length (14.22 cm), minimum root weight (95.79 g), and thinnest root diameter (2.15 cm) were observed in the control treatment (T_0). The increase in dry matter production, root-leaf ratio, root length, root weight, and root diameter may be attributed to the decrease in soil bulk density and the increase in porosity and water-holding capacity due to organic manures. The enhanced root growth in treatment T8 may be due to higher availability of nitrogen (N) and phosphorus (P) from FYM and PSB. Increased nutrient availability probably allowed more carbohydrate formation within the plant, leading to a greater diameter of the roots. This view is supported by the observations reported by Kumar *et al.* (2014) [6].

Root Volume (cm³)

Radish produced a huge variation in the volume of roots due to the integrated nutrient management. The highest root volume was obtained with the application of treatment T_8 (226.30 cm³). The highest value after it was obtained with T_4 (160.81 cm³) followed by T_7 (137.94 cm³). The minimum root volume was obtained with the control (T_0) treatment, with 51.84 cm³.

Root Yield per Plot (kg)

Among the various Integrated Nutrient Management (INM) treatments evaluated, treatment T8 exhibited the highest root yield at 4.15 kg per plot. This treatment consisted of a combination of 50% RDF + 25% PSB + 25% FYM. In contrast, the control treatment (T_0) yielded the lowest root yield at 3.32 kg per plot. The increased yield may be attributed to the increased root length and diameter. Similar results were reported by Meena *et al.* (2007) [8].

Conclusion

Based on the findings of this study, treatment T_8 (50% RDF + 25% PSB + 25% FYM) demonstrated the most significant positive impact on enhancing various plant growth and root yield parameters. These included plant height, number of leaves per plant, leaf length, fresh weight, dry weight, root-leaf ratio, root length, root weight, root diameter, root volume, and root yield per plot of radish (*Raphanus sativus* L.) cv. Kashi Sweta, when cultivated under the agro-climatic conditions of Lucknow.

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