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Growth, Yield and Quality Response of Application of Bio-Stimulants in Radish (*Raphanus sativus* L.)

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Radish (*Raphanus sativus* L.) is a root crop grown because of its edible fleshy roots. In the context of sustainable agriculture, reducing chemical fertilizer use and integrating bio-stimulants can provide an environmentally sound approach to improve crop performance. The experiment was carried out to find the effect of bio-stimulants and chemical fertilizers on the development, production, and nutritional value of radish. A field experiment was carried out during Rabi 2023–24 at DAV University, Jalandhar, to find out the impact of bio stimulants on the growth, yield, and quality of radish. In these study, two varieties (Punjab Safed Mooli-2 and Mino Early) and ten

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treatments comprising the recommended dose of fertilizers (NPK), *Azotobacter*, and seaweed extract were included. The experiment was done in a factorial randomized block design having three replications. The results showed that the combination of NPK + *Azotobacter* + seaweed extract (T_5) significantly improved the plant height, length of leaves, width of leaves, length of root, diameter of root, root weight, root yield, TSS, and ascorbic acid content. The variety Punjab Safed Mooli-2 showed better performance compared to Mino Early. Thus, integrated use of bio stimulants proved effective in enhancing radish growth, yield and quality.

Keywords: Radish; bio-stimulants; Azotobacter; seaweed extract; growth parameters; quality and productivity.

1. INTRODUCTION

Radish is a vegetable crop, grown due to its edible roots and tender pods. It belongs to the family Brassicaceae (2n = 2x = 18) (Preeti et al., 2024). The Latin word Raphanos, means "fast-growing plant," is the source of the name Raphanus. In the world, radish is a popular root vegetable that is grown in both tropical and temperate climates. Although some sources place its origin in the Mediterranean and Black Sea regions, it is thought to have originated from central or western China and the Indo-Pak subcontinent (Aasim et al., 2018; Mehmood et al., 2022). This winter crop belongs to the Brassicaceae family and originated in parts of Asia and Europe. In its natural habitat, a number of radish species can be found, such as *Raphanus sativus*, *R. raphanistrum*, *R. microcarpus*, *R. rostras*, *R. landra*, and *R. maritimus*. *Raphanus sativus* var. radicula (or sativus) and *Raphanus sativus* var. niger are the two botanical varieties that make up the majority of the cultivated radish (Singh, 2021). Radishes can have white, red, or purple roots, with anthocyanin pigments giving them their red color (Sami et al., 2019). Radish contains bioactive compounds that have been proven to be anti-inflammatory, anti-cancer, antioxidant, anti-diabetic, antibacterial, and kidney-protective (Riya et al., 2024). It has an abundance of antioxidants like as flavonoids, phenolic compounds, and vitamin C. Radish is abundant in micronutrients, including potassium (233 mg), vitamin C (14.8 mg), calcium, magnesium, iron, and B-complex vitamins. It also contains 16 kcal, 3.4 g carbohydrates, 1.6 g dietary fiber, and 0.68 g protein per 100 g (Tripathi et al., 2017). Radish quality and quantity can be considerably increased by using various fertilizers; combining chemical fertilizers with biostimulants also increases soil health (Ajmeri et al., 2024). Because nitrogen is a necessary component of proteins, amino acids, and chlorophyll, inorganic fertilizers, particularly those containing nitrogen (N), phosphorous (P), and potassium (K), are vital external sources of nourishment. Although the best use of nitrogen improves growth and yield, excessive usage can harm soil ecosystems and potentially reduce productivity (Kondal et al., 2024; Gomasta et al., 2024). Organic and biostimulants are becoming increasingly popular due to their ability to boost production and promote plant development. Aside from increasing the physical and biological characteristics of soil consortia, they boost plant physiological processes and overall well-being, resulting in superior yield with acceptable quality (Bashir et al., 2021; Apu et al., 2022; Kayesh et al., 2023; Ajmeri et al., 2024). Among these, free-living nitrogen-fixing bacteria such as Azotobacter species are notable for producing growth-promoting chemicals such as gibberellic acid, IAA, and other vitamins (Kaur et al., 2021). It is becoming increasingly clear that inoculating soil with these biofertilizers is critical for vegetable farming. Seaweed extracts are another effective bio-stimulant since they are high in bioactive compounds such vitamins, minerals, amino acids, polysaccharides, and phytohormones. These enhance soil organic carbon, photosynthesis, chlorophyll content, and nutrient availability (Khan et al., 2009; Mancuso et al., 2006; Dobromilska et al., 2008). This study examined the combined effects of chemical and biofertilizers on radish growth and production in the agroclimatic conditions of Jalandhar, Punjab. It also strives to educate farmers, researchers, and agricultural workers on sustainable farming practices.

2. MATERIALS AND METHODS

2.1 Experimental Site

The field experiment took place during the Rabi season of 2023-24 at the experimental farm of the Faculty of Agricultural Sciences, DAV University, Jalandhar, Punjab (31°33′N latitude, 75°37′E longitude; 220 m above mean sea level).

The region has a subtropical climate, with chilly winters.

2.2 Plant Material

Two types of radishes, Punjab Safed Mooli-2 and Mino Early, were used in this investigation. The Department of Vegetable Science at Punjab Agricultural University in Ludhiana provided the seeds for Punjab Safed Mooli-2, while the Jalandhar vegetable seed market provided the seeds for Mino Early.

2.3 Chemical Fertilizers and Bio-Stimulants

Inorganic fertilizers and biofertilizer formulations of NPK, Azotobacter (IFFCO), and seaweed extract (Biovita) were procured from the local market in Jalandhar, Punjab, India, and tested alongside the experimental formulations.

2.4 Experimental Design

The experiment was carried out in the Factorial Complete Randomized Design, having three replications and ten treatment combinations with two varieties. levels of factor A (Variety), *viz*., V_1: Punjab Safed mooli-2, V_2: Mino early and five levels of factor A (treatment), *viz*., T_1: Control, T_2: NPK, T_3: NPK+ Azotobacter, T_4: NPK + Seaweed extract, and T_5: NPK+ Azotobacter + Seaweed extract. The whole area was 250 m², and the seeds of radish at 4-5 kg/acre were manually broadcast at 1-2 cm depth and spaced 45 cm between rows and 7 cm between plants.

2.5 Preparation and Application of Bio Stimulants

The bio-stimulants *Azotobacter* spp. and seaweed extract were used in their commercially available form and were put in the soil near the plants' roots, following the manufacturer's treatment information and directions. Inorganic fertilizers were used in split doses throughout the cropping season. Crop growth and yield observations were made during the growing season.

2.6 Collection of Experimental Data

The morphological observations were taken at the harvest stage. From each plot, five plants were selected. All observations, *viz.*, height of plant, number of leaves, width of leaves, and length of leaves, were recorded from these plants. Various observations were recorded *viz*., length of root, diameter of root, weight of root, root yield per plot/per hectare. Several quality attributes (*viz*., TSS, ascorbic acid content) were measured as performed previously by Kaur et al. (2024). TSS were calculated by using a handheld refractometer (MA871 Digital Refractometer, Milwaukee, Europe). In radish, ascorbic acid was measured using the 2, 6-dichlorophenol-indophenol titration method (Rekha et al., 2012).

$$\text{Ascorbic acid (mg/g FW)} = (\text{Titre reading} \times \text{dye factor} \times \text{Volume made up}) / (\text{Aliquot of extract taken} \times \text{Weight of sample}) \times 100$$

2.7 Statistical Analysis

OPSTAT and SPSS (version 15.0) were used to statistically evaluate the recorded data. Following procedures by Sheoran et al. (1998) and Gomez and Gomez (1984), analysis of variance (ANOVA) was carried out in a Randomized Block Design (RBD), and treatment means were compared using Fisher's post-hoc test to identify the critical difference (CD) at the 5% significance level ($p \leq 0.05$).

Table 1. Treatment details

Treatment combination	Treatments
V_1T_1	Punjab Safed mooli-2 + No fertilizer
V_1T_2	Punjab Safed mooli-2 + N:P:K (25:12:0, kg/acre, N:P:K, respectively)
V_1T_3	Punjab Safed mooli 2 + N:P:K +*Azotobacter*
V_1T_4	Punjab Safed mooli-2 + N:P:K + Seaweed extract
V_1T_5	Punjab Safed mooli 2 + N:P:K+ *Azotobacter*+ Seaweed extract
V_2T_1	Mino early + No fertilizer
V_2T_2	Mino early + N:P:K (25:12:0, kg/acre, N, P, K, respectively)
V_2T_3	Mino early + N:P:K+ *Azotobacter*
V_2T_4	Mino early + N:P:K + Seaweed extract
V_2T_5	Mino early + N:P:K + *Azotobacter* +Seaweed

3. RESULTS

The vegetative parameters of radish were markedly influenced by different combinations of bio stimulants and varieties. The application of *Azotobacter* and seaweed extract, with NPK, substantially enhanced growth and foliage dimensions.

3.1 Impact of Varieties and Bio-Stimulants on Growth Parameters of Radish

The effects of treatments and types on radish growth and maturity are shown in Fig. 1 (a-e) and Table 2. There were notable variations. Punjab Safed Mooli-2 (V_1) far better than Mino Early (V_2) in terms of plant height (44.22 cm), number of

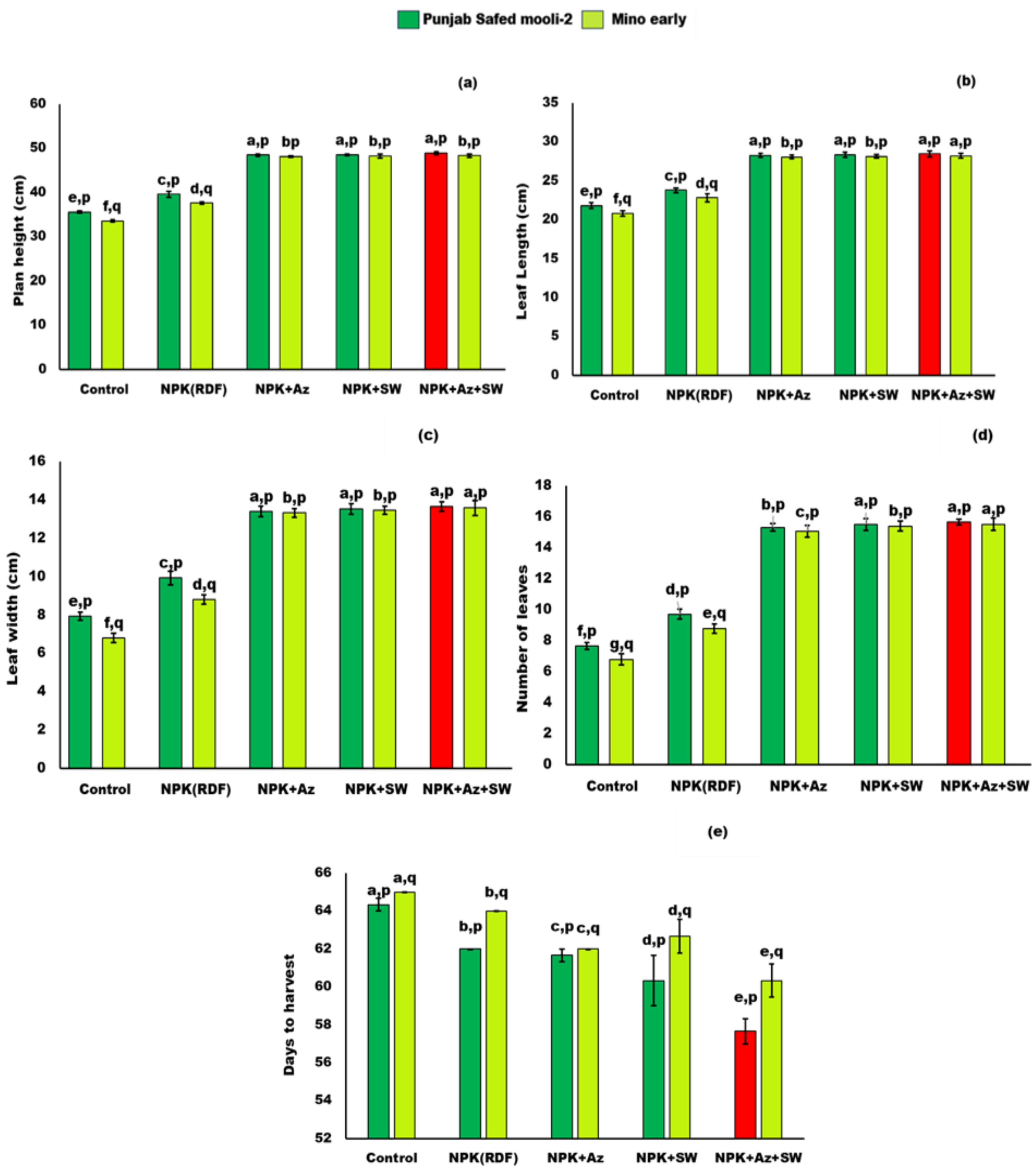

Fig. 1. The bar graphs show the interaction effect of bio-stimulants and two radish varieties (Punjab Safed mooli-2 and Mino early) on a) plant height (cm) b) length of leaf (cm) c) width of leaf (cm) d) number of leaves e) days to harvest under bio stimulants

Graphs showed mean value, ± SE with different letters (a, b, c, d, e and p, q) are significantly different from each other ($p \leq 0.05$). The red-colored bar represents the maximum improvement in growth parameters in radish under bio-stimulant

Table 2. Impact of bio-stimulants and radish varieties on plant height, length of leaf, width of leaf, and number of leaves

Variety (V)	Plant height (cm)	Length of leaf (cm)	Width of leaf (cm)	No. of leaves	Days to harvest
V_1	44.22^a	26.13^a	11.69^a	12.78^a	61.2^a
V_2	43.18^b	25.60^b	11.20^b	12.32^b	62.8^b
SE(m) ±	0.078	0.04	0.03	0.035	0.257
CD0.05	0.235	0.12	0.089	0.106	0.769
T_1	34.60^c	23.30^b	7.36^d	7.23^d	64.66^d
T_2	38.60^b	28.16^a	9.36^c	9.26^c	63^c
T_3	48.30^a	28.23^a	13.36^b	15.20^b	61.83^b
T_4	48.40^a	28.33^a	13.50^a	15.46^a	61.5^b
T_5	48.63^a	0.063	13.63^a	15.60^a	59^a
SE(m) ±	0.124	0.19	0.047	0.056	0.406
CD0.05	0.371	0.19	0.141	0.167	1.216

Table 3. Impact of varieties and bio stimulants on length of root, diameter of root, weight of root and root yield

Variety (V)	Length of root (cm)	Diameter of root (cm)	Weight of root (g)	Root yield (kg/plot)	Root yield (q/ha)
V_1	18.10^a	4.91^a	123.33^a	3.86^a	64.33^a
V_2	17.60^b	4.58^b	121.58^b	3.75^b	62.61^b
SE(m) ±	0.042	0.027	0.191	0.007	0.111
$CD_{0.05}$	0.127	0.08	0.573	0.02	0.333
Treatments					
T_1	13.30^c	3.14^d	96.16^e	2.82^e	47.08^e
T_2	15.30^b	3.84^c	118.63^d	3.20^d	53.48^d
T_3	20.13^a	5.05^b	127.86^c	3.84^c	64.01^c
T_4	20.20^a	5.79^a	133.73^b	4.49^b	74.97^b
T_5	20.33^a	5.90^a	135.90^a	4.66^a	77.80^a
SE(m) ±	0.067	0.042	0.302	0.011	0.176
$CD_{0.05}$	0.201	0.126	0.905	0.031	0.527

leaves (12.78), leaf length (26.13 cm), and leaf breadth (11.69 cm). T_5 had the greatest growth outcomes among the treatments, with the maximum plant height (48.63 cm), leaf length (28.33 cm), leaf breadth (13.66 cm), and leaf count (15.6). On the other hand, T_1 had the lowest numbers across the board. V_1 and T_1 took the longest (64.66 and 62.8 days, respectively), whereas T_5 also produced the fastest maturity (59 days), followed by V_1 (61.2 days).

3.2 Impact of Varieties and Bio-Stimulants on Yield Parameters of Radish

The effects of treatments and varieties on the yield and characteristics of radish roots are displayed in Table 3 and Fig. 2(a-e). Root diameter, weight, length, and total yield all showed notable variations. The longer roots (18.10 cm), a larger diameter (4.91 cm), and a higher weight (123.33 g), Safed Mooli-2 (V_1) performed better than Mino Early (V_2). For every root parameter, T_5 had the greatest values among the treatments, whereas T_1 had the lowest. Additionally, V_1 produced the highest yield (3.86 kg/plot, 64.33 q/ha), which was marginally greater than V_2. Root yields were lowest in T_1 (2.82 kg/plot, 47.08 q/ha) and highest in T_5 (4.66 kg/plot, 77.80 q/ha).

3.3 Impact of Varieties and Bio-Stimulants on Quality Parameters

The data pertaining to quality attributes of radish, including TSS and ascorbic acid, as impacted by varieties and treatments, are shown in Table 4 and illustrated in Fig. 3 (a-b). A significant impact of varieties and treatments was found on the TSS and ascorbic acid content of radish roots during harvest. Among the varieties, Punjab Safed Mooli-2 (V_1) recorded higher quality parameters, with a maximum TSS (5.45 °Brix), compared to Mino Early (V_2), which recorded a lower TSS (5.04 °Brix). Similarly, V_1 also exhibited higher ascorbic acid (17.38 mg/g FW) than V_2, which recorded lower ascorbic acid (16.90 mg/g FW). Among the treatments, application of T_5 significantly improved the quality profile of radish. It recorded the highest TSS content (6.3 °Brix) as well as maximum ascorbic acid content (18.30 mg/g FW). Whereas, the lowest values for these two parameters were found under T_1, where TSS content was lower (3.5 °Brix) and ascorbic acid was also lower (15.16 mg/g FW).

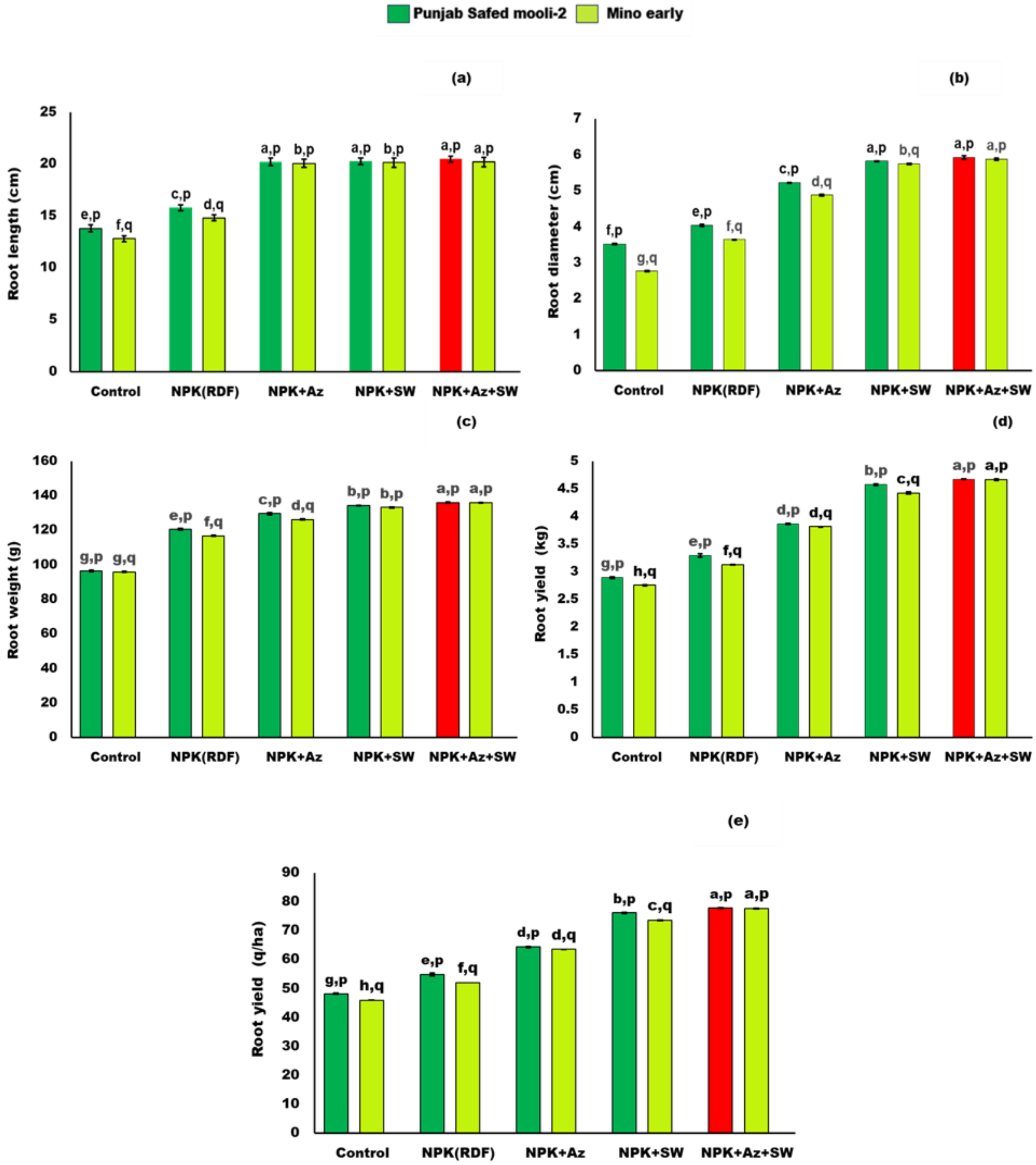

Fig. 2. The bar graphs show the interaction effect of bio-stimulants and two radish varieties (Punjab Safed mooli-2 and Mino early) on a) length of root (cm) b) diameter of root (cm) c) weight of root (g) d) Root yield (kg/plot) e) Root yield (q/ha) under bio stimulants

Graphs showed mean value, ± SE with different letters (a, b, c, d, e and p, q) are significantly different from each other ($p \leq 0.05$). The red- colored bar represents the maximum improvement in yield parameters in radish under bio-stimulant

Table 4. Impact of varieties and bio stimulants on TSS and ascorbic acid

Variety (V)	TSS (Brix^0)	Ascorbic acid (mg/g FW)
V_1	5.45^a	17.38^a
V_2	5.04^b	16.90^b
SE(m) ±	0.032	0.032
$CD_{0.05}$	0.097	0.097
Treatments		
T_1	3.50^d	15.16^d
T_2	4.30^c	16.20^c
T_3	5.96^b	17.90^b
T_4	6.16^a	18.16^a
T_5	6.30^a	18.30^a
SE(m) ±	0.051	0.051
$CD_{0.05}$	0.154	0.154

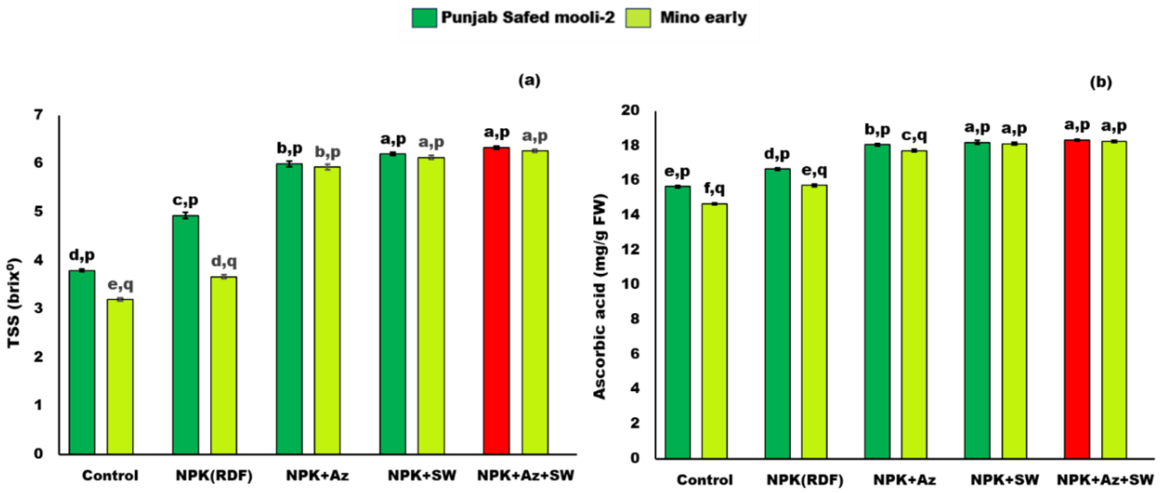

Fig. 3. The bar graphs show the interaction effect of bio-stimulants and two radish varieties (Punjab Safed mooli-2 and Mino early) on a) TSS b) Ascorbic acid under bio stimulants

Graphs showed mean value, ± SE with different letters (a, b, c, d, e and p, q) are significantly different from each other (p ≤ 0.05). The red- colored bar represents the maximum improvement in quality parameters in radish under bio-stimulant

4. DISCUSSION

4.1 Effect of *Azotobacter* and Seaweed Extract on Vegetative Attributes

The improvement in plant height may be because of the availability of readily accessible nitrogen from both inorganic nutrients and bio stimulants. In addition, the incorporation of bio stimulants may have had an important impact on the improvement of soil physiochemical parameters. Similar influence on the improvement in plant growth by height after bio-stimulant application was also noticed by Ray et al. (2023) in onion and Khanam et al (2023) in broccoli under subtropical weather conditions. Additionally, it could be attributed to the rapid growth of cells and the multiplication in the availability of nitrogen (Berman et al*.,* 2014; Kumar et al*.*, 2014; Shani et al., 2016 in radish; and Bhattarai and Maharjan, 2013, in carrot). Likewise, Rahman et al. (2023) argued that nitrogen has the ability to promote plant growth as the nutrient element is directly associated with enhanced cell division and formation of more tissues resulting in profuse vegetative growth and thereby increased plant height. Furthermore, bio-fertilizers have been shown to promote the growth of *Hibiscus sabdariffa* and okra (Kaur et al., 2021), in addition to radish. Another possible reason for the increase in plant height is the secretion of growth-promoting substances secreted by bio stimulants such as *Azotobacter* and Seaweed, which could have resulted in greater root development, water transportation, nutrient uptake, and deposition. These findings are comparable to those of Mali et al*.* (2018) in radish. Integration of organic and chemical fertilizer inputs for enhanced plant height was examined by Howlader et al. (2019) in tomato and Apu et al (2022) in strawberry.

A greater number of leaves is a desirable trait in radish, because more leaves aid in the development of ample photosynthates, which increase yield. It might be due to the application of seaweed, which enhances the growth-promoting hormones in plants, ultimately increasing the number of leaves (Ahmad et al., 2022). More leaves per plant could have been caused by seed inoculation with biofertilizers, which may have increased the availability of phosphorus and biological nitrogen fixation needed for robust growth. The same results were partially consistent with those obtained by Kirad et al. (2010), Singh et al*.* (2017), Subramani et al. (2011), and Mani and Anburani (2018).

The highest length of leaf (28.33 cm) was obtained with the use of NPK + *Azotobacter* + seaweed extract. This might be because using *Azotobacter* along with NPK raised the rate of mineralization, resulting in the rapid release of nutrients (Ramana et al*.,* 2010). The presence of nutrients and phytohormones in seaweed extract may be the reason for its ability to increase leaf length. Furthermore, hormones present in seaweed may help in delaying leaf senescence, allowing leaves to grow and attain length (Melo et al., 2020). These results are fairly similar to those of Mali et al. (2018) in radish and Yadav et al. (2021) in turnip. The possible reason behind the boost in breadth could be due to the availability of nitrogen from chemical fertilizers and bio stimulants, which aids in the assimilation of dietary components by plants, leading to enhanced meristematic activity. Similar results were reported by Kumar et al. (2014), Shani et al*.* (2016), Rao et al. (2010) and Koly et al. (2024).

4.2 Effect of *Azotobacter* and Seaweed Extract on Yield Attributes

The observed improvement in root length may be because of adequate application of NPK, which is required for plant metabolism and the production of essential compounds like purines, pyrimidines, enzymes, coenzymes, and alkaloids (Gill et al., 1993). These nutrients enhance photosynthesis and improve the C:N ratio, promoting carbohydrate storage in both root and shoot, ultimately increasing root yield (Chang and Chang, 2000). Similar findings were found by Ahmad et al*.* (2004) and Gethe (2006) in radish. Seaweed extract may also promote root growth because it improves nutrient absorption and support vegetative growth, such as increased leaf size and number (Podsedek, 2007). Mrkovacki and Milic (2001) noted that bio stimulants like *Azotobacter* and seaweed extract help improve soil fertility and enhance traits like root length and diameter. These results align with the recordings of Ingole et al. (2018) in beetroot and Singh et al. (2019) and Nisar et al. (2019) in radish (Kitamura, 1958).

The improvement in root diameter could be because RDF provides readily available nutrients such as NPK to the crop. The findings are consistent with Bloom's (2006) finding that N's growth-promoting impact boosts cytokinin production, which influences cellular wall flexibility, meristematic cell number, and development of cells. In contrast, enhanced soil N treatment gave more nitrogen to the plants, resulting in the greatest diameter. These findings correspond with the results presented by Sharma et al*.* (2013), Mohammad et al. (2015), Verma et al. (2017), and Kushwah et al. (2020) in radish. Seaweed extract contains not only macro- and micronutrients, vitamins, and antibiotics but also a good quantity of plant growth hormones by stimulating protein synthesis, cell differentiation, and cell division. Hormones also influence the uptake of nutrient-dissolved water and the distribution of nutrients and sugars within the plant body. This in turn increased the diameter of treated plants. The findings of this study agree with those of Raghunandan et al. (2019). Seed treatment with *Azotobacter* may have boosted nutrients in the plant, particularly nitrogen and phosphorus, and plant nutrient uptake, resulting in increased root diameter. The increase in root diameter might be attributed to the solubilization of plant nutrients caused by the application of chemicals and biofertilizers, which leads to higher NPK uptake. These results are consistent with those of Singh et al*.* (2019), Patel et al. (2019) in radish, and Nisar et al. (2019) in carrot.

Root weight is a crucial horticultural characteristic that has a direct impact on radish output because the root is the crop's most valuable component. According to Kiran et al. (2016), increased root weight is a result of better nutrient availability and uptake, particularly for phosphate, nitrogen, and potassium. Due to their abundance of nutrients and growth hormones, including as auxins, cytokinins, and gibberellins, which encourage cell division, protein synthesis, and nutrient translocation, seaweed extracts increase root weight. As a result, roots accumulate more dry matter (Ramulu and Rao, 2003). The application of Azotobacter to seeds also increases the availability of nitrogen and phosphorus, which promotes root growth and productivity. These findings are consistent with those of Kataria (2009), Kumar et al. (2016), and Mali et al. (2018) for radish.

Maximizing yield is the main objective of crop cultivation in order to improve financial returns. The effects of seaweed extract on root length, nitrogen uptake, and translocation are favourable and may increase radish root output. Rich in nutrients, growth hormones, and bioactive compounds, seaweed regulates hormone levels and encourages root development (Ahmad et al., 2022). Additionally, better plant traits including height, leaf breadth, and root dimensions lead to higher yields. Continuous nitrogen supply from chemical and biofertilizers, along with balanced phosphorus, increase auxin activity and metabolism. A blend of organic, inorganic, and biofertilizers may have produced the perfect soil conditions and increased plant nutrient availability, leading to increased radish uptake and assimilation and yield. Similar findings indicate that by promoting vigorous growth and efficient nutrient usage, balanced nutrient treatment significantly boosted root output in radish (Shani et al., 2016; Naveen et al., 2018; Kiran et al., 2016; Jat et al., 2017).

4.3 Effect of *Azotobacter* and Seaweed Extract on Quality Attributes

Total soluble solids (TSS), which are essential for evaluating the quality of radish, show the amount of dissolved sugars present. The rise in TSS could be caused by seaweed extract, which, because of its abundance of hormones and bioactive chemicals, promotes photosynthesis, sugar buildup, and stress tolerance (Ahmad et al., 2022). It also enhances nutrient uptake, taste, and root growth. Increased doses of nutrients also improve growth features by improving TSS and vitamin C levels, as well as photosynthate translocation and carbohydrate storage (Rayorath et al., 2008). Furthermore, combining biofertilizers with chemical fertilizers enhances nutrient availability, enzyme activity, and soil health, enabling better metabolic and quality attributes. Similar results have been reported by Sharma et al. (2013), Pathak et al. (2018), Tripathi et al. (2017), Nargave et al. (2018), and Mishra et al. (2020) in radish; Sunandarani and Mallareddy (2007) in carrot; Mullaimaran and Haripriya (2016) in tomato; Kopta and Pokluda (2013) in radish; Khanam et al. (2023) in broccoli and Koly et al. (2024) in strawberry.

Ascorbic acid is an essential constituent of radish roots. It is significantly affected by various treatments. The improvement in ascorbic acid may be attributed to the fact that biofertilizers boosted photosynthetic and metabolic activity, resulting in higher acid, metabolite, and glucose production. The created reserves may be used to synthesize ascorbic acid. Another reason for the rise in ascorbic acid content with added biofertilizers could be its capacity to fix ambient nitrogen and boost carbohydrate synthesis (Beijerinck, 1901). These findings are similar to those of Kumar et al. (2016) and Mali et al. (2018) in radish.

5. CONCLUSION

According to the present investigation, it can be found that the combination of inorganic fertilizers, bio stimulants and biofertilizers results in good vegetative development, production, and radish quality. The continued use of inorganic fertilizers in larger amounts has an adverse effect on soil health and water quality, even though the treatment that received the recommended dose of fertilizer produced more. As a result, applying chemical fertilizers more frequently is not recommended. In addition to increasing crop yield and quality, using both chemical fertilizers and biofertilizers helps to reduce soil and water pollution. Root yield was observed to be higher (77.80 q/ha) in the T_5 (NPK + Azotobacter + seaweed extract) treatment and is suggested for radish cultivation. Therefore, based on the current investigation’s findings, it can be said that the bio stimulant can synchronize nutrient supply and crop nutrient requirements, which can enhance the nutrient use efficiency and thus increase the yield.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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