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Effect of organic manures and bio-fertilizers on growth and yield of radish (*Raphanus sativus* L.)

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Abstract
The present investigation was conducted during the rabi season of 2021 at the Experimental Farm of the Faculty of Agricultural Sciences, DAV University, Jalandhar, to find out the effect of organic manures and bio-fertilizers on the growth and yield of radish (*Raphanus sativus* L). The experiment consisted of twelve treatments laid in RBD with three replications *viz.* T_1 (FYM @ 20 t/ha), T_2 (Vermicompost @ 5 t/ha), T_3 (Neemcake @ 2.5 t/ha), T_4 (*Azotobacter* @ 4 kg/ha), T_5 (*Azotobacter* @ 2 kg/ha + FYM @ 10 t/ha), T_6 (*Azotobacter* @ 2 kg/ha + Vermicompost @ 2.5 t/ha), T_7 (*Azotobacter* @ 2 kg/ha + Neemcake @ 1.25 t/ha), T_8 (PSB @ 4 kg/ha), T_9 (PSB @ 4 kg/ha + FYM @ 20 t/ha), T_{10} (PSB @ 4 kg/ha + Vermicompost @ 5 t/ha), T_{11} (PSB @ 4 kg/ha + Neem cake @ 2.5 t/ha), T_{12} Control (RDF 70:50:50 Kg NPK). CR-45 variety was used for the experiment. Observations were recorded on number of leaves per plant, leaf length (cm), leaf area per plant (cm^2), root length (cm), root diameter (cm), plant height (cm), root weight (g), fresh weight of plant (g), dry weight of plant (g), root yield per plot (kg/plot), TSS (◦Brix), ascorbic acid (mg/100 g) and benefit cost ratio. Analysis of variance (ANOVA) revealed significant differences among treatments for all the characters under study. It was concluded that with the application of vermicompost, better results in growth, yield and quality parameters were observed. Furthermore, with the application of vermicompost highest Benefit: Cost ratio was obtained.

Keywords: Radish, organic manures, bio-fertilizers, vermicompost, PSB, *azotobacter* and benefit cost ratio

Introduction
Radish (*Raphanus sativus* L.) is a herbaceous annual root vegetable belonging to the Brassicaceae family. It is one of the most quickly growing root vegetables. It probably originated in Central or Western China and Indo-Pak sub-continent. In India, it is grown all around the year throughout the country. However, West Bengal, Bihar, Uttar Pradesh, Karnataka, Haryana and Rajasthan are the major radish growing states. It is being cultivated in India over an area of 206 Thousand hectares and with an annual production of 3220 Thousand MT (Anonymous, 2021) [3].

It is grown for its fleshy tender and fusiform roots which are eaten raw as salad or cooked as a vegetable. The radish leaves are rich in minerals and vitamin A (5IU) and vitamin C (14.8 mg per 100 g of edible portion. It supplies a variety of minerals like calcium, potassium and phosphorus. The pink skin radish is generally rich in ascorbic acid than the white skin radish (Singh and Bhandari, 2015) [29]. The characteristic pungent flavour of radish is due to othiocyanate (Kushwah, 2016) [16]. It has high medicinal value and is prescribed for patients suffering from piles, liver troubles and jaundice (Brar *et al.*, 1972) [7]. Its use is also suggested for neurological, headache, sleeplessness and chronic diarrhoea in homoeopathic treatments. (Aswathi *et al*., 2021) [5]. Besides, it's leaves are a good source for the extraction of protein on a commercial scale and radish seeds are a potential source of non-drying fatty oil suitable for soap making illuminating and edible purposes (George, 1999) [8].

Fertilizer application, cultural practices, soil type, method of sowing and cultural practices etc. are the factors that affect yield and quality of specific vegetables. Inorganic fertilizers which are applied indiscriminately and in an overdose which may cause many problems for human health and the environment and leads to a reduction of microbial activity in soil resulting in decreased humus content (Singh and Kalloo, 2000) [30]. Direct contact with chemical fertilizers also affects root growth adversely. On the other hand, organic manure is reported to be rich in almost all essential nutrients, improves soil structure by improving its physical, chemical and biological properties and increases the number of micro-organisms leading to maintenance of the quality of crop production.

Commonly used organic manures are FYM (Farm Yard Manure), vermicompost, poultry manure, biogas slurry, urine and liquid manure etc. (Kumar *et al*., 2018) [14].

Another important and widely used form of organic fertilizers is biofertilizers. These are natural fertilizers that consist of micro-organisms like bacteria, algae, and fungi alone or in combination. These are beneficial for agriculture as they fix N, solubilize P and helps in the mobilization of nutrient even a small dose of biofertilizer is capable of enhanced growth and development as each gram of carrier of biofertilizers contains at least 10 million viable cells of a specific strain (Anandaraj and Delapierre, 2010) [2].

Phosphate solubilizing microorganisms (PSMs) are the microorganisms that are capable of solubilizing insoluble phosphate, besides this, they also enhance the nitrogen fixation efficiency and synthesize important growth promoting substances thereby accelerating the accessibility of other trace elements by like siderophores, antibiotics, etc. They also produce plant hormones such as auxins, cytokinins, gibberellins and improve crop productivity by protecting the plants against soil borne pathogens (Abbas *et al*., 2013) [1]. *Trichoderma* species have been identified and characterized as potential opportunistic, avirulent plant symbionts and biological agents against different soil-borne pathogens (Uddin *et al.*, 2018) [35].

Although organic manures can replace the mineral fertilizers by improving soil structure and microbial biomass even then single nutrient source may not supply the rest of the required nutrients for the plant therefore using all the available nutrient sources in an integrated manner can provide balanced plant nutrition (Arora, 2008). Keeping in view the importance of crops and the need to integrate the use of available organic nutrient sources to enhance growth and production, the present investigation was conceptualized and executed.

Material and Methods

The present study's effect of organic manures and bio-fertilizers on the growth and yield of radish (*Raphanus sativus* L.) was carried out at the Experimental Farm of the Faculty of Agricultural Sciences, DAV University, Jalandhar in winter 2021. The experiment was laid out in randomized block design (RBD) with three replications having twelve treatments. The treatments include *viz.* T_1 (FYM @ 20 t/ha), T_2 (Vermicompost @ 5 t/ha), T_3(Neemcake @ 2.5 t/ha), T_4 (*Azotobacter* @ 4 kg/ha), T_5 (*Azotobacter* @ 2 kg/ha + FYM @ 10 t/ha), T_6 (*Azotobacter* @ 2 kg/ha + Vermicompost @ 2.5 t/ha), T_7 (*Azotobacter* @ 2 kg/ha + Neemcake @ 1.25 t/ha), T_8 (PSB @ 4 kg/ha), T_9 (PSB @ 4 kg/ha + FYM @ 20 t/ha), T_{10} (PSB @ 4 kg/ha + Vermicompost @ 5 t/ha), T_{11} (PSB @ 4 kg/ha + Neem cake @ 2.5 t/ha), T_{12} Control (RDF 70:50:50 Kg NPK). The experiment was done on the CR-45 variety and seed sowing was done in October i.e., 15 t^h of October with a spacing of 30×10 cm. Treatment wise application of fertilizers was done manually. Organic manures such as FYM, Vermicompost, and Neemcake were incorporated in the field 15 days before sowing as per treatments, first irrigation was given immediately after sowing. Subsequent irrigations were given after 6-7 days, while various intercultural operations like weeding followed by hand weeding, and thinning were carried out after 25-30 days of sowing to avoid the overcrowding of plants. The observations were recorded on the basis of various growth and yield parameters such as number of leaves per plant, leaf length (cm), leaf area per plant (cm^2), root length (cm), root diameter (cm), root weight (g), fresh weight of plant (g), dry weight of plant (g), plant height (cm), root yield per plot (kg), TSS (◦Brix), ascorbic acid (mg/100 g) and Benefit cost ratio was also calculated. Data analysis was done on OPSTAT software.

Results and Discussion

Growth parameters

Enhanced photosynthesis and accumulation of metabolites in plants can be achieved by more number of leaves per plant, leaf length (cm) and leaf area per plant (cm^2). Thus it is an important factor that influences of growth yield and production. Table 2 represents the influence of organic matter on number of leaves per plant leaf length (cm) and leaf area per plant (cm^2). Perusal of data revealed maximum number of leaves (20.22) in T_{10} (PSB @ 4 kg/ha + vermicompost @ 5 t/ha) which was significantly highest among all the treatments. Minimum number of leaves (11.30) was observed in T_8 (PSB @ 4 kg/ha) which was significantly at par with T_1 (FYM @ 20 t/ha) resulting in 11.42 number of leaves per plant. Maximum leaf length (26.90 cm) was observed in T_2 (vermicompost @ 5 t/ha) which was significantly highest among all the treatments. Minimum leaf length (17.32 cm) was observed in T_{11} (PSB @ 4 kg/ha + neem cake @ 2.5 t/ha) which was significantly at par with T_8 (PSB @ 4 kg/ha) which resulted in leaf length to the tune of 19.04 cm. It was observed that T_4 (*Azotobacter* @ 4 kg/ha) resulted in maximum leaf area per plant (371.88 cm^2) which was statistically at par with T_2 (vermicompost @ 5 t/ha) (348.48 cm^2). Minimum leaf area per plant (242.50 cm^2) was observed in T_7 (*Azotobacter* @ 2 kg /ha) + neem cake @ 1.25 t/ha) which was significantly at par with T_5 (*Azotobacter* @ 2 kg/ha) + FYM @ 10 t /ha) (250.88 cm^2), T_9 (PSB @ 4 kg/ha)+FYM @ 20 t/ha) and T_{10} (PSB @ 4 kg/ha) + vermicompost @ 5 t/ha) resulting in leaf area to the tune of 250.88 cm^2, 261.75 cm^2 and 269.20 cm^2, respectively. Regarding plant height, the tallest plants (33.86 cm) were obtained in T_{12} (control (RDF 70:50:50 Kg NPK) which were statistically at par with plants grown in T_2 (vermicompost @ 5 t/ha) (33.48 cm). Shortest plants (24.40 cm) were observed in T_9 (PSB @ 4 kg/ha) + FYM @ 20 t/ha) which were significantly shortest among all the treatments.

It was observed that the number of leaves per plant, and leaf length increased with the application of vermicompost and this can be attributed to the enhanced availability of vital macro and micronutrients such as zinc, copper, iron and manganese etc. in the adequate amount to the plant with the application of vermicompost as suggested by Bhattarai and Maharjan (2013) [16]. The application of organic fertilizers has also been reported as a nutrient booster for the microbial degradation process, allowing crops to use nutrients and water more efficiently. The results with respect to number of leaves per plant are in conformity to the findings of earlier researchers *viz.*, Mali *et al*., (2018) [18], Poonkodi *et al*., (2019) [27] and Upadhyay and Prasad (2021) [36] in radish and Jeptoo *et al*., (2013) [11] in carrot and the results of leaf length are supported by Kumar *et al*. (2018) [14], Subedi *et al*. (2018) [33], Mishra *et al*. (2020) [20], Upadhyay and Prasad (2021) [36]. Higher leaf area (cm^2) was also observed with the application of vermicompost. While it was maximum with the application of (*Azotobacter* @ 4 kg/ha). The increased leaf area with the application of organic and biofertilizer can be justified by the fact that the combined application of different organic and

biofertilizers influences the physical and chemical properties of soil which make macro and micronutrients easily available and increase the enhanced enzymatic activities which leads to better growth and development. Similar results were obtained by earlier researchers *viz*. Singh *et al*. (2009) [32], Verma *et al*., (2017) [37], Upadhyay and Prasad (2021) [36] in radish and Parry *et al*., (2021) [25] in Chinese cabbage. Vermicompost's nitrification inhibitory properties and improved soil structure in soil could be associated with the increased plant height. The results corroborate with the findings of Uddain *et al*. (2010) [34], Jeptoo *et al*. (2013) [11], Bhattarai and Mahajan (2013) [16] in carrot; Kumar *et al* (2014) [15], Mali *et al*. (2018) [18] in radish.

Yield parameters

Yield parameters studied in the present investigation were root length, root diameter, root weight, fresh weight of plant, dry weight of plant and root yield per plot. The data on the effect of various organic and bio-fertilizers on yield parameters has been presented in Table 2. The results showed that T_2 (vermicompost @ 5 t/ha) resulted in maximum root length (30.77 cm), root diameter (3.23 cm), root weight (113.42 g), fresh weight (227.77 g), root yield per plot (7.49 kg). T_2 was statistically at par with T_1 (FYM@ 20 t/ha) for root length, and T_8 (PSB @ 4 kg/ha) (112.77g) for root weight. While, it was significantly superior among all the treatments for root diameter, fresh weight of plant, and root yield per plot. Maximum dry weight (17.36 g) was recorded in T_{10} (PSB @ 4 kg/ha) + vermicompost @ 5 t/ha) which was significantly highest among all the treatments. Lowest dry weight (6.36 g) was observed in T_5 (azotobacter @ 2 kg/ha +FYM (@ 10 t/ha) which was significantly lowest among all the treatments. Minimum root diameter (2.39 cm) was observed in T_1 (FYM @ 20 t/ha) which was statistically at par with T_3 (Neem cake @ 2.5 t/h) showing 2.46 cm root diameter. Minimum root length (18.35 cm) was observed in T_{11} (PSB @ 4 kg/ha + neem cake @ 2.5 t/ha) which was significantly smallest among all the treatments. Minimum root weight (73.63 g) was observed in T_{10} (PSB @ 4 kg/ha) + vermicompost @ 5 t/ha) which was statistically at par with T_{11} (PSB @ 4 kg/ha + neem cake @ 2.5 t/ha) resulting 77.22 g root weight. Lowest fresh weight (109.97 g) was observed in T_{11} (PSB @ 4 kg/ha + neem cake @ 2.5 t/ha) which was significantly lowest among all the treatments. Minimum root yield per plot (3.31 kg) was observed in T_{12} (control (RDF 70:50:50 Kg NPK) which was statistically at par with T_{11} (PSB @ 4 kg/ha+ neem cake @ 2.5 t/ha) resulting in 3.51 kg root yield per plot.

Vermicompost @ 5 t/ha resulted in maximum root length, root diameter, root weight, fresh weight of the plant, and root yield per plot. Organic manures reduce the bulk density and increase the porosity and water-holding capacity of the soil and accelerated metabolic and auxin activities in plants would have contributed towards the increase in the root length. It has also been observed that the size of the root which includes root length, root diameter, and root weight was directly influenced by the enhanced vegetative growth of the plants like leaf length, leaf area and number of leaves of the plant which might have accumulated more carbohydrates, resulting into increased root target. Higher root length with the application of vermicompost was also observed by Verma *et al*., (2017) [37]; Panwar *et al*., (2003) [24]; Kumar *et al*., (2014) [15] in radish and Narayan *et al*., (2014) [22] in potato, Findings with respect to root diameter are in agreement with those reported by Mali *et al* (2018) [18], Uddain *et al*., (2010) [34], Kumar *et al*., (2014) [15] in radish, and Kushwah *et al*., (2020) [17] in radish. Vermicompost might also have increased the efficiency of added chemical fertilizers in the soil activities of nitrogen fixing bacteria and increased rate of humification which enhanced the availability of both native and added nutrients in the soil resulting in increased yield attributes like root weight of radish (Oliveira *et al*., 2001) [23]. Similar results of root weight have also been reported by Uddain *et al*., (2010) [34], Kumar *et al*., (2014) [35], Mehwish *et al*., (2016) [19], Jat *et al*., (2017) [16] and Khede *et al*., (2019) [13] in radish.

The increase in fresh weight of roots and whole plant may be due to higher levels of nitrogen from vermicompost. The nitrogen will also be synthesized into amino acids which are built into complex proteins and help in promoting the luxurious growth of crops (Muthuswamy and Muthukrishnan, 1971) [21]. The maximum fresh weight of plant was observed in vermicompost 5 t/ha. Yadav and Vijaykumari (2003) [38] reported that the fresh weight of plants was higher in chilli supplemented with vermicompost and NPK. The results are in agreement with the findings of Kumar *et al*., (2014) [15], Jat *et al*., (2017) [16], Verma *et al* (2017) [37], Mali *et al*. (2018) [18], Mishra *et al*., (2020) [20] and Upadhyay and Prasad (2021) [36]. The dry weight of plant was significantly influenced by the application of different treatments but it was observed maximum when treated with PSB @ 4 kg+ vermicompost @ 5 t/ha. PSB has higher phosphorus availability which largely influences root growth by helping in cell division, photosynthesis, carbohydrate metabolism, enzyme activation, and nutrient translocation (Subedi *et al*., 2018) [33]. The similar findings were reported by Yadav and Vijaykumari (2003) [38] and Kumar *et al*. (2014) [15] in radish.

Application of vermicompost resulted in enhanced metabolic activities in plants resulting in increased root weight, root diameter, root length and finally total yield. Improved vegetative growth was also observed with the application of vermicompost which might be due to the accumulation of more carbohydrates resulting in increased root yield parameters like root diameter, length etc. which is food storage organ for radishes. These findings corroborate with the finding of Singh *et al*., (2012) [31] in garlic, Jadhav *et al*., (2014) [9]; Ziaf *et al*., (2016) [39] and Khalid *et al*., (2015) [12], Mali *et al*., (2018) [18]; Mishra *et al*., (2020) [20]; Kushwaha *et al*. (2020) [17] and Aswasthi *et al*., (2021) [5] in radish.

Quality parameters

T_2 (vermicompost @ 5 t/ha) which was statistically at par with T_9 (PSB @ 4 kg/ha) + FYM @ 20 t/ha) (5.95^0B) and T_{12} control (RDF 70:50:50 Kg NPK) (5.98^0B). Minimum TSS (2.16^0B) was found in T_{10} (PSB @ 4 kg/ha) + vermicompost @ 5 t/ha) which was statistically at par with T_{11} (PSB @ 4 kg/ha+ neem cake @ 2.5 t/ha) and T_6 (*Azotobacter* @ 2 kg/ha) + vermicompost @ 2.5 t/ha) showing TSS to the tune of 2.57^0B and 2.73^0B, respectively. The maximum ascorbic acid (12.53 mg/100 g) was recorded in T_4 (*Azotobacter* @ 4 kg/ha) which was statistically at par with T_{10} (PSB@ 4 kg/ha +vermicompost @ 5 t/ha) (12.35 mg/100 g). The minimum ascorbic acid (8.55 mg/100 g) was observed in T_8 (PSB @ 4 kg/ha) which was statistically at par with T_5 (*Azotobacter* @ 2 kg/ha +FYM @ 10 t/ha) (8.88 mg/100 g), T_2 (vermicompost @ 5 t/ha) (8.92 g/100 g) and T_9 (PSB @ 4 kg/ha) + FYM @

20 t/ha) (8.93 mg/100 g).

Total Soluble Solids (TSS) developed in a favourable manner with the use of bio-fertilizers. It might be due to increased production of carbohydrates resulting in improved physiological and biochemical activities in the plant system. The results are in line with the findings of Shanu *et al.*, (2019) [18] in carrot. Increase in growth parameters might have resulted in improved uptake of nutrients and photosynthetic activities leading to improved quality parameters like ascorbic acid through the process of enzymatic activities stimulated by plant growth components. Similar reports were also made by Kumar *et al*., (2016) [40] and Pathak *et al*., (2017) [26] in radish.

Relative Economics

Relative economic in radish was calculated on yield basis revealed that treatment T_2 (vermicompost @ 5 t/ha) recorded maximum gross returns (187250). Highest B:C ratio (4.2) was also obtained by (vermicompost @ 5 t/ha) and T_1 (FYM @ 20 t/ha) with (4.1). Minimum benefit cost ratio(1.2) was observed in T_{11} (PSB @ 4 kg/ha+ neem cake @ 2.5 t/ha) followed by T_{12} (control (RDF 70:50:50 Kg NPK) with (1.3). Balanced nutrition in integration is essential to enhance the benefit cost ratio in radish. The results are in line with the findings of Adhikari (2009) [41] in carrot and Narayan *et al*., (2014) [22] in potato; Jadhav *et al*., (2014) [9] in radish.

Table 1: Analysis of variance for growth and yield parameters of radish

Observations	Replication	Treatments	Error
Number of leaves per plant	48.76	281.95*	5.28
Leaf length (cm)	160.39	200.83*	36.60
Leaf area per plant (cm^2)	23,951.86	59,346.38*	6,168.69
Root length (cm)	78.68	656.72*	20.80
Root diameter (cm)	1.56	1.80*	0.37
Plant height (cm)	108.59	348.36*	4.073
Root weight (g)	445.77	5,412.22*	107.00
Fresh weight of plant (cm)	1,051.66	33,788.51*	405.16
Dry weight of plant (cm)	88.039	402.49*	13.71
Root yield per plot (kg)	0.662	42.58*	0.77
Ascorbic acid (mg/100 g)	87.34	64.56*	2.28
TSS (^{0}Brix)	30.80	88.27*	17.21

Table 2: Effect of bio-fertilizers and organic manures on growth, yield and economics of radish

Treatment	Number of leaves per plant	Leaf length (cm)	Leaf area per plant (cm^2)	Root length (cm)	Root diameter (cm)	Root weight (g)	Fresh weight of plant (g)	Dry weight of plant (g)	Plant height (cm)	Root yield per plot (kg)	TSS (^{o}Brix)	Ascorbic acid	B:C Ratio
T_1	11.42	23.78	276.47	29.60	2.39	98.62	208.02	7.84	25.15	5.71	3.70	9.51	4.1
T_2	18.00	26.90	348.58	30.77	3.23	113.42	227.77	8.87	33.48	7.49	7.36	8.92	4.2
T_3	16.43	23.56	334.74	27.69	2.46	93.88	210.63	10.45	27.99	5.15	5.68	10.59	1.8
T_4	17.37	22.06	371.88	27.36	2.64	89.55	170.99	15.33	25.59	5.25	5.84	12.53	2.2
T_5	14.89	22.24	250.88	22.44	2.79	97.79	157.94	6.36	26.86	5.11	5.16	8.88	3.6
T_6	19.02	21.28	330.76	33.42	3.00	90.73	170.22	10.93	32.45	5.92	2.73	10.90	3.7
T_7	14.47	20.04	242.5	22.31	2.81	90.37	213.8	14.44	27.92	4.14	3.86	11.78	2.0
T_8	11.30	19.04	326.36	25.25	2.84	112.77	197.11	13.84	28.66	4.61	4.31	8.55	2.4
T_9	14.96	22.62	261.75	26.64	2.69	77.96	181.21	15.76	24.4	5.11	5.95	8.93	3.5
T_{10}	20.22	20.04	269.2	22.72	2.95	73.63	183.32	17.36	25.83	4.22	2.16	12.35	2.3
T_{11}	13.71	17.32	328.85	18.35	2.96	77.22	109.97	13.59	27.84	3.51	2.57	10.51	1.2
T_{12}	12.38	20.91	311.38	20.63	2.75	101.16	207.47	14.92	33.86	3.31	5.98	9.85	1.3
C.D	0.83	2.19	28.53	1.657	0.22	3.75	7.31	1.34	0.73	0.32	1.5	0.54	
S.E(m ±)	0.28	0.74	9.66	0.56	0.07	1.27	2.47	0.45	0.24	0.1	0.5	0.18	

Conclusion

The discussion mentioned earlier about the effect of organic manures and bio-fertilizers on growth and yield of radish led to the conclusion that use of organic manures and bio-fertilizers plays an important role in terms of growth and yield. It was found that the application of Vermicompost @ 5 t/ha gave better results in growth as well as in quality parameters. However, the application of Vermicompost @ 5 t/ha has resulted in the highest Benefit: cost ratio.

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Conflicts of Interest: None.

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