Biological Forum – An International Journal **16(3): 95-100(2024)**

ISSN No. (Print): 0975-1130
ISSN No. (Online): 2249-3239

Impact of Bioinoculants and Organic Manures on Growth and Yield of Radish (*Raphanus sativus* L.)

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(Received: 13 January 2024; Revised: 27 January 2024; Accepted: 20 February 2024; Published: 15 March 2024)
(Published by Research Trend)

ABSTRACT: Radish is a major root vegetable widely cultivated in tropical and temperate areas of the world. Evaluating the influence of organic manures and biofertilizers on growth and yield of radish is important for improving soil health. 17 treatment combinations comprised organic manures *viz.,* FYM and vermicompost along with biofertilizers such as Azotobacter and Phosphate Solubilizing Bacteria. The experiment was laid out in Randomized Complete Block Design with three replications. Although more yield was obtained in treatment receiving the recommended dose of fertilizer but continuous use of chemical fertilizers at higher amounts has a negative impact on the soil health. Combined application of Phosphate Solubilizing Bacteria and FYM was found best for growth and yield parameters. Combined use of organic manures and biofertilizer not only helps in improving the yield and quality of crops but also helps in reducing soil and water pollution.

Keywords: Organic manures, Biofertilizers, Radish, Growth, Yield.

INTRODUCTION

Radish is a major root vegetable that is widely cultivated in both tropical and temperate areas of the world. It belongs to the Brassicaceae family and diploid chromosome numbers are 18. It originated from Central, Western China and India (Monika *et al*., 2022). Radish is mainly a cool-season vegetable, but the Asiatic types of cultivars can tolerate higher temperatures than the European type of cultivars. It is cultivated for its young tender tuberous root and is eaten either raw as a salad or cooked as vegetable. Radish is an important dietary component of human daily food. Radish is low in calories and a good source of vitamin C, protein, fat, minerals, fiber, and carbohydrates (Singh and Nath 2012). The presence of volatile isothiocyanates causes the characteristic pungent flavor of radish.

Radish roots are an excellent appetizer. Different preparations of radish are useful in the healing of gall bladder and liver problems. As a diuretic and laxative, juice from fresh leaves is helpful (Khede *et al*., 2019). The high nutritional value of radish is found to be very useful in patients with piles, hepatic disorders, increased spleen, and jaundice (Brar and Nandpuri 1972). Application of fertilizers by farmers without information regarding soil fertility status and crop requirement for nutrients adversely affect both crop and the soil (Ray *et al*., 2000). Because of the higher cost of synthetic fertilizers and their contribution to poor health of water and soil, it becomes imperative to go for alternative and cheaper sources like organic 2 manures (Kumar *et al*., 2014). Organic farming primarily focuses on the use of plant residues and manures in agriculture. Other than chemical fertilizers, there are many organic materials such as FYM, mustard oil cake, vermicompost, poultry manure and bio-slurry that are made up of many plant nutrients that improve the physical and chemical properties of soil which are necessary for the plant (Pandey *et al*., 2024). Organic manures increase water holding capacity and improve the nutrient supply of the soil. Besides improving the fertilizer use efficiency and microbial population of soil, it reduces the nitrogen loss due to the slow release of nutrients. Organic fertilizer, compost, vermicompost, biofertilizer and low-dose chemical fertilizer applications improve the production parameters of radish and dry matter production (Subramani *et al*., 2010; Imthiyas and Seran 2015; Kiran *et al*., 2016).

Biofertilizers containing living cells of various types of microorganisms that colonize the rhizosphere or the interior of the plant when applied to seed, plant surface, or soil and promote growth by converting nutritionally important elements such as nitrogen and phosphorous from unavailable to available form through biological processes such as nitrogen fixation and rock phosphate solubilization (Basnet *et al*., 2021). Azotobacter and Phosphate Solubilizing Bacteria play a vital role in sustaining both soil health and crop production on a long-term basis, ensuring the availability of major nutrients (Wani *et al*., 2023). Nitrogen-fixing microorganisms such as Azotobacter generate ammonia for their use and provide the plants with nitrogen as an exchange for carbon and protected habitat. Azotobacter besides nitrogen fixation is well known for the IAA production capability. Use of Phosphate Solubilizing Bacteria has been reported to improve root yield and radish productivity (Chattopadhyay *et al*., 2007). Radish is a short-term crop and the proper use of bio-fertilizers is very important to achieve the maximum and excellent root quality and yield.

MATERIALS AND METHODS

The research was carried out during rabi season, 2020 at Experimental Farm of Department of Vegetable Science, College of Horticulture and Forestry, Neri, Hamirpur, H.P. at an altitude of 650 m above mean sea level between 31° 41′47.6″N & 72° 28′6.3″E. The climate of the region is characterized as subtropical, with hot summers and mild to cool winters. Generally, December and January are coldest months, while May and June are hottest month. Majority of precipitation is received during monsoon period i.e. from June to September. The experiment comprised of seventeen treatments *viz*., [FYM (100 q/ha)], [Vermicompost (50 q/ha)], [Jeevamrit (drenching @ 10 %)], [Azotobacter], [Azotobacter + FYM (100 q/ha)], [Azotobacter + Vermicompost (50 q/ha)], [Azotobacter + Jeevamrit (drenching @ 10 %)], [Phosphate Solubilizing Bacteria], [Phosphate Solubilizing Bacteria + FYM (100 q/ha)], [Phosphate Solubilizing Bacteria + Vermicompost (50 q/ha)], [Phosphate Solubilizing Bacteria + Jeevamrit (drenching @ 10 %)], [Azotobacter + Phosphate Solubilizing Bacteria], [Azotobacter + Phosphate Solubilizing Bacteria + FYM (100 q/ha)], [Azotobacter + Phosphate Solubilizing Bacteria + Vermicompost (50 q/ha)], [Azotobacter + Phosphate Solubilizing Bacteria + Jeevamrit (drenching @ 10 %)], [Recommended Dose of Fertilizers (100N:48P:36K kg/ha)] and [Control].

These treatments were combination of organic manures along with biofertilizers such as Azotobacter and Phosphate Solubilizing Bacteria. The radish variety Japanese White was arranged in Randomized Complete Block Design with three replications having plot size of 1.2 m × 1.0 m with 30 × 10 cm spacing accommodating 40 plants per plot. The experimental field was thoroughly ploughed 1-2 times. Deep ploughing was done to bring the soil to a fine tilth and all the clods of the soil were thoroughly broken. All the stubble and weeds were removed. Plots were prepared according to the layout plan. Calculated amount of inorganic fertilizers Nitrogen, Phosphorous and potassium (100:48:36 kg/ha) were applied in the form of urea (217.39 kg/ha), SSP (300 kg/ha) and MOP (60 kg/ha) in respective treatments before sowing of seed. Half dose of N along with the full doses of P and K were applied as basal dose. Remaining half dose of N was split into two equal doses. The first dose was applied at the time of first earthing up and second dose was applied one month after the application of first dose. Organic manures such as FYM (100 q/ha) and vermicompost (50 q/ha) were applied during field preparation in the respective treatments. Seeds were treated with biofertilizers *viz*., Azotobacter and Phosphate Solubilizing Bacteria prior to sowing as per the treatments. Seeds were inoculated with Azotobacter culture, Phosphate Solubilizing Bacteria culture and Azotobacter + Phosphate Solubilizing Bacteria culture as per treatments. Seeds were soaked in Jaggery solution for 15-20 minutes and seeds were dried under shade. Thereafter, these seeds were coated with Azotobacter culture @ 25 g/kg, Phosphate Solubilizing Bacteria @ 25 g/kg and mixed culture of Azotobacter and Phosphate Solubilizing Bacteria as per treatments. Treated seeds were dried in shade before planting. Jeevamrit (@ 10 % drenching) was given at fortnight interval in the respective treatments. Sowing was done on 8th October 2020. Seeds were sown on the ridges at a spacing of 30 × 10 cm. First irrigation was done immediately after sowing. Irrigate the crop once in 6-7 days to retain optimum soil moisture, depending upon weather conditions. The thinning operation was performed twice to remove sick and overcrowded seedlings. The first thinning was performed after 15 days of sowing mainly to remove overcrowded, unhealthy and lanky seedlings. The second thinning was carried out 10 days after the first thinning to maintain optimum space of 10 cm between the two plants. Weeding was done manually on a regular basis to keep the plot free from weeds and to keep the soil loose and airy. Two shallow weeding were done to keep the field free from weeds. Earthing up was done twice, first 30 days after sowing and second after 40 days of sowing to cover the bulge out radish root to protect it from direct sunlight. The crop was harvested at full maturity when soil moisture was optimum. The roots of the radish were pulled out of the plots without damaging the roots. The soil adhering to the roots was removed.

Observations were recorded for days to marketable maturity, plant height (cm), number of leaves per plant, leaf length (cm), leaf breadth (cm), root weight (g), root length (cm), root diameter (cm), fresh weight of the plant (g), root yield per plot (kg) and crown diameter (cm). The mean values of data were subjected to analysis of variance as described by Gomez and Gomez (1984) for Randomized Complete Block Design.

RESULTS AND DISCUSSION

A. Growth and yield parameters

The days to marketable maturity is a significant trait for any crop, because it shows the time period at which the crop attains maturity. Harvesting at the right time is critical because harvesting too early or too late will result in a significant loss in yield and quality of radish roots. The data recorded on days to marketable maturity is presented in Table 1. The results revealed that treatment T_{16} (Recommended Dose of Fertilizer) was earliest in terms of marketable maturity (60.00 days) due to quick release of N, P, K to the soil and their quick uptake by plants which resulted in early maturity of crop as compared to combined application of organic manures and biofertilizers (Shesharao, 2014). Plant height increased significantly with respect to different treatments of organic manures and biofertilizers. Maximum plant height (49.46 cm) was recorded with treatment T_{16} (Recommended Dose of Fertilizer) (Table 1) may be due to a better nutritional environment in the root zone for plant growth and development. Nitrogen and Phosphorous are major nutrients needed for the plant's metabolism to function properly. The response of recommended dose of fertilizer was more pronounced compared to organic manures and this may be due to the proper supply of nutrients which create favourable nutritional conditions for better growth and development of plant (Jat *et al*., 2017; Khatri *et al*., 2019).

Number of leaves per plant (15.26) was obtained maximum by the treatment T_{16} (Recommended Dose of Fertilizer) (Table 1). Kiran *et al*. (2016) stated that N, P, K based fertilizers provided readily available nutrients as compared to organic manures, which resulted in increased vegetative growth. Highest leaf length (29.76 cm) was recorded in treatment T_{16} (Recommended Dose of Fertilizer) (Table 1). Islam *et al*. (2011) observed that when N, P, K based fertilizers were applied; the plants received more readily available nutrients like nitrogen, phosphorous and potassium which may have increased the vegetative growth and leaf length. Maximum (8.40 cm) leaf breadth was obtained in treatment T_{16} (Recommended Dose of Fertilizer) (Table 1). The N, P, K based fertilizers enhanced the soil fertility which promoted plant growth, thus causing increased leaf breadth of plants.

Table 1: Effect of organic manures and biofertilizers on days to marketable maturity, plant height, number of leaves per plant, leaf length and leaf breadth.

Treatment Code	Treatment Details	Days to Marketable maturity	Plant height(cm)	Number of leaves per plant	Leaf length (cm)	Leaf breadth (cm)
T_1	FYM (100q/ha)	68.33	42.16	12.20	25.26	6.13
T_2	Vermicompost (50q/ha)	68.66	40.73	12.06	24.33	6.10
T_3	Jeevamrit (drenching@ 10%)	68.66	40.16	12.00	24.00	6.10
T_4	Azotobacter	68.33	40.66	12.26	24.53	6.23
T_5	Azotobacter + FYM(100q/ha)	65.33	44.40	14.13	26.96	6.80
T_6	Azotobacter + Vermicompost (50q/ha)	65.66	44.00	13.86	26.80	6.83
T_7	Azotobacter + Jeevamrit (drenching@10 %)	65.33	43.40	13.73	26.10	6.73
T_8	Phosphate Solubilizing Bacteria	68.33	41.46	12.53	24.56	6.23
T_9	Phosphate Solubilizing Bacteria + FYM (100q/ha)	63.33	48.61	14.73	27.91	8.20
T_{10}	Phosphate Solubilizing Bacteria + Vermicompost (50q/ha)	64.00	45.49	14.33	26.35	7.96
T_{11}	Phosphate Solubilizing Bacteria + Jeevamrit (drenching@10%)	64.66	44.02	14.00	25.86	7.16
T_{12}	Azotobacter + Phosphate Solubilizing Bacteria	67.66	42.28	12.73	25.35	6.40
T_{13}	Azotobacter + Phosphate Solubilizing Bacteria + FYM (100q/ha)	63.33	48.72	14.60	28.23	8.13
T_{14}	Azotobacter + Phosphate Solubilizing Bacteria + Vermicompost (50 q/ha)	63.66	47.93	14.40	27.93	8.00
T_{15}	Azotobacter + Phosphate Solubilizing Bacteria + Jeevamrit (drenching@ 10%)	64.00	45.62	14.13	27.43	7.56
T_{16}	Recommended Dose of Fertilizer (100N:48P: 36 K kg/ha)	60.00	49.46	15.26	29.76	8.40
T_{17}	Control	69.00	38.76	11.60	23.06	5.98
	Mean	65.78	43.99	13.44	26.14	6.99
	$CD_{(0.05)}$	4.75	3.31	0.74	1.84	0.43

Maximum root weight (169.46 g) was recorded in treatment T_{16} (Recommended Dose of Fertilizer) (Table 2). The higher amount of readily available nutrients such as nitrogen, phosphorous and potassium moreover, their uptake may have increased radish fresh root weight. Maximum root length (20.79 cm) was recorded by the treatment T_9 (Phosphate Solubilizing Bacteria + FYM) (Table 2). This increase could be due to the incorporation of bio-fertilizers *viz*., Azotobacter and Phosphorous Solubilizing Bacteria which play a significant role in improving soil fertility and yield attributes like root length, root breadth and thus final vegetable yield (Khede *et al*., 2019). Meena *et al*. (2022) reported that inorganic fertilizer had a significant influence on the root weight and the number of leaves in the radish plant, although the inorganic fertilizer had no significant impact on the length of the radish root. Root diameter (3.90 cm) was observed maximum in treatment T_{16} (Recommended Dose of Fertilizer) (Table 2) due to the supply of readily available nutrients like nitrogen, phosphorous, potassium from RDF to the plants. Makinde (2013) noted an increase in the readily available nitrate from the NPK fertilizer, which the crops can easily utilize.

Maximum fresh weight of plant (238.40 g) was observed in treatment T_{16} (Recommended Dose of Fertilizer) (Table 2). Data indicated that incorporation of recommended dose of NPK and manures significantly improved fresh root weight of radish. Moreover, the availability of higher amount of readily available nutrients through Recommended Dose of Fertilizer and their uptake, which could have increased fresh weight of plant as reported by Meena *et al*. (2022); Jat *et al*. (2017). Maximum root yield per plot

(4.20 kg) was obtained in treatment T_{16} (Recommended Dose of Fertilizer) (Table 2) due the application of 100 % of the recommended dose of nitrogen and phosphorous favoured auxin and metabolic activities in plants which ultimately resulted in increased root yield as reported by Meena *et al*. (2022); Ram *et al*. (2001). Crown diameter (2.08) was recorded maximum with treatment T_{16} (Recommended Dose of Fertilizer) (Table 2) due to readily availability of nutrients like nitrogen, phosphorous and potassium from the recommended dose of fertilizers to the plants.

Economics: Data for economic of radish cultivation *viz*., total cost of cultivation, gross income, net income and cost: benefit ratio of different treatment is presented in Table 3. Among different treatments maximum gross income of Rs. 2,45,000/ha was obtained with treatment T_{16} (Recommended Dose of Fertilizer) followed by Rs.2,43,250/ha in treatment T_9 (Azotobacter + Phosphate Solubilizing Bacteria + FYM) while, minimum gross income (Rs.1,06,160) was obtained with treatment T_{17} (Control). Maximum net income (Rs. 1,76,810/ha) was recorded by treatment T_9 (Phosphate Solubilizing Bacteria + FYM) followed by Rs. 1,74,470/ha in treatment T_{13} (Azotobacter + Phosphate Solubilizing Bacteria + FYM) whereas, minimum net income (Rs.24,370/ha) was recorded by treatment T_2 (Vermicompost). Highest B: C ratio (2.66) was recorded by treatment T_9 (Phosphate Solubilizing Bacteria + FYM) followed by treatment T_{13} (Azotobacter + Phosphate Solubilizing Bacteria + FYM) recording B: C ratio of 2.62. Whereas, lowest B: C ratio (0.24) was recorded by treatment T_2 (Vermicompost).

Table 2: Effect of organic manures and biofertilizers on root weight, root length, root diameter, fresh weight of plant, root yield per plot and crown diameter in radish.

Treatment code	Treatment Details	Root weight(g)	Root Length (cm)	Root Diameter (cm)	Fresh weight of plant (g)	Root yield per plot (kg)	Crown diameter (cm)
T_1	FYM (100q/ha)	110.73	16.90	2.94	137.60	2.11	1.48
T_2	Vermicompost (50q/ha)	108.26	16.40	2.89	135.66	2.09	1.47
T_3	Jeevamrit (drenching@ 10%)	106.00	16.16	2.80	134.80	2.04	1.39
T_4	Azotobacter	106.13	16.13	3.00	136.83	2.06	1.49
T_5	Azotobacter + FYM (100q/ha)	132.90	17.43	3.24	177.26	2.96	1.81
T_6	Azotobacter + Vermicompost (50q/ha)	130.56	17.20	3.21	172.46	2.90	1.78
T_7	Azotobacter + Jeevamrit (drenching@10%)	127.23	17.30	3.17	169.16	2.76	1.75
T_8	Phosphate Solubilizing Bacteria	112.26	16.90	3.08	144.63	2.09	1.54
T_9	Phosphate Solubilizing Bacteria + FYM (100q/ha)	164.00	20.79	3.49	215.06	4.17	1.96
T_{10}	Phosphate Solubilizing Bacteria + Vermicompost (50q/ha)	152.10	19.13	3.31	201.63	3.65	1.91
T_{11}	Phosphate Solubilizing Bacteria+ Jeevamrit (drenching@ 10%)	141.03	18.16	3.16	191.83	2.95	1.85
T_{12}	Azotobacter + Phosphate Solubilizing Bacteria	119.20	16.93	3.10	158.67	2.39	1.65
T_{13}	Azotobacter + Phosphate Solubilizing Bacteria + FYM (100q/ha)	160.33	20.49	3.41	208.96	4.13	1.94
T_{14}	Azotobacter + Phosphate Solubilizing Bacteria +Vermicompost (50q/ha)	155.86	20.00	3.33	204.63	3.80	1.92
T_{15}	Azotobacter + Phosphate Solubilizing Bacteria + Jeevamrit (drenching@10 %)	145.26	18.19	3.26	193.60	3.11	1.86
T_{16}	Recommended Dose of Fertilizer (100 N:48P: 36K kg/ha)	169.46	19.70	3.90	238.40	4.20	2.08
T_{17}	Control	102.33	15.70	2.46	131.16	1.82	1.32
	Mean	131.98	17.84	3.16	173.67	2.89	1.71
	$CD_{(0.05)}$	19.91	2.49	0.62	29.98	0.97	0.20

Table 3: Effect of organic manures and biofertilizers on economics of radish cultivation.

Sr. No.	Treatment details	Total root Yield (q/h)	Total cost of Cultivation (Rs/ha)	Gross Income (Rs/ha)	Net Income (Rs/ha)	B:C ratio
T_1	FYM (100q/ha)	123.08	65,540	1,23,080	57,540	0.87
T_2	Vermicompost (50q/ha)	121.91	97,540	1,21,910	24,370	0.24
T_3	Jeevamrit (drenching@10%)	119.00	66,040	1,19,000	52,960	0.80
T_4	Azotobacter	120.16	48,040	1,20,160	72,120	1.50
T_5	Azotobacter + FYM (100q/ha)	172.66	66,040	1,72,660	1,06,620	1.61
T_6	Azotobacter + Vermicompost (50q/ha)	169.16	98,040	1,69,160	71,120	0.72
T_7	Azotobacter + Jeevamrit (drenching@10%)	161.00	66,540	1,61,000	94,460	1.41
T_8	Phosphate Solubilizing Bacteria	121.91	47,940	1,21,910	73,970	1.54
T_9	Phosphate Solubilizing Bacteria + FYM (100q/ha)	243.25	66,440	2,43,250	1,76,810	2.66
T_{10}	Phosphate Solubilizing Bacteria + Vermicompost (50q/ha)	212.91	97,940	2,12,910	1,14,970	1.17
T_{11}	Phosphate Solubilizing Bacteria + Jeevamrit (drenching@10%)	172.08	66,440	1,72,080	1,05,640	1.59
T_{12}	Azotobacter + Phosphate Solubilizing Bacteria	139.41	48,440	1,39,410	90,970	1.87
T_{13}	Azotobacter + Phosphate Solubilizing Bacteria + FYM (100q/ha)	240.91	66,440	2,40,910	1,74,470	2.62
T_{14}	Azotobacter + Phosphate Solubilizing Bacteria + Vermicompost (50q/ha)	221.66	98,440	2,21,660	1,23,220	1.25
T_{15}	Azotobacter + Phosphate Solubilizing Bacteria + Jeevamrit (drenching @10%)	181.41	66,940	1,81,410	1,14,470	1.71
T_{16}	Recommended Dose of Fertilizer (100N:48P: 36K kg/ha)	245.00	71,213	2,45,000	1,73,787	2.44
T_{17}	Control	106.16	47,540	1,06,160	58,620	1.23

CONCLUSIONS

From the present investigation, it can be concluded that the combined use of organic manures and biofertilizers results in good vegetative growth, yield and quality of radish. Although more yield was obtained in treatment receiving the recommended dose of fertilizer (RDF) but continuous use of chemical fertilizers at higher amounts has a negative impact on the soil health and water. So, it is not advisable to use chemical fertilizers at a higher rate. Combined the use of organic manures and biofertilizer not only helps in improving the yield and quality of crops but also helps in reducing soil and water pollution. B:C ratio was found higher (2.66) in treatment T_9 (Phosphate Solubilizing Bacteria + FYM) as compared to treatment T_{16} (Recommended Dose of Fertilizers) *i.e.* 2.44. Combined application of Phosphate Solubilizing Bacteria + FYM was found best considering the above points and is suggested for radish cultivation.

FUTURE SCOPE

Organic manures along with biofertilizers leads to sustainability in soil health and crop production on a long-term basis, ensuring the availability of major nutrients and may serve as alternative *to* mineral fertilizers for improving fertility of soil and yield of the crops.

Acknowledgement. The study was assisted, supported and financed by College of Horticulture and Forestry, Neri, Hamirpur, HP India.
Conflict of Interest. None.

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How to cite this article: Santosh Kumari, Manisha, Shivali Dhiman and Anubha Saini (2024). Impact of Bioinoculants and Organic Manures on Growth and Yield of Radish (*Raphanus sativus* L.). *Biological Forum – An International Journal, 16*(3): 95-100.