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Effect of bio-fertilizers on growth, yield and quality of carrot (*Daucus carota* L.) cv. Pusa rudhira

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Abstract

The present investigation entitled “Effect of Bio-fertilizers on Growth, Yield and Quality of Carrot (*Daucus carota* L.) cv. Pusa Rudhira” was carried out at the Agriculture Research Field, Department of Horticulture, Prof. Rajendra Singh (Rajju Bhaiya) University during 2025-26. The experiment was conducted in Randomized Block Design (RBD) with 7th treatments and 3 replications to evaluate the influence of different bio-fertilizers on growth, yield, quality and economics of carrot cultivation. The treatments included Azospirillum, PSB, VAM and their combinations along with an untreated control. Among the treatments, T₅ (Azospirillum @50% + VAM @50%) recorded the best growth and yield performance with maximum plant height (37.66 cm), number of leaves (13.80), leaf length (28.46 cm), fresh root weight (99.39 g), root length (21.00 cm), root diameter (45.44 mm) and root yield (24.85 t/ha). The same treatment also gave the highest gross return (3,47,900 Rs./ha), net return (2,32,028 Rs./ha) and B:C ratio (3.00). However, T₆ (PSB @50% + VAM @50%) showed superior quality parameters with highest TSS (9.47 °Brix), ascorbic acid (7.90 mg/100 g) and total sugar (2.75%). The lowest values for most parameters were recorded in T₇ (control).

Keywords: Carrot, bio-fertilizers, growth, yield, quality, economic-studies, parameters

Introduction

Carrot (*Daucus carota* L.) is one of the most important root vegetable crops belonging to the family Apiaceae and chromosome number 2n=18. It is believed to have originated in South-West Asia and is widely cultivated throughout the world for its edible fleshy roots. In India, carrot is mainly cultivated in Uttar Pradesh, Haryana, Punjab, Karnataka and Andhra Pradesh. The crop is highly valued for its nutritive value, medicinal importance and economic returns. Carrot roots are rich in carbohydrates, carotenoids, vitamins, minerals and dietary fiber, making them an essential component of a healthy diet (Bhat *et al.*, 2017) [3].

Carrot is a cool season crop and grows best under temperature range of 15-20°C in well-drained sandy loam soil with pH 6.0-7.0. The variety Pusa Rudhira is gaining popularity because of its attractive colour, high anthocyanin content and superior nutritional quality. Carrots contain important bioactive compounds such as carotenoids, flavonoids and antioxidants, which help in preventing several diseases and improving human health (Ahmad *et al.*, 2019) [1].

Among different bio-fertilizers, Azospirillum, Phosphate Solubilizing Bacteria (PSB) and Vesicular Arbuscular Mycorrhiza (VAM) are widely used in vegetable crops. Azospirillum fixes atmospheric nitrogen and produces plant growth hormones such as indole acetic acid and gibberellins, thereby improving root and shoot growth (Bashan and de-Bashan, 2010). VAM improves uptake of phosphorus and micronutrients, increases water absorption and enhances root development (Smith and Read, 2008) [13].

These bioactive compounds possess strong antioxidant, anti-carcinogenic and immune-boosting properties and are beneficial for maintaining eye health. Carrot also exhibits several health-promoting effects such as cholesterol-lowering, anti-diabetic, anti-hypertensive, hepato protective and reno protective activities. In addition, carrot seed extracts have shown antibacterial, antifungal, anti-inflammatory and cardioprotective properties. Carrot pomace, a by-product rich in β-carotene, is also utilized for value-added food products such as biscuits, bread and cakes, thereby increasing its economic importance (Ikram *et al.*, 2024) [5].

The combined application of these bio-fertilizers has shown significant improvement in growth, yield, quality and soil health in vegetable crops. Several researchers have reported that integrated use of bio-fertilizers enhances nutrient uptake, root development, sugar accumulation and economic returns in carrot cultivation (Kumar and Sharma, 2019; Singh and Singh, 2020) [6, 7, 11].

In India, carrot is cultivated over an area of about 62,200 hectares with an annual production of nearly 1.15 million tonnes (Anonymous, 2024). In Madhya Pradesh, carrot cultivation covers approximately 1,400 hectares with a production of about 8.5 thousand tonnes annually. Initially, cultivated carrots were mostly purple and yellow in colour with long and slender roots. Depending upon the variety, carrot roots may be spherical, conical or cylindrical in shape. Carrot is a biennial crop in which the plant undergoes vegetative growth during the first season and produces flowers and seeds during the second season.

In modern agriculture, excessive use of chemical fertilizers has adversely affected soil fertility, environmental quality and crop sustainability. Therefore, emphasis is now being given towards eco-friendly nutrient management practices through the use of bio-fertilizers. Bio-fertilizers are beneficial microorganisms that improve nutrient availability and plant growth by biological nitrogen fixation, phosphorus solubilization and secretion of growth promoting substances (Gaur, 2006) [4].

Materials and Methods

The present investigation entitled “Effect of Bio-fertilizers on Growth, Yield and Quality of Carrot (*Daucus carota* L.) cv. Pusa Rudhira” was conducted during 2025-26 at the Agriculture Research Field, Department of Horticulture, Faculty of Agriculture, Prof. Rajendra Singh (Rajju Bhaiya) University, Naini, Prayagraj, Uttar Pradesh. The experimental field is situated at 25.35°N latitude, 81.89°E longitude and at an altitude of 98 m above mean sea level. The experiment was laid out in Randomized Block Design (RBD) with seven treatments and three replications. The carrot variety used for the experiment was cv. Pusa Rudhira. Each plot measured 2.5 m × 2.0 m with spacing of 40 cm × 10 cm. A total of 21 plots were maintained during the investigation. The treatments consisted of different bio-fertilizers and their combinations, viz., T1: Azospirillum@100%, T2: PSB@100%, T3: VAM@100%, T4: Azospirillum@50%+PSB@50%, T5: Azospirillum@50%+ VAM@50%, T6: PSB@50%+VAM@50% and T7: Control. The soil of the experimental field was sandy loam in texture, well-drained

and suitable for carrot cultivation. The field was prepared properly by ploughing and levelling before sowing. Seeds were treated with respective bio-fertilizers prior to sowing. Sowing was done on 04 November 2025. All recommended cultural practices such as irrigation, weeding, thinning, earthing-up and plant protection measures were carried out uniformly for all treatments. Observations on growth parameters such as plant height(cm), number of leaves, leaf length(cm) and fresh weight of plant(g) were recorded at 45, 60, 75 and at harvesting stages. Yield parameters including fresh root weight(g), root length(cm), root diameter(mm), dry weight(g), root yield per plot and root yield per hectare were recorded at harvest. Quality parameters like TSS, reducing sugar, non-reducing sugar, total sugar, ascorbic acid and pH value were also analyzed. Economic parameters such as cost of cultivation, gross return, net return and benefit-cost (B:C) ratio were calculated for different treatments. The recorded data were statistically analyzed by using the analysis of variance (ANOVA) technique appropriate for Randomized Block Design(RBD) and treatment means were compared at 5% level of significance.

Results and Discussion

The present investigation was carried out to study the effect of different bio-fertilizers on growth, yield, quality and economics of carrot (*Daucus carota* L.) cv. Pusa Rudhira. The results obtained during the course of investigation are discussed under the following headings.

Growth Parameters

Plant height (cm)

Plant height increased progressively from 45 DAS to harvesting stage under all treatments. Significant variation was observed among different bio-fertilizer treatments. Among all treatments, T₅ (Azospirillum@50% + VAM@50%) recorded the maximum plant height at all growth stages with 20.51 cm, 29.91 cm, 32.97 cm and 37.66 cm at 45 DAS, 60 DAS, 75 DAS and harvesting stage, respectively. The minimum plant height was observed in T₇ (Control). The increase in plant height under combined bio-fertilizer application may be due to improved nutrient availability, nitrogen fixation and enhanced uptake of phosphorus and micronutrients. Similar findings were reported by Bhat *et al.*, (2017) [3], who observed increased plant height in carrot due to bio-fertilizer application. Also reported that combined inoculation of Azospirillum and VAM significantly improved vegetative growth in root vegetables. (Table.1)

Table 1: Effect of bio-fertilizers on growth characters to Plant height (cm).

Growth Parameters	Plant Height(cm)			
	45 DAS	60 DAS	75 DAS	At Harvesting Stage
T ₁ -Azospirillum@100%	19.56	28.69	30.52	34.5
T ₂ -PSB@100%	18.78	27.32	28.28	31.38
T ₃ -VAM@100%	19.54	28.58	30.47	33.29
T ₄ - Azospirillum@50%+PSB@50%	19.86	29.02	32.04	37.26
T ₅ -Azospirillum@50%+VAM@5%	20.52	29.91	32.97	37.66
T ₆ -PSB@50% + VAM@50%	19.73	28.80	31.02	35.82
T ₇ -Control	16.21	25.14	27.43	30.86
C.D. at 5%	2.254	2.369	1.686	2.068
SE(m)±	0.724	0.76	0.541	0.664

Number of leaves per plant

The number of leaves per plant increased continuously from 45 DAS up to harvesting stage. The highest number of leaves was recorded in T₅ (Azospirillum @50% + VAM@50%) with 6.83, 9.33, 11.67 and 13.80 leaves at 45 DAS, 60 DAS, 75 DAS and harvesting stage, respectively. The lowest values were recorded in control treatment (T₇).

The increased leaf production might be attributed to better vegetative growth due to improved nutrient absorption and production of growth promoting substances by bio-fertilizers. These findings are in accordance with Kumar and Sharma (2019) ^[6, 7], who reported that bio-fertilizer application significantly increased leaf production and vegetative growth in carrot crop. (Table.2)

Table 2: Effect of bio-fertilizers on growth characters.

Growth Parameters	Number of Leaves Per Plant				Leaf Length(CM)			
	45 DAS	60 DAS	75 DAS	At Harvesting stage	45 DAS	60 DAS	75 DAS	At Harvesting stage
T ₁ -Azospirillum@100%	6.43	8.57	9.43	11.57	13.84	19.81	22.47	25.33
T ₂ -PSB@100%	6.07	8.33	9.16	10.23	12.91	18.42	20.62	22.90
T ₃ -VAM@100%	6.30	8.50	9.37	10.47	13.66	19.61	21.91	24.40
T ₄ -Azospirillum@50% + PSB@50%	6.70	8.70	10.03	12.73	14.11	20.30	23.73	27.58
T ₅ -Azospirillum@50% + VAM@50%	6.83	9.33	11.67	13.80	14.42	21.74	24.64	28.46
T ₆ -PSB@50% + VAM@50%	6.60	8.60	9.50	12.16	13.99	20.07	23.03	26.71
T ₇ -Control	5.80	8.13	8.47	9.66	11.64	16.69	20.17	22.50
C.D. at 5%	0.577	0.395	0.108	0.153	1.643	2.57	0.476	1.031
SE(m)±	0.185	0.127	0.035	0.049	0.527	0.825	0.153	0.331

Leaf length (cm)

Significant differences in leaf length were observed among treatments. The maximum leaf length was recorded in T₅ (Azospirillum@50% + VAM@50%) with 14.41 cm, 21.74 cm, 24.64 cm and 28.46 cm at different growth stages, while minimum leaf length was recorded under control treatment. Enhanced nutrient uptake and better physiological activities under combined bio-fertilizer application may have contributed to increased leaf growth. Similar observations were reported by Singh and Singh (2020) ^[11], who stated that VAM and Azospirillum inoculation improved vegetative growth and leaf development in vegetable crops.

T₇ (control) treatment. The increase in yield attributes may be due to improved root proliferation, nutrient uptake and better translocation of photosynthates. These findings are supported by Meena and Singh (2016) ^[8], who reported that integrated nutrient management increased biomass accumulation and root weight in carrot.

Root diameter, leaf weight and dry weight

The maximum root diameter (45.44 mm), leaf weight (39.71 g) and dry weight (11.59 g) were recorded under T₅ treatment followed by T₄ (Azospirillum@50% + PSB@50%). The minimum values were recorded in T₇ (Control). Combined application of bio-fertilizers improved growth and dry matter accumulation due to enhanced nutrient availability and microbial activity in soil. Similar results were reported by Rana *et al.*, (2020) ^[9], who observed significant improvement in root growth and yield attributes in carrot under combined inoculation of VAM and PSB. (Table.3)

Yield Parameters

Fresh weight of plant, root weight and root length

Different bio-fertilizer treatments significantly influenced yield attributes of carrot. The treatment T₅ (Azospirillum @50% + VAM @50%) recorded maximum fresh weight of plant (132.11 g), fresh root weight (99.39 g) and root length (21.00 cm), whereas minimum values were observed under

Table 3: Effect of bio-fertilizers on yield parameters.

Treatments	Fresh weight of plant(g)	Fresh weight of root(g)	Root Length (cm)	Root Diameter (mm)	Leaf weight (g)	Dry weight (g)	Root Diameter (mm)	Root Yield/Plot (kg)	Root Yield (t/ha)
T ₁ -Azospirillum@100%	127.73	77.79	19.30	42.31	33.98	9.67	42.30	9.72	19.45
T ₂ -PSB@100%	122.28	67.90	17.71	39.58	26.80	8.15	39.58	8.49	16.98
T ₃ -VAM@100%	126.61	70.76	18.77	41.21	28.42	8.82	41.21	8.85	17.69
T ₄ -Azospirillum@50% +PSB@50%	129.86	90.69	20.19	43.66	36.63	10.87	43.66	11.34	22.67
T ₅ -Azospirillum@50% + VAM@50%	132.11	99.34	21.01	45.44	39.71	11.59	45.44	12.43	24.85
T ₆ -PSB@50% + VAM@50%	128.73	86.36	19.90	43.37	35.29	10.36	43.37	10.80	21.59
T ₇ -Control	103.94	61.81	16.72	38.14	25.45	7.75	38.14	7.73	15.45
C.D.±	11.569	1.349	1.807	3.698	0.014	0.62	3.698	0.078	0.098
SE(m)±	3.713	0.433	0.58	1.187	0.005	0.199	1.187	0.025	0.031

Root yield per plot and per hectare

Root yield was significantly influenced by different bio-fertilizer treatments. The highest root yield per plot (12.43 kg) and root yield per hectare (24.85 t/ha) were obtained under T₅ (Azospirillum@50% + VAM@50%), followed by

T₄ treatment. The lowest yield was recorded in T₇ (control) treatment (7.73 kg per plot and 15.45 t/ha). Higher yield under integrated bio-fertilizer treatments may be attributed to improved nutrient uptake, enhanced root development and efficient utilization of available resources. These results

are in agreement with Sharma *et al.*, (2018), who reported that integrated use of bio-fertilizers significantly enhanced root yield in root crops. (Table.3)

Quality Parameters

Quality parameters of carrot were significantly affected by different bio-fertilizer treatments. The highest TSS (9.47 °Brix), ascorbic acid (7.90 mg/100 g), reducing sugar (2.04%), non-reducing sugar (0.72%) and total sugar (2.75%) were recorded under T₆ (PSB @50% + VAM@50%). The lowest quality values were recorded in

T₇ (control) treatment. Improved quality parameters under combined bio-fertilizer application may be due to enhanced synthesis and accumulation of sugars, vitamins and other metabolites in roots. Similar findings were observed by Kumar *et al.*, (2019) ^[6, 7], who reported increased TSS and sugar content in carrot due to PSB and VAM inoculation. These findings are supported by Ahmad *et al.*, (2019) ^[1], who reported improved antioxidant compounds and nutritional quality in carrot with sustainable nutrient management practices. (Table.4)

Table 4: Effect of bio-fertilizers on quality parameters.

Treatments	TSS (°Brix)	Ascorbic acid (mg/100gm)	pH Value	Reducing Sugar(%)	Non-reducing Sugar(%)	Total Sugar(%)
T ₁ -Azospirillum@100%	8.33	6.04	6.29	1.57	0.55	2.12
T ₂ -PSB@100%	8.59	5.60	6.33	1.67	0.58	2.25
T ₃ -VAM@100%	8.62	6.47	6.34	1.82	0.64	2.46
T ₄ -Azospirillum@50%+ PSB@50%	8.77	7.33	6.35	1.83	0.64	2.47
T ₅ -Azospirillum@50%+VAM@50%	8.97	7.76	6.37	1.84	0.71	2.55
T ₆ -PSB@50% + VAM@50%	9.47	7.90	6.40	2.04	0.72	2.75
T ₇ -Control	8.20	5.18	6.28	1.53	0.54	2.07
C.D. at 5%	0.658	0.028	0.022	0.038	0.011	0.028
SE(m)±	0.211	0.009	0.007	0.012	0.003	0.009

Economic Analysis

Economic analysis revealed significant differences among treatments. The highest gross return (3,47,900 Rs./ha), net return (2,32,028 Rs./ha) and benefit-cost ratio (3.00) were recorded under T₅ (Azospirillum@50% + VAM@50%), followed by T₄ treatment. The lowest economic returns were recorded under T₇ (control) treatment. Higher

profitability in combined bio-fertilizer treatments was mainly due to increased yield and better marketable produce. Similar economic advantages of bio-fertilizer application were reported by Singh *et al.*, (2021) ^[12], who found higher net returns and benefit-cost ratio in bio-fertilizer treated carrot crop. (Fig.1)

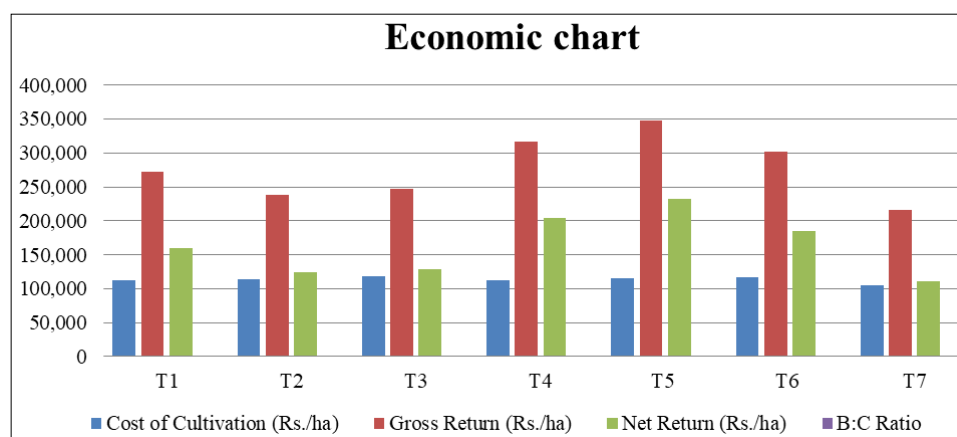


Fig 1: Effect of combination to bio- fertilizers on economics studies.

Conclusion

The present study revealed that the application of bio-fertilizers significantly influenced the growth, yield, quality and economics of carrot (*Daucus carota* L.) cv. Pusa Rudhira. Among the different treatments, Azospirillum@50% + VAM@50%; (T₅) recorded the highest values for growth and yield attributes, including plant height, number of leaves, leaf length, root weight, root length, root diameter and root yield. The same treatment also resulted in maximum gross return, net return and benefit-cost ratio, indicating its economic superiority. On the other hand, PSB@50% + VAM@50%; (T₆) produced

the best quality roots with higher TSS, ascorbic acid and total sugar content. Therefore, the combined application of Azospirillum and VAM can be recommended for obtaining higher yield and profitability, while PSB and VAM may be preferred for improving root quality. The study suggests that integrated use of bio-fertilizers is an effective and eco-friendly approach for sustainable carrot production under Prayagraj agro-climatic conditions.

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