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Effect of biofertilizers on growth of jackfruit (*Artocarpus heterophyllus* L.) and soil nutrients in South-East Rajasthan

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ABSTRACT

The soil application of different microbial consortia significantly influenced the growth, development, and soil nutrient status of jackfruit (Artocarpus heterophyllus L.) cv. Singapore Jack in South-East Rajasthan. Among the various treatments, the application of T_6 (a combination of Azospirillum, PSB, and KSB, 75g each per plant) was found to be significantly superior. The T_6 treatment resulted in notable improvements in growth and development parameters, including an 8.05% increase in rootstock girth, 15.0% in scion girth, 69.0% in plant height, 70.0% in the number of nodes per plant, 178.10% in the number of leaves per plant, a 22.92% increase in leaf area, and a chlorophyll content of 41.25 mg/100g in leaves. Additionally, T6 demonstrated superiority in enhancing soil health parameters viz., organic carbon content (0.61%), available nitrogen (326.33 kg/ha), phosphorus (36 kg/ha), and potassium (309.0 kg/ha).

Introduction

Jackfruit (*Artocarpus heterophyllus* L.) is one of the most important and widely cultivated fruit trees in tropical regions, belonging to the family Moraceae. It is native to the rainforests of the Western Ghats, a biodiversity hotspot in India. Jackfruit is also found in the wild and evergreen forests of Assam and Myanmar. Traditionally, the fruit has been a staple for the economically disadvantaged, often replacing rice as a primary meal component, earning it the title "the poor man's food" (Rahman *et al.*, 1999). Jackfruit is a powerhouse of phyto-nutrients with properties such as anti-cancer, antioxidant, antihypertensive, anti-ulcer, and anti-inflammatory effects. These attributes help combat oxidative stress, reduce the risk of chronic conditions like diabetes and heart disease, boost immune response, and promote skin and hair health. Additionally, the root of jackfruit has medicinal applications, offering relief from asthma and aiding in the treatment of diarrhoea and fever (Samaddar, 1985).

While modern intensive farming methods have increased crop yields, they are often associated with environmental pollution and health hazards, eventually leading to reduced agricultural productivity and threatening global food security. Fertilizer management plays a critical role in enhancing the growth and productivity of crops. Biofertilizers provide an eco-friendly and sustainable alternative to synthetic fertilizers. These live formulations, containing beneficial microorganisms, can be applied to roots, soil, or seeds, enhancing soil health and nutrient availability (Ismail *et al.*, 2013). Certain bacteria, such as phosphorus solubilizing bacteria (PSB) and potassium solubilizing bacteria (KSB), mobilize these essential nutrients into plant-usable forms. When used in combination, biofertilizers not only

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improve nutrient uptake but also offer additional benefits such as acting as bio-control agents against plant diseases, reclaiming degraded soils, breaking down organic waste, and remediating pesticides in the rhizosphere.

Despite its nutritional and ecological significance, jackfruit remains a neglected crop, with limited research on the role of biofertilizers in its cultivation. Hence, this study aims to evaluate the effect of biofertilizers on the growth and development of jackfruit plants, paving the way for more sustainable and productive farming practices for this underutilized crop.

Material and Methods

The study on the effect of different biofertilizers on the growth of jackfruit and soil nutrient status was carried out during 2020-2021 at the Instructional Farm, Department of Fruit Science, College of Horticulture and Forestry, Jhalarapatan, Jhalawar. The experiment was conducted on a newly established orchard of jackfruit cv. Singapore Jack. The experimental site is located between 23°4'and 24°52' N latitude and 75°29' and 76°56' E longitude. The experiment comprised seven treatments viz., T_0 (Control), T_1 (Azospirillum 25g), T_2 (PSB 25g), T_3 (KSB 25g), T_4 (Azospirillum 25g + PSB 25g + KSB 25g), T_5 (Azospirillum 50g + PSB 50g + KSB 50g) and T_6 (Azospirillum 75g + PSB 75g + KSB 75g). The experiment was arranged in a Randomized Block Design (RBD) with three replications.

Initial values for growth parameters, including rootstock girth, scion girth, plant height, number of nodes per plant, number of leaves per plant, leaf area, and chlorophyll content in leaves, were recorded in August 2020. Following the commencement of the experiment, observations on plant parameters were recorded at two-month intervals until March 2021. Soil parameters, such as available nitrogen (N), phosphorus (P), potassium (K), organic carbon percentage, bulk density, particle density, and porosity, were assessed at the beginning and end of the experiment. During the experimental period from August 2020 to March 2021, plant parameters were recorded at three intervals: October, December, and March. The data collected during the experiment were statistically analyzed using the methods outlined by Panse and Sukhatme (1995).

Results and Discussion

Growth parameters

The growth parameters of jackfruit plants, as influenced by different biofertilizers at varying levels, are presented in Table 1. Significant differences among treatments were observed across all stages of plant growth. The highest increases in rootstock girth (8.05%), scion girth (15%) and percentage increase in plant height (69%) were recorded under treatment T_6 (Azospirillum, PSB, and KSB at 75g each) during the final observations in March. Conversely, the lowest values were observed in the T_0 control treatment after the experiment. Treatment T_6 (Azospirillum, PSB, and KSB at 75g each) was significantly superior to all other treatments.

The data presented in Table 2 indicate that, at the end of the experiment in March, the maximum percentage increase in the number of nodes (70.0%) was observed under treatment T_6 (Azospirillum, PSB, and KSB at 75g each). This was closely followed by treatments T_5 and T_4 (Azospirillum, PSB, and KSB at 50g and 25g each, respectively), recording a 60.0% increase, with T_5 and T_4 being statistically at par. The minimum percentage increase in the number of nodes (37.50%) was recorded in the T_0 control treatment at the end of the experiment. These findings align with the results reported by Srivastava *et al.* (2019), Kumar *et al.* (2013), and Dheware *et al.* (2020) in guava cultivation. Better growth under this treatment over other treatments may be due to the higher effectivity of this treatment in the improvement of rhizosphere micro-environment providing all the macro and micronutrients required for the growth and development of plants. The effect of this treatment comparatively better over other treatments may also be explained in the background of better improvement of physico-chemical properties of the soil due to moderation of pH and EC, enrichment of the organic carbon, N, P, K status of the soil as reflected in the result besides probably due to better increased release of growth factors like auxins, gibberellins and cytokinin in root zone.

The data presented in Table 2 on the number of leaves per plant revealed significant differences among the various treatments. The maximum percentage increase in the number of leaves per plant (178.10%) was recorded under treatment T_6 (Azospirillum, PSB, and KSB at 75g each), followed by treatment T_5 (Azospirillum, PSB, and KSB at 50g each) with a 133.39% increase, observed during the final observations in March. In contrast, the minimum increase (63.69%) in the number of leaves per plant was recorded in the T_0 control treatment at the conclusion of the experiment. At the end of the experiment in March, the maximum percentage increase in leaf area (22.92%) was observed under treatment T_6 (Azospirillum, PSB, and KSB at 75g each), which was significantly higher than all other treatments. Additionally, the data indicated that T_6 also achieved the highest increase in chlorophyll content (41.45 mg/100g), followed closely by T_4 (39.23 mg/100g). In contrast, the minimum increase in chlorophyll content (35.24 mg/100g) was recorded in the T_0 control treatment. This may be due to the ability of phosphorous solubilizing bacteria (PSB) to produce growth-promoting substances such as IAA and gibberellins acid. It is also well known that PSB produces organic, inorganic acids and CO_2, which perhaps led to moderating soil acidity and consequently might convert the insoluble forms of phosphorus into soluble ones (Mosse *et al.*, 1981). Such an effect may also account for better results under treatment T_6 (Azospirillum, PSB, KSB) (75g each). Better improvement in proline content in the leaf may be due to water stress created during the growth period and the production of amino acid-like proline by this treatment containing different PGPR applied. These results agree with those of Mathur and Vyas (2000) as reported in *Ziziphus mauritiana* Lam. Kumar *et al.* (2013), who also a maximum increase in growth in banana plants inoculated with a combined inoculation of nitrogen fixers and PSB and Nandish *et al.* (2020) in jamun trees.

Table 1. Effect of biofertilizers on rootstock girth, scion girth and plant height of jackfruit

Treatments	Rootstock girth (mm)*				Scion girth (mm)*				Plant height (cm)*			
	Initial value (August 2020)	October 2020	December 2020	March 2021	Initial value (August 2020)	October 2020	December 2020	March 2021	Initial value (August 2020)	October 2020	December 2020	March 2021
T_0 (Control)	2.53	2.55 (1.04)	2.59 (2.36)	2.64 (2.75)	2.00	2.03 (1.56)	2.07 (3.74)	2.12 (6.07)	13.46	14.96 (11.13)	16.36 (21.53)	17.73 (31.68)
T_1 (Azospirillum 25g)	2.36	2.59 (0.55)	2.42 (2.53)	2.47 (4.95)	1.79	1.84 (2.96)	1.90 (5.93)	1.96 (99.39)	13.36	16.03 (19.95)	18.93 (41.64)	20.6 (54.11)
T_2 (PSB 25g)	2.83	2.85 (0.70)	2.87 (1.29)	2.93 (3.49)	1.66	1.71 (3.05)	1.75 (5.26)	1.87 (12.47)	11.36	13.50 (18.76)	14.50 (27.56)	15.63 (37.53)
T_3 (KSB 25g)	2.63	2.64 (0.45)	2.71 (2.98)	2.77 (5.48)	1.90	1.95 (2.58)	1.85 (4.98)	2.04 (7.19)	10.33	11.06 (7.09)	11.80 (14.19)	14.00 (35.48)
T_4 (Azospirillum 25g + PSB 25g + KSB 25g)	2.98	3.01 (0.93)	3.04 (1.94)	3.10 (3.88)	1.78	1.81 (1.53)	1.85 (4.15)	1.95 (9.50)	12.03	13.06 (8.58)	14.06 (16.89)	16.23 (34.90)
T_5 (Azospirillum 50g + PSB 50g + KSB 50g)	2.53	2.56 (1.24)	2.58 (2.03)	2.68 (5.74)	1.40	1.47 (4.71)	1.50 (7.100	1.60 (14.20)	11.76	15.00 (27.47)	18.06 (53.54)	19.66 (67.13)
T_6 (Azospirillum 75g + PSB 75g + KSB 75g)	2.89	2.92 (1.21)	2.98 (3.05)	3.12 (8.05)	1.82	1.94 (6.42)	2.00 (9.89)	2.09 (15.00)	10.43	14.36 (37.69)	16.50 (58.14)	17.63 (69.00)
CD at 5%	-	0.37	0.34	0.34	-	0.25	0.25	0.23	-	2.37	2.79	4.07
SEm±	-	0.12	0.11	0.11	-	0.08	0.08	0.07	-	0.77	0.90	1.32

*Percent values in parentheses

Table 2. Effect of biofertilizers on number of leaves, number of nodes and leaf area of jackfruit

Treatments	Number of nodes*				Number of leaves*				Leaf area (cm^2)*				Chlorophyll content (mg/100g)	
	Initial value (August 2020)	October 2020	December 2020	March 2021	Initial value (August 2020)	October 2020	December 2020	March 2021	Initial value (August 2020)	October 2020	December 2020	March 2021	Initial	Final
T_0 (Control)	5.33	5.66 (6.25)	6.00 (12.50)	7.33 (37.50)	2.10	2.22 (5.91)	2.44 (16.13)	3.44 (63.69)	3.99	4.07 (1.84)	4.14 (3.67)	4.28 (7.13)	34.24	35.24
T_1 (Azospirillum 25g)	3.66	4.00 (9.09)	4.33 (18.18)	5.33 (45.54)	0.95	1.16 (22.09)	1.34 (41.27)	2.10 (120.03)	4.40	4.56 (3.65)	4.65 (5.54)	4.86 (10.51)	35.28	37.60
T_2 (PSB 25g)	3.66	4.00 (9.09)	5.00 (36.36)	5.66 (54.54)	1.14	1.52 (32.56)	1.76 (54.00)	2.48 (116.73)	3.28	3.47 (5.66)	3.57 (8.70)	3.87 (17.87)	36.28	38.92
T_3 (KSB 25g)	3.33	3.66 (10.0)	4.60 (40.0)	5.00 (50.0)	1.37	1.67 (23.84)	1.86 (39.12)	2.86 (114.37)	2.72	2.90 (6.53)	3.09 (13.37)	3.27 (20.12)	34.14	36.20
T_4 (Azospirillum 25g + PSB 25g + KSB 25g)	3.33	3.66 (10.0)	5.00 (50.0)	5.33 (60.0)	1.14	1.51 (32.26)	1.72 (50.60)	2.29 (100.02)	3.08	3.15 (2.13)	3.18 (3.10)	3.31 (7.24)	35.26	39.23
T_5 (Azospirillum 50g + PSB 50g + KSB 50g)	3.33	3.66 (10.0)	4.00 (20.0)	5.33 (60.0)	1.14	1.64 (43.32)	1.89 (65.66)	2.67 (133.39)	3.37	3.54 (4.93)	3.70 (9.57)	4.08 (21.08)	36.33	38.39
T_6 (Azospirillum 75g + PSB 75g + KSB 75g)	3.33	4.00 (20.0)	5.33 (60.0)	5.66 (70.0)	1.72	2.83 (64.72)	3.41 (98.64)	4.78 (178.10)	4.36	4.73 (8.32)	5.09 (16.72)	5.36 (22.92)	35.45	41.45
CD at 5%	-	0.82	1.12	1.15	-	0.68	0.94	1.44	-	1.13	1.17	1.20	-	1.90
SEm±	-	0.26	0.36	0.37	-	0.22	0.30	0.46	-	0.36	0.38	0.39	-	0.61

*Percent values in parentheses

Soil parameters

The data presented in Figure 1 illustrate the variation in electrical conductivity and pH of the rhizosphere soil of jackfruit plants (cv. Singapore Jack) in response to different biofertilizer treatments, measured after the growth period from August 2020 to March 2021. Soil electrical conductivity (0.39 dS/m) and pH (7.34) were significantly lower under treatment T_6 (Azospirillum, PSB, and KSB at 75g each). In contrast, the highest soil electrical conductivity (0.65 dS/m) and pH (7.75) were observed in the control treatment. Similar findings were reported by Nandish *et al*. (2020), who observed a significant reduction in soil electrical conductivity in jamun with the application of Azospirillum, PSB, KSB, VAM and *Trichoderma harzianum* (100g).

The available nitrogen (N), phosphorus (P), and potassium (K) levels (kg/ ha) are presented in Figure 1. The highest levels of available nitrogen (326.33 kg/ ha), phosphorus (36 kg/ ha), and potassium (309.0 kg/ ha) were recorded under treatment T_6 (Azospirillum, PSB, and KSB at 75g each), which was found to be significantly superior to all other treatments. Conversely, the lowest levels of available N, P, and K were observed in the T_0 (Control) treatment. This may be due to its better effectiveness over other treatments in increased biological nitrogen fixation and phosphate solubilization. Some bacteria can solubilize inorganic P due to chelation, exchange reaction, phosphate production and excretion of organic acids that have a moderating effect on soil pH and render the insoluble phosphate into soluble form. Generally, the solubility of calcium phosphates and magnesium increases with decreasing pH. The increase in potassium content under the biofertilizer treatment T_6 (Azospirillum, PSB, KSB) (75g each) was found to be better than other treatments. This may be attributed to the comparatively higher dissolution rate of silicates and minerals, which release potassium (K), as well as the production of enzymes like chitinase and cellulase. These enzymes help break down minerals and enhance root exudation, which, in turn, accelerates microbial proliferation and respiration. This microbial activity may lead to oxygen depletion in the rhizosphere, facilitating denitrification, as reported by Mishustin *et al.* (1981) and Barker *et al.* (1997). These findings are consistent with the research work of Esitken *et al*. (2010), Manjunath *et al*. (1983), Hussain *et al*. (2017) and Singh *et al*. (2021) in custard apple cv. Raydurg.

The application of treatments increased soil organic carbon percentage, with the highest value (0.61%) observed under treatment T_6 (Azospirillum, PSB, and KSB at 75g each), as shown in Figure 2. Treatment T_2 (0.52%) was statistically at par with treatment T_3 (0.51%). The lowest soil organic carbon content (0.41%) was recorded in the control treatment (T_0). Among the different biofertilizer treatments, the minimum bulk density (1.28 Mg/ cubic m) and particle density (2.62 Mg/ cubic m) were recorded in treatment T_6 (Azospirillum, PSB, KSB at 75g each). In contrast, the highest bulk density (1.37 Mg/ cubic m) and particle density (2.66 Mg/ cubic m) were observed in the T_0 (Control) treatment. Additionally, treatment T_6 (Azospirillum, PSB, KSB at 75g each) exhibited the highest porosity (51.27%), followed by T_1 (Azospirillum at 25g) with 50.30%. The minimum porosity (33.61%) was recorded in the T_0 (Control) treatment. The improvement in physico-chemical properties of soil in treatment T_6 (Azospirillum, PSB, KSB) (75g) might be attributed to increased organic matter status and improved soil physical structure (bulk density, porosity), as suggested by (Gogoi *et al*., 2004). Relatively better soil pH in this treatment may be due to better production of various organic and inorganic acids produced by microorganisms. Microbial sources generally keep the soil pH neutral (Bagyaraj and Manjunath, 1980).

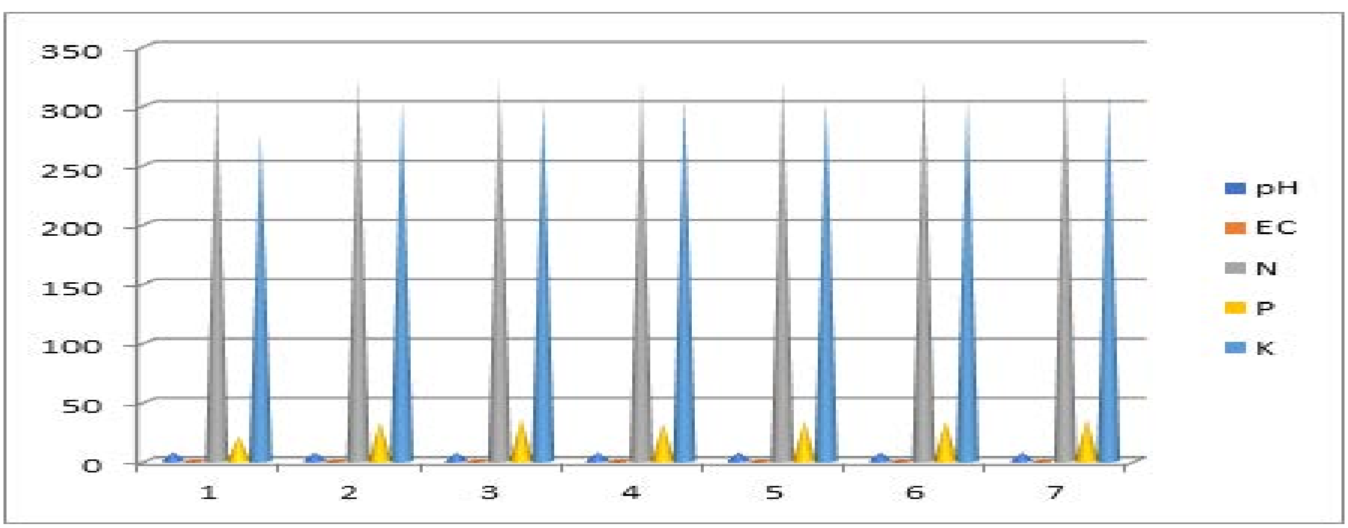
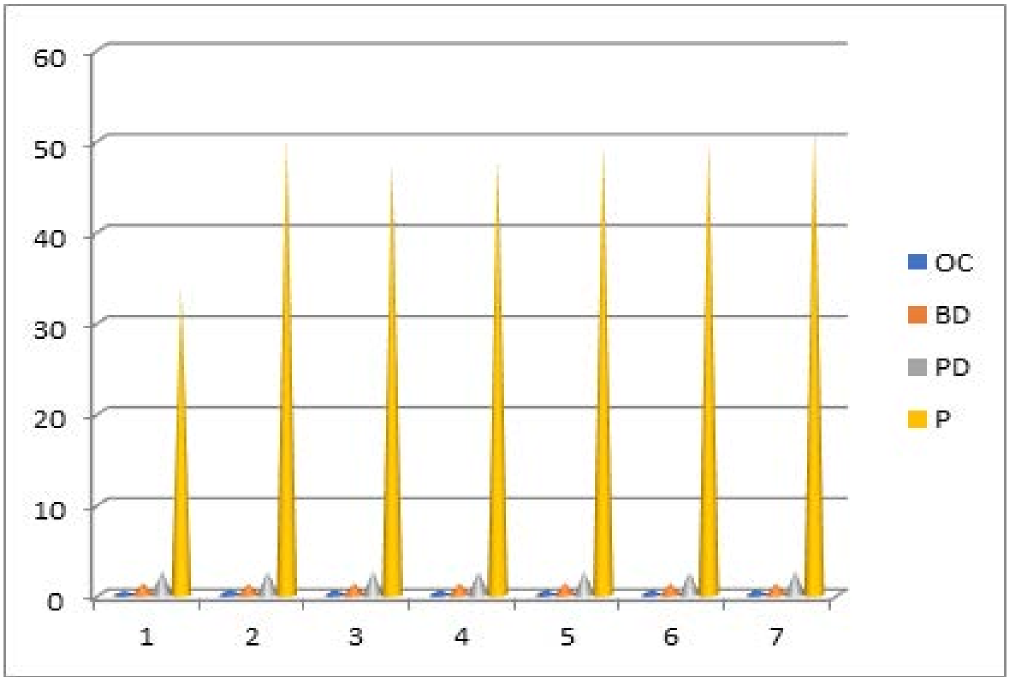


Fig. 1. Effect of biofertilizers on pH, Electrical Conductivity (EC), Nitrogen (N), Phosphorus (P) and Potassium (K) of orchard soil

Treatments



Treatments

Fig. 2. Effect of biofertilizers on Organic Carbon (OC), Bulk Density (BD), Particle Density (PD) and Porosity (P) of orchard soil

Conclusion

Based on the investigation, it can be concluded that the application of T6 (a combination of Azospirillum, PSB, and KSB, 75g each per plant) in jackfruit (*Artocarpus heterophyllus L.*) cv. Singapore Jack was significantly superior in improving both plant growth and development characteristics, as well as soil parameters. This treatment led to notable improvements in growth and development, including an 8.05% increase in rootstock girth, 15.0% in scion girth, 69.0% in plant height, 70.0% in the number of nodes per plant, a 178.10% increase in the number of leaves per plant, a 22.92% increase in leaf area, and a chlorophyll content of 41.25 mg/100g in leaves. The T_6 treatment demonstrated superiority in enhancing organic carbon content (0.61%), available nitrogen (326.33 kg/ha), phosphorus (36 kg/ha), and potassium (309.0 kg/ha). Therefore, the study concludes that T_6 (Azospirillum 75g + PSB 75g + KSB 75g) is the most effective treatment, surpassing both individual and combined microbial consortia in promoting jackfruit plant growth and improving soil quality.

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Conflict of Interest

The authors have no conflict of interest.

Data Sharing

All relevant data are within the manuscript.

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