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Effect of biofertilizers on germination and growth attributes of papaya (*Carica papaya* L.) cv. Pusa Nanha in polybags under shade net condition

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Abstract

The present study aims to investigate the "Effect of biofertilizers on germination and growth attributes of papaya (*Carica papaya* L.) cv. pusa nanha in polybags under shade net condition", at The Department of Horticulture, Sam Higginbottom University of Agriculture, Technology and Sciences, Allahabad, during the period 2023-25. The experiment was laid in completely randomized block design with three replications and fourteen treatment combinations. *viz*, T0 Control T_1 Azotobacter (100%), T_2 Bacillus (100%), T_3Trichoderma (100%), T_4Pseudomonas (100%), T_5Azotobacter (50%) + Trichoderma (50%), T_6Bacillus (50%) + Pseudomonas (50%), T_7Azotobacter (50%) + Pseudomonas (50%), T_8 Azotobacter (50%) + Bacillus (50%), T_9Pseudomonas (30%) + Bacillus (30%) + Azotobacter (40%), T_{10} Bacillus (30%) + Trichoderma (30%) + Azotobacter (40%), T_{11} Pseudomonas (30%) + Trichoderma (30%) + Azotobacter (40%) (40%), T_{12}Azotobacter (25%) + Bacillus (25%) + Trichoderma (25%) + Pseudomonas (25%), T_{13}Pseudomonas (25%) + Trichoderma (25%) + Bacillus (30%) + Azotobacter (20%)

Keywords: Azotobacter, bacillus, pseudomonas, Trichoderma, seed germination, seedling growth and establishment, papaya var. Pusa Nanha

Introduction

Papaya (*Carica papaya* L.) is an evergreen, herbaceous, and commercially important fruit crop, commonly referred to as the "wonder fruit of the tropics." Belonging to the family *Caricaceae*, papaya is believed to have originated in tropical America, particularly Mexico (Hofmeyr, 1938), and comprises about 48 known species. Historical evidence suggests that papaya was introduced to Africa and Asia following the discovery of the Americas.

Papaya is frequently described as a "heavy feeder crop" due to its rapid growth, continuous flowering and fruiting, and high productivity compared to many other fruit crops. It is widely cultivated as a filler plant in orchards and is ideally suited for kitchen gardens, backyards, and homestead gardens, particularly near urban and semi-urban areas.

The fruit is highly valued for its medicinal and curative properties, being effective in the treatment of piles, digestive disorders, spleen and liver issues, diphtheria, and skin blemishes. In India, papaya is cultivated across nearly all states, with a total area of approximately 1.38 lakh hectares and a production volume of 61.45 lakh metric tonnes (NHB, 2016-17). In Andhra Pradesh alone, the crop is grown over 13.56 thousand hectares with a production of 1288.58 thousand metric tonnes (Anonymous, 2017) [3].

Nutrient supply through organic manures and biofertilizers plays a critical role in maintaining soil fertility and ensuring optimum nutrient availability for sustained crop productivity and fruit quality. Papaya demonstrates adaptability to diverse soil types and is recognized as one of the richest sources of vitamin A. It also contains niacin, thiamine, riboflavin, and a unique yellow pigment called caricaxanthin, rather than the commonly assumed carotene.

Trichoderma species, a type of beneficial fungus, have been shown to induce metabolic changes in papaya that enhance resistance to various plant pathogens and viruses. Recent studies highlight the anti-inflammatory, wound-healing, antioxidant, and immunomodulatory properties of papaya (Agarwal *et al.*, 2016) [1]. Papaya leaves are rich in compounds such as cystatin, tocopherol, ascorbic acid, flavonoids, and cyanogenic glycosides like glucosinolates. Additionally, alkaloids, saponins, tannins, and glycosides present in the leaves contribute to their antibacterial, anti-tumor, and immune-modulating effects.

Papaya is also a rich source of vitamins C and E, along with powerful antioxidants that help reduce the risk of cardiovascular diseases. Per 100 grams of ripe fruit, papaya provides approximately 32 calories, 0.6 g of protein, 0.1 g of fat, 7.2 g of carbohydrates, and 2.6 g of fiber, making it beneficial for weight management, diabetes control, and stress reduction.

Due to its rapid growth, continuous flowering and fruiting, and high yield potential, papaya is especially sensitive to both major and minor nutrient deficiencies (Hari *et al.*, 2021) [9]. Since the fruiting is intermittent and begins soon after planting, nutrient management must be precise and consistent throughout the crop cycle (Mendonea *et al.*, 2006) [11].

The use of biofertilizers is gaining increasing attention as an eco-friendly alternative to chemical fertilizers, offering benefits such as improved soil health and sustainability (Chaudhri *et al.*, 2001) [5]. Overreliance on chemical fertilizers can negatively affect soil structure, health, and long-term productivity. In this context, the present study was undertaken to investigate the effects of organic manures and biofertilizers on the growth, yield, and nutrient uptake of papaya. Microorganisms present in biofertilizers enhance nutrient availability by converting nutrients from unavailable to available forms through biological processes (Athani *et al.*, 2009) [4].

2. Materials and Methods

2.1 Geographical location and Climate condition of the experimental area

The experimental site is located at 25.41° N latitude and 81.84° E longitude, at an elevation of about 98 m above mean sea level. The climate of Prayagraj is classified as subtropical, with distinctly hot summers and cool winters. During summer, temperatures may rise above 48 °C accompanied by dry, desiccating winds, whereas in winter, they may fall to around 2 °C with occasional frost. The region receives an average annual rainfall of approximately 1013 mm, the majority of which occurs during the monsoon months of July to September, with a few light showers in winter. Meteorological observations recorded during the experimental period (2024) were obtained from the Agro-Meteorological Observatory, Department of Horticulture, SHUATS, Prayagraj.

2.2 Experiment Details

The experiment was conducted at Commercial Fruit Nursery Unit; Department of Horticulture, Sam Higginbottom Institute of Agriculture, Technology and Sciences, Prayagraj, during the year 2024.

Table 1: Experiment Details

T. No.	Treatment Details
T_0	Control
T_1	Azotobacter (100%)
T_2	Bacillus (100%)
T_3	Trichoderma (100%)
T_4	Pseudomonas (100%)
T_5	Azotobacter (50%) + Trichoderma (50%)
T_6	Bacillus (50%) + Pseudomonas (50%)
T_7	Azotobacter (50%) + Pseudomonas (50%)
T_8	Azotobacter (50%) + Bacillus (50%)
T_9	Pseudomonas (30%) + Bacillus (30%) + Azotobacter (40%)
T_{10}	Bacillus (30%) + Trichoderma (30%) + Azotobacter (40%)
T_{11}	Pseudomonas (30%) + Trichoderma (30%) + Azotobacter (40%)
T_{12}	Azotobacter (25%) + Bacillus (25%) + Trichoderma (25%) + Pseudomonas (25%)
T_{13}	Pseudomonas (25%) + Trichoderma (25%) + Bacillus (30%) + Azotobacter (20%)

3. Results and Discussions

Days to 1st germination does not vary among different treatment combinations. However, maximum Days to 1st germination (8) was observed with T_{10} {Bacillus (30%) + Trichoderma (30%) + Azotobacter (40%)} followed by T_6 {Bacillus (50%) + Pseudomonas (50%)} and minimum Days to 1st germination (7) was observed in T_0 (Control).

Similar findings were reported by Nanjundappa *et al.* (2019) [12], who stated that enhanced plant growth may be due to Bacillus species stimulating nutrient uptake, activating plant defense, or interacting with AMF. Co-inoculation of AMF and Bacillus spp. has been shown to effectively boost plant growth.

The maximum seedling height (cm) at 30, 60 and 90 DAS was observed in T_{10} {Bacillus (30%) + Trichoderma (30%) + Azotobacter (40%)} (9.3, 24.6, 51.411) respectively. The minimum value of seedling height (cm) was observed in T_0 Control (7.21, 18.689, 43.444) respectively. The result obtained in this research work was found significant throughout the study. Similar findings were also reported by Dayeswari *et al.* (2017) [6] in papaya and by Hartmann and Kester (1997) too.

The maximum no. of leaves/plant at 30, 60 and 90 DAS was observed in T_{10} {Bacillus (30%) + Trichoderma (30%) + Azotobacter (40%)} (9.556, 13.111, 14.889) respectively. The minimum value of seedling height (cm) was observed in T_0 Control (7.11, 8.333, 11.889) respectively. The result obtained in this research work was found significant throughout the study. Similar results were reported by Sen *et al.* (1990) [13] in papaya seeds.

The maximum no. of branches/plant at 30, 60, and 90 DAS was observed in T_{10} {Bacillus (30%) + Trichoderma (30%) + Azotobacter (40%)} (9.33, 13.889, 16.222) respectively. The minimum value of seedling height (cm) was observed in T_0 Control (6.889, 10.556, 12.556) respectively. The result obtained in this research work was found significant throughout the study. Similar results were recorded by Fatria *et al.* (2021) [8] who observed that AMF and Trichoderma spp. act as biofertilizers that promote plant growth by enhancing nutrient uptake improving stress resistance, suppressing pathogens, and increasing plant survival and fruit quality.

The maximum days to emergence (8.556) was observed at T_{10} {Bacillus (30%) + Trichoderma (30%) + Azotobacter (40%)}. Minimum number of leaves per plant (8.111) was observed in T_0 (Control). Similar results were reported by Nanjundappa *et al.* (2019) [12].

The maximum Leaf Area Index (cm^2) at 30 and 60 DAS was observed in T_{10} {Bacillus (30%) + Trichoderma (30%) + Azotobacter (40%)} (32.492, 42.181) respectively. The minimum Leaf Area Index (cm^2) was observed in T_0 Control (18.952, 32.669) respectively. The result obtained in this research work was found significant throughout the study. Similar findings were reported by Wang *et al.* (2014) [14] terminate that leaf age and light intensity significantly influence papaya photosynthesis, with mature upper canopy leaves contributing most.

The maximum seedling vigour index (4,153.07) was observed with T_{10} {Bacillus (30%) + Trichoderma (30%) + Azotobacter (40%)}. The minimum value of seedling vigour index (1,734.61) was observed in T_0 (Control). The results were obtained in this research work was found significant throughout the study. Similar results were reported by Dayeswari *et al.* (2017) [6] found that the combination of Cocopeat, Vermicompost, Azospirillum, phosphobacteria, and Pseudomonas fluorescens significantly improved germination, growth, and biomass of seedlings due to enhanced nutrient availability and microbial synergy.

The maximum Germination percentage (80.553) was observed with T_{10} {Bacillus (30%) + Trichoderma (30%) + Azotobacter (40%)}. The minimum value Germination percentage (39.812) was observed in T_0 (Control). The results obtained in this research work was found significant throughout the study. Similar results were obtained by Dayeswari *et al.* (2017) [6] reported that maximum germination occurred with cocopeat, vermicompost, Azospirillum, phosphobacteria, and Pseudomonas fluorescens due to improved nitrogen fixation, moisture retention, and better media structure.

The maximum stem diameter (mm) (0.9) was observed in T_{10} {Bacillus (30%) + Trichoderma (30%) + Azotobacter (40%)}. The minimum value of stem diameter (mm) was observed in T_0 Control (0.622). The result obtained in this research work was found significant throughout the study. Anand *et al.* (2022) [2] reported that combining biofertilizers, FYM, and inorganic fertilizers significantly improved papaya growth and yield traits like plant height, stem girth, leaf number, and fruit size, while reducing plant height at first flower initiation.

The maximum Survival percentage (63.887) was observed with at T_{10} {Bacillus (30%) + Trichoderma (30%) + Azotobacter (40%)}. The minimum Survival percentage (35.183) was observed in T_0 (Control). The result obtained in this research work was found significant throughout the study. Desai *et al.* (2022) [7] found that *Trichoderma* enhances seed germination, promotes seedling vigour, and protects against pathogens through mycoparasitism and activation of plant defense. Similarly, Kumar *et al.* (2023) [10] reported that *Bacillus subtilis* produces growth-promoting and disease-suppressing metabolites.

Table 2: Effect of biofertilizers on germination and growth attributes of papaya (*Carica papaya* L.) cv. pusa nanha in polybags under shade net condition on different parameters.

T No.	Treatment Details	Days to 1st germination	Seedling height	No. of leaves / plant	No. of branches / plant	Days to emergence	Leaf area Index (cm^2)	Seedling vigour Index	Seed Germination (%)	Stem Diameter (mm)	Survival (%)
T_0	Control	7.000	23.11	9.11	10.00	8.111	25.811	1,734.61	39.812	0.622	35.18
T_1	Azotobacter (100%)	7.111	23.36	9.63	10.37	8.333	26.716	1,907.51	43.516	0.644	40.74
T_2	Bacillus (100%)	7.222	23.47	9.51	10.59	8.222	27.461	2,065.27	47.220	0.644	39.81
T_3	Trichoderma (100%)	7.222	23.92	9.55	10.40	8.222	29.512	2,002.47	46.295	0.667	37.96
T_4	Pseudomonas (100%)	7.556	24.44	9.74	10.25	8.222	29.116	1,852.77	41.664	0.667	36.11
T_5	Azotobacter (50%) + Trichoderma (50%)	7.556	25.20	9.40	10.96	8.222	31.187	2,190.19	46.294	0.633	37.03
T_6	Bacillus (50%) + Pseudomonas (50%)	7.889	23.95	9.48	11.11	8.222	30.512	1,959.08	43.516	0.667	37.03
T_7	Azotobacter (50%) + Pseudomonas (50%)	7.778	24.51	9.81	10.29	8.444	32.778	2,158.33	47.22	0.644	40.74
T_8	Azotobacter (50%) + Bacillus (50%)	7.556	24.90	9.40	10.81	8.333	32.327	2,392.01	50.923	0.711	41.66
T_9	Pseudomonas (30%) + Bacillus (30%) + Azotobacter (40%)	7.444	26.27	10.37	11.85	8.333	32.303	2,046.05	41.665	0.867	52.77
T_{10}	Bacillus (30%) + Trichoderma (30%) + Azotobacter (40%)	8.000	28.43	12.51	13.14	8.556	37.337	4,153.07	80.553	0.9	63.88
T_{11}	Pseudomonas (30%) + Trichoderma (30%) + Azotobacter (40%)	7.667	27.40	12.07	12.40	8.333	36.104	3,845.83	76.85	0.811	57.40
T_{12}	Azotobacter (25%) + Bacillus (25%) + Trichoderma (25%) + Pseudomonas (25%)	7.556	27.34	11.92	12.85	8.333	36.292	3,773.87	74.997	0.867	61.10
T_{13}	Pseudomonas (25%) + Trichoderma (25%) + Bacillus (30%) + Azotobacter (20%)	7.778	27.63	11.88	11.81	8.222	35.778	3,399.13	68.517	0.844	58.33
	F-test	NS	S	S	S	NS	S	S	S	S	S
	S. Ed.(±)	0.29	0.94	0.35	0.41	0.20	1.28	262.29	5.37	0.04	4.60
	C.D. at 0.5%	0.60	1.95	0.73	0.85	0.41	2.80	539.14	11.05	0.09	9.46

4. Conclusion

Based on the findings from the study, it can be inferred that treatment T_{10} {Bacillus (30%) + Trichoderma (30%) + Azotobacter (40%)} proved to be the most effective in facilitating overall plant growth and development in the agro-climatic conditions of Prayagraj. This treatment consistently surpassed others across various growth metrics. It demonstrated significant improvements in growth and yield parameters exhibiting a beneficial synergistic effect on vegetative growth and physiological performance. Consequently, T_{10} is recommended as the optimal treatment for enhancing plant growth in the Prayagraj region.

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