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Influence of Biofertilizers on Germination and Early Seedling Growth of *Artocarpus heterophyllus* Lam. under Nursery Conditions

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***Abstract*:** The effect of biofertilizer on seed germination and growth of *Artocarpus heterophyllus* Lam. under nursery conditions was evaluated during the 2023-24 at the College of Forestry, Sirsi, University of Agricultural Sciences, Dharwad. The experiment comprises seven treatments (control, *Azotobacter*, PSB, AM fungi, *Azotobacter* + PSB, PSB + AM fungi and *Azotobacter* + PSB + AM fungi) with three replications each. There was statistically significant improvements in all growth parameters with the use of biofertilizers over the control. Among all treatments, the combination of *Azotobacter* + PSB + AM fungi resulted in highest germination percentage (82.22%), maximum seedling height (33.50 cm at 90 days after sowing), highest number of leaves (5.70), maximum stem girth (1.12 cm), root length (17.1 cm), and the most vigorous seedlings as indicated by the seedling vigor index (4160.33). This treatment was significantly superior to the control which recorded the lowest performance across all parameters. Dual inoculation treatments (*Azotobacter* + PSB and PSB + AM fungi) also showed marked improvement compared to single inoculant applications (*Azotobacter*, PSB and AM fungi), highlighting the benefit of synergistic interactions among microbial species. The study concludes that the combined use of *Azotobacter*, PSB, and AM fungi significantly enhances seed germination and early seedling growth in jackfruit.

***Keywords*:** Biofertilizer, *Azotobacter*, Phosphate Solubilizing Bacteria (PSB), Arbuscular Mycorrhizal (AM), *Artocarpus heterophyllus*

Artocarpus heterophyllus Lam. is one of the most important tropical fruit tree species, extensively cultivated across many parts of Asia, particularly in India. Native to the Western Ghats, thrives in warm and humid climates and is highly valued for its large, sweet and nutritious fruits, which serve both as a staple food and a delicacy (Azad et al., 2007). Besides its fruit, jackfruit is also appreciated for its durable timber, contributing to its economic significance (Jambhale et al., 2016). However, cultivation and propagation face several challenges at the nursery stage like, poor seed germination rates and weak seedling vigour. These factors pose significant obstacles to large-scale propagation and field establishment (Singh et al., 2019). In recent years, there has been an increasing emphasis on sustainable and eco-friendly agricultural practices. Among these, the application of biofertilizers has emerged as a promising alternative to chemical fertilizers. Biofertilizers are formulations containing beneficial microorganisms that improve plant growth by facilitating the uptake of essential nutrients through natural processes like nitrogen fixation, phosphorus solubilization and the production of plant growth-promoting substances (Vessey 2003, Bhattacharyya and Jha 2012). Compared to synthetic fertilizers, biofertilizers are more environmentally sustainable, contribute to long-term soil fertility and enhance microbial diversity in the rhizosphere (Mishra and Dash 2014, Maharana Rashmiprava et al., 2018). Applying biofertilizers at the nursery stage has shown considerable benefits by establishing early microbial associations with plant roots, thereby improving seedling growth, root development and resilience against biotic and abiotic stresses (Bhardwaj et al., 2014). For perennial species like jackfruit, which demand robust and vigorous seedlings for successful transplantation and long-term survival, integrating biofertilizers into nursery practices can play a crucial role in ensuring higher productivity and sustainability (Kumar et al., 2017). With this background, the present study was undertaken to evaluate the effects of different biofertilizers like, *Azotobacter*, Phosphate Solubilizing Bacteria (PSB) and Arbuscular Mycorrhizal (AM) fungi on the germination and early growth of jackfruit seedlings under nursery conditions. The study aims to support the development of sustainable nursery management practices by identifying effective microbial combinations that enhance seedling quality and reduce dependency on chemical inputs.

MATERIAL AND METHODS

The study was conducted at the College of Forestry, Sirsi, which is located in the Uttara Kannada district of Karnataka. The experimental site lies at 14.620°N latitude and 74.850°E longitude, within the core region of the Western Ghats. The elevation of the site ranges from 1860 to 2600 feet above mean sea level. The experiment was conducted under polyhouse conditions, which are maintained under warm and humid tropical environment with an average temperature of 25-30 °C and relative humidity around 70 to 80%, ensuring optimum conditions for jack seed germination and seedling

growth. The experiment was laid out in a completely randomized block design comprising seven treatments each replicated three times (Table 1).

Each treatment included 20 seeds and the experimental units were randomly arranged to reduce environmental variability. These treatments were designed to evaluate both individual and combined effects of biofertilizers on seed germination and early seedling growth of jackfruit. For the experiment, healthy, mature, and undamaged jackfruit seeds were collected during August 2023. The seeds were thoroughly washed with clean water to remove adhering mucilage and other debris, followed by shade-drying for 12 to 24 hours. The dried seeds were then stored in polythene bags until sowing. Prior to sowing, a 10 ml solution of jaggery was prepared to serve as a binding agent for the biofertilizer. Each seed was coated with this jaggery slurry and 20 g of the carrier-based biofertilizer, according to the respective treatment, was applied evenly over the seeds to form a uniform microbial layer. The treated seeds were first sown in a standard nursery bed of dimensions 1.2 × 12.2 meters. After 30 days, the germinated seedlings were carefully transplanted into polybags measuring 5 × 7 inches. The potting mixture used in the polybags consisted of red soil, sand and vermicompost mixed in a 2:1:1 ratio. This mixture was thoroughly blended to ensure uniform texture and nutrient content. To facilitate proper drainage, three to four small holes were made at the base of each polybag. Regular nursery maintenance practices were followed throughout the experimental period. Watering was done once daily using a rose can to maintain adequate moisture levels in the rooting media. Observations were recorded at regular intervals of 30 days after sowing (DAS), with data collection continuing up to 90 DAS. The parameters observed included days to germination, plant height, number of leaves, stem girth, root length and seedling vigor index.

Germination was recorded based on the number of days taken for the seeds to sprout, which typically occurred by 15 DAS. Plant height was measured from the base to the tip of the shoot. The number of leaves was manually counted for each seedling. Stem girth was calculated by measuring the collar diameter at 1 cm above the ground level using a digital calliper and then multiplying it by π (3.142) to obtain the girth in centimetres. Root length was recorded at 90 DAS using a measuring scale. The seedling vigor index was computed by multiplying the germination percentage with the average seedling height recorded at 90 DAS.

Statistical analysis: The data was analysed by using opstat app.

RESULTS AND DISCUSSION

Germination percentage: The significant variations among the different treatments was observed (Table 1). The highest germination percentage was observed in T_7 (82.22%), which involved a combined application of *Azotobacter*, phosphate solubilizing bacteria (PSB), and Arbuscular mycorrhizal (AM) fungi. In contrast, the lowest germination percentage (64.45%) was recorded in the control.

Seedling growth: Maximum seedling height at 30 DAS was in T_7 (*Azotobacter*+Phosphate solubilizing bacteria+ Arbuscular mycorrhiza fungi) (18.73 cm) followed by T_5

Table 1. Influence of microbial inoculants on jack fruit seedlings growth and vigor index at different intervals

Treatments	Germination percentage (%)	Plant height (cm)			Number of leaves per seedlings			Stem girth (cm)			Root length (cm)	Seedling vigor index at 90 DAS
		30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS		
$T_{1=}$ Control	64.45	11.00	13.67	20.53	1.60	2.53	4.00	0.34	0.52	0.57	9.80	1954.98
$T_{2=}$ *Azotobacter* (20g)	71.11	13.40	16.40	23.07	2.33	2.83	4.50	0.38	0.64	0.72	10.50	2386.93
$T_{3=}$ Phosphate solubilizing bacteria (20g)	74.56	16.60	19.57	26.37	2.67	3.30	4.53	0.40	0.68	0.77	12.20	2875.53
$T_{4=}$ Arbuscular mycorrhiza fungi (20g)	71.11	14.77	17.33	23.33	2.33	3.07	4.80	0.44	0.70	0.81	14.30	2676.11
$T_{5=}$ *Azotobacter* (10g) + Phosphate solubilizing bacteria (10g)	80.56	17.63	22.27	30.17	2.67	3.60	5.00	0.57	0.78	0.98	14.70	3614.46
$T_{6=}$ Phosphate solubilizing bacteria (10g) + Arbuscular mycorrhiza fungi (10g)	78.44	16.63	20.13	28.17	2.83	3.17	4.80	0.51	0.73	0.88	15.40	3417.37
$T_{7=}$ *Azotobacter* (7g) + Phosphate solubilizing bacteria (7g) + Arbuscular mycorrhiza fungi (6g)	82.22	18.73	24.37	33.50	3.00	4.17	5.70	0.67	0.94	1.12	17.10	4160.33
CD (p=0.05)	4.97	1.50	1.63	2.48	0.76	0.73	0.83	0.06	0.09	0.09	1.35	190.32

DAS=Days after sowing

(Table 1). The lowest plant height was in T_1 (11.0 cm), which had no microbial inoculation. At 60 DAS, the same trend was observed with minimum plant height was in T_1 (13.67 cm). At 90 DAS, the maximum seedling height was also in T_7 (33.50 cm). At 30 DAS, T_7 treatment produced maximum number of leaves (3.0) followed by T_5. The lowest number of leaves were recorded in uninoculated control seedling T_1 (1.60). At 60 DAS, same trend was observed.

The lowest number of leaves (2.53) were recorded in T_1. At 90 DAS, maximum number of leaves were observed in T_7 (5.70) followed by T_5 and the lowest number of leaves were in T_1 (4).At 30 DAS, the maximum stem girth (0.67 cm) was recorded in T_7 (*Azotobacter* + PSB + AM fungi) followed by T_5 (*Azotobacter* + PSB) (Table 1). The minimum stem girth was in T_1 (0.34 cm). At 60 DAS maximum stem girth was in T_7 (0.94 cm) followed by T_5. The minimum stem girth was found in T_1 (0.52 cm) which includes uninoculated treatments. At 90 DAS, the maximum stem girth was recorded in T_7 (1.12 cm) followed by T_5. The minimum stem girth was in T_1 (0.57 cm) which includes control treatment. The root length of *A. heterophyllus* seedlings, was influenced by various biofertilizers applications. At the end of the experiment maximum root length was d in T_7 (17.1 cm) followed by T_6. The lowest root length was recorded in T_1 (9.8 cm). The seedling vigor index (SVI) at 90 days after sowing (DAS) showed significant variation across the different biofertilizer treatments. The highest SVI was recorded in treatment T_7 (4160.33) followed by T_5 and T_6 which is 3614.459 and 3417.37, respectively. Lowest SVI was observed in T_1 (1954.98) which includes control treatment.

The present study demonstrates that microbial inoculation significantly influenced the germination, seedling height, number of leaves per plant, stem girth, root development and vigor of *A. heterophyllus.* The highest germination percentage due to *Azotobacter* + PSB + AM fungi application confirms that a consortium of beneficial microorganisms can synergistically enhance seed germination and early establishment. This enhancement can be credited to greater accessibility of key nutrients, notably nitrogen and phosphorus. The production of growth-promoting phytohormones such as indole-3-acetic acid (IAA) and gibberellins that stimulate seed metabolism and embryo development. Khalid et al. (2017) in similar studies reported that microbial consortia containing beneficial fungi and bacteria improved germination and vigor in fruit crops through nutrient enrichment and hormonal stimulation. Kumar et al. (2022) also observed that biofertilizers improved nutrient mobilization, leading to faster germination and stronger seedling emergence. Parveen and Kumar (2020) found that the use of microbial inoculants (*Azospirillum brasilense* + *Bacillus polyxyma* + VAM) in *Acacia nilotica* enhanced early seedling vigor through better root colonization and nutrient uptake.

Seedling growth parameters like plant height, number of leaves, stem girth and root length were consistently higher in inoculated seedlings, particularly in T_7 (*Azotobacter* + PSB + AM fungi). The improvement in plant height and leaf number can be attributed to the combined functional roles of the inoculants. *Azotobacter* fixes atmospheric nitrogen, PSB solubilizes insoluble phosphates, and AM fungi enhance nutrient and water absorption through their extensive hyphal networks. Kumar et al. (2022) reported a similar trend in multiple horticultural species, where microbial inoculants promoted shoot elongation and leaf expansion due to increased nutrient uptake and phytohormone production. Mohan and Rajendran (2020) observed that combined inoculation of biofertilizers, *Azospirillum* + AM fungi + pseudomonas improved shoot growth and collar diameter in *Feronia elephantum*, attributing it to the complementary actions of nitrogen-fixing and phosphate-solubilizing microbes. After six months of biofertilizer inoculation in *Casuarina equisetifolia*, the treatment combining *Frankia*, *Azospirillum*, and *Phosphobacterium* resulted in significantly greater root length, shoot length, collar diameter, and both root and shoot biomass compared to other treatments (Saravanan et al., 2012). Similarly, the enhancement in seedling biomass production is likely associated with increased nitrogen accumulation facilitated by *Azospirillum* and *Azotobacter* and elevated phosphorus uptake resulting from inoculation with AM fungi and PSB (Ratha Krishnan et al., 2004), while Rajeshkumar et al. (2009) concluded that combined inoculation of biofertilizers improved shoot height and dry matter accumulation in *Melia azedirach*. Ayswarya (2008), *Tectona grandis* seedlings treated with the combined inoculation of AM fungi + *Azospirillum* + *Azotobacter* + PSB showed the highest microbial inoculation effect (MIE), shoot and root growth, biomass accumulation, and overall vigor, indicating that combined application of microbial inoculants effectively improved nutrient uptake and plant development compared to single or dual inoculations.

Enhanced stem girth and root length in inoculated seedlings indicate that microbial inoculants promoted superior nutrient assimilation, carbon allocation, and tissue differentiation. *Azotobacter* and PSB likely enhanced the nitrogen and phosphorus supply, while AM fungi stimulated root branching and root hair formation, improving soil nutrient exploration. Nowak (1998) explained that microbial associations particularly AM fungi have greater importance to improve root colonization and overall root system architecture, leading to better nutrient uptake and water

absorption. Further, the association of AM fungi greatly enhances the root surface area through the development of extensive hyphal networks. This symbiosis improves water uptake and transpiration efficiency, helps regulate leaf temperature, slows down chlorophyll degradation, and ultimately contributes to better overall seedling quality (Ajeesh et al., 2015). Chauhan et al. (2023) found that Neolamarckia cadamba seedlings inoculated with AM fungi exhibited greater stem thickness and root length compared to uninoculated controls. Khalid et al. (2017) also noted that microbial inoculants containing *Azotobacter* and AM fungi improved root structure and function through the production of auxin-like compounds. Madan et al. (1995) observed that AM fungal inoculation significantly increased root dry weight in Anthocephalus excelsa, Pongamia glabra, and Cassia siamea. The seedling vigor index (SVI) was highest in T_7 (*Azotobacter* + PSB + AM fungi), reflecting the cumulative benefits of improved germination, enhanced shoot elongation, and robust root growth. The combined effect of *Azotobacter*, PSB, and AM fungi enhanced overall nutrient uptake, hormonal stimulation, and physiological efficiency. Sreedhar and Mohan (2016) observed that dual inoculation of VAM and Azospirillum significantly increased SVI and biomass in *Neolamarckia cadamba*. Firuzsalari et al. (2012) also identified SVI as a reliable indicator of vigor improvement in inoculated seedlings with *Azospirillum, Azotobacter* and *Pseudomonas*. Vairamani and Rajendran (2021) confirmed that integrated microbial inoculation (*Azospirillum* + *Paenibacillus polymyxa* + AMF) enhanced SVI and stress tolerance in *Casuarina junghuhniana* seedlings. Therefore, the integrated microbial inoculation with *Azotobacter*, PSB, and AM fungi is an effective and sustainable approach to enhance the early growth and establishment of jack seedlings. Khalid et al. (2017) emphasized the role of microbial consortia in stimulating plant growth and nutrient cycling in fruit crops, while Kumar et al. (2022) highlighted the sustainability benefits of biofertilizers as eco-friendly alternatives to chemical fertilizers. Therefore, the integrated biofertilization can play a vital role in improving nursery productivity and field establishment in *Artocarpus heterophyllus* cultivation.

CONCLUSION

Among the seven treatments, the combined application of *Azotobacter*, Phosphate Solubilizing Bacteria and Arbuscular Mycorrhizal fungi consistently outperformed all other treatments across key growth parameters. This treatment recorded the highest germination percentage, plant height, number of leaves, stem girth, root length, and seedling vigor index at all observation stages. In contrast, the control group without any microbial treatment exhibited the lowest performance in all measured traits, reinforcing the importance of microbial inputs for seedling development. These findings indicate that the use of selected biofertilizers can greatly improve the early growth, establishment and overall vigour of jackfruit seedlings. *Azotobacter* + PSB + AM fungi offers a practical, sustainable and cost-effective strategy to produce high-quality planting material.

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