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Study on Inorganic Fertilizers and Biofertilizers on Growth and Production of Papaya (*Carica Papaya L.)* Cv. Red Lady

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Abstract
The present investigation entitled "Study on Inorganic Fertilizers and Biofertilizers on Growth and Production of Papaya (Carica papaya L.) cv. Red Lady" was carried out during the Rabi season at the Instructional Research Farm of G. H. Raisoni University, Dhoda Borgaon, Village–Saikheda, Tah. Sausar, Dist. Pandhurna (M.P.), with the objective of studying the effect of different levels of inorganic fertilizers integrated with varying doses of biofertilizers (Azotobacter, Phosphate Solubilizing Bacteria, and Potassium Solubilizing Bacteria) on the vegetative growth, yield, and economics of papaya cv. Red Lady. The experiment was laid out in Randomized Block Design (RBD) with nine treatments and three replications, comprising T_1: 100% RDF (Control), T_2: 100% RDF + 50 g each of Azotobacter, PSB and KSB, T_3: 100% RDF + 25 g each of Azotobacter, PSB and KSB, T_4: 75% RDF + 50 g each of Azotobacter, PSB and KSB, T_5: 75% RDF + 25 g each of Azotobacter, PSB and KSB, T_6: 50% RDF + 50 g each of Azotobacter, PSB and KSB, T_7: 50% RDF + 25 g each of Azotobacter, PSB and KSB, T_8: 25% RDF + 25 g each of Azotobacter, PSB and KSB, and T_9: 25% RDF + 50 g each of Azotobacter, PSB and KSB. Data recorded on eleven growth and yield parameters were subjected to analysis of variance, and the treatment effects were found highly significant ($p < 0.01$) for all the characters studied. Among the nine treatments, T_4 (75% RDF + 50 g Azotobacter + 50 g PSB + 50 g KSB) recorded the maximum plant height (243.39 cm), plant (31.60 kg/plant), and also recorded the minimum (earliest) days to first flowering (140.14 days) and days to fruit maturity (199.37 days). The maximum Leaf Area Index (5.00) was plant girth (32.21 cm), number of leaves per plant (62.25), leaf area (1912.04 cm²), number of nodes (71.21), number of fruits per plant (32.78), fruit weight (1924.30 g), and fruit yield per recorded under T_2, statistically at par with T_4 (4.96). The lowest performance across nearly all growth and yield parameters was recorded under T_1 (100% RDF alone, control), confirming that sole reliance on inorganic fertilization was the least effective nutrient management strategy. Treatment T_4 recorded approximately 49 per cent more fruits per plant and 54.8 per cent higher fruit yield per plant than the control.

Keywords: Papaya, Red Lady, biofertilizers, Azotobacter, PSB, KSB, RDF, integrated nutrient management, growth, yield, economics, benefit-cost ratio

Introduction

Horticulture occupies a position of immense significance in Indian agriculture, contributing substantially to nutritional security, rural employment, and economic prosperity. Among the various fruit crops that constitute the horticultural wealth of India, papaya (*Carica papaya* L.) holds a place of exceptional distinction. Belonging to the family Caricaceae, papaya is a fast-growing, soft-wooded, herbaceous, semi-perennial tree that is native to tropical America, with its centre of origin traced to the lowlands of South Mexico and Central America (Purseglove, 1968). It has since spread across all tropical and subtropical regions of the world and today stands as one of the most widely cultivated and commercially important fruit crops globally. Papaya is often referred to as the '*fruit of angels*' — a term famously attributed to Christopher Columbus — owing to its exceptionally pleasant taste, attractive appearance, and remarkable nutritional profile. The fruit is an outstanding source of vitamin A (in the form of carotenoids), vitamin C, folate, potassium, and dietary fibre. It also contains papain and chymopapain, two powerful proteolytic enzymes with wide applications in the pharmaceutical, food processing, textile, leather, and cosmetic industries Badrie and Schauss, 2010 [1].

Green papaya latex is commercially harvested for papain, which is used as a meat tenderizer, in the brewing industry, and in the preparation of digestive supplements. The seeds, leaves, and roots of the plant also possess well-documented medicinal properties, including antimicrobial, anti-inflammatory, and anthelmintic activities.

India occupies the foremost position among all papaya-producing nations in the world. According to the National Horticulture Board (NHB, 20232), India contributes approximately 44 per cent of the world's total papaya production, making it the undisputed global leader in this crop. The major papaya-growing states in India include Andhra Pradesh, Gujarat, Karnataka, Maharashtra, Tamil Nadu, Madhya Pradesh, West Bengal, Assam, Kerala, and Orissa. The crop is cultivated across diverse agro-climatic zones and is particularly well-suited to the warm, humid tropical and subtropical conditions that prevail in the Deccan Plateau, the Indo-Gangetic Plain, and the peninsular regions of the country.

According to the Final Estimates for 2024–25 and the First Advance Estimates for 2025–26 released by the Department of Agriculture and Farmers Welfare, Government of India (DAFKW, 2026), India's total horticultural production has reached a new high of 370.74 lakh tonnes in 2024–25, up from 354.74 lakh tonnes in 2023–24. Total fruit production in 2024–25 is estimated at 117.65 lakh tonnes, reflecting a growth of 4.13 per cent over the previous year, driven significantly by gains in banana, mango, mandarin, papaya, guava, watermelon, and jackfruit. For the year 2025–26, total horticulture production is projected to reach 370.85 lakh tonnes, with fruit production anticipated at 118.68 lakh tonnes, indicating a sustained upward trajectory. Within fruits, papaya has been specifically identified as one of the key contributors to this national production surge. At the state level, Madhya Pradesh — the state in which the present investigation was conducted — is one of the leading producers of papaya in India, contributing significantly to the national basket (Indiastat, 2025).

The present investigation was carried out at the Instructional Research Farm of G. H. Raisoni University, Dhoda Borgaon, Village — Saikheda, Tah. Sausar, Dist. Pandhurna, Madhya Pradesh. This region falls within the Satpura hill range belt of central India, characterized by deep black cotton soil (Vertisols), warm semi-arid climate, and well-defined monsoon rainfall patterns. The soil and climatic conditions of this zone are broadly conducive to the cultivation of tropical and subtropical fruit crops including papaya, offering an appropriate environment to study the response of the crop to different nutritional management strategies. Situated in the agrarian landscape of the Chhindwara–Pandhurna corridor, the university farm provides an ideal experimental platform for research aimed at developing economically viable and ecologically sustainable horticulture production systems for the farming communities of the region.

Papaya is a remarkably versatile crop that can be grown in a wide range of soils, provided adequate drainage is ensured. It thrives best in deep, well-drained, loamy soils with a pH range of 6.0 to 6.5 and requires a warm temperature between 25°C and 30°C for optimal growth. Being sensitive to waterlogging, frost, and strong winds, careful site selection is essential for successful cultivation. The crop has a relatively short gestation period and begins fruiting within six to nine months of transplanting under favourable conditions, making it one of the quickest-income-generating perennial fruit crops available to farmers. The productive commercial life of a papaya orchard typically spans two to four years. The average yield ranges from 40 to 60 tonnes per hectare under normal management, while modern high-yielding varieties and improved cultural practices can push productivity well beyond 100 tonnes per hectare (NHB, 2023). The variety selected for the present study, *cv.* Red Lady (F^1 hybrid; Taiwan 786), is one of the most commercially successful papaya hybrids in the world. Developed and marketed by Known-You Seed Company, Taiwan, Red Lady is an early-maturing, vigorous, and high-yielding F^1 hybrid that exhibits strong tolerance to Papaya Ring Spot Virus (PRSV), the most economically damaging pathogen of papaya worldwide. The plants begin to bear fruits at a height of only 60–80 cm, with over 30 fruits per plant in each fruiting season. Fruits are short-oblong on female plants and elongated on bisexual plants, weighing approximately 1.5 to 2.0 kg each. The flesh is thick, red, and sweet with a total soluble solids (TSS) content of approximately 13 per cent, making it highly preferred in both fresh markets and food processing. The potential yield of *cv.* Red Lady has been recorded at up to 120 tonnes per hectare over its two-year productive life cycle (TNAU, 2020). Its excellent fruit quality, disease tolerance, and market acceptance make it the most widely recommended variety for commercial papaya cultivation in India, including the central Indian region.

Papaya is an exceptionally heavy feeder and has high nutrient demands commensurate with its rapid vegetative growth and prolific fruiting. Adequate and timely supply of nutrients — particularly nitrogen (N), phosphorus (P), and potassium (K) — is critical to achieving optimal growth, maximizing yield, and improving fruit quality attributes. The recommended dose of fertilizers (RDF) for papaya in India generally varies by state and variety but commonly falls in the range of 200–300 g N, 200–250 g P^2O^5, and 400–500 g K^2O per plant per year. Inorganic fertilizers — particularly urea, single superphosphate, and muriate of potash — have traditionally been the primary nutrient sources in papaya cultivation and are known to produce significant improvements in vegetative and reproductive growth when applied at optimal rates and schedules Chandra, 2014 [2]. However, exclusive dependence on chemical fertilizers has raised serious concerns regarding soil health, progressive decline in soil organic matter, long-term reduction in the population and diversity of beneficial soil microflora, and negative environmental externalities including leaching and eutrophication Dahunsi *et al*., 2021 [3]. In this context, the strategic integration of biofertilizers with reduced doses of inorganic fertilizers has emerged as a scientifically sound and practically viable approach for sustainable intensification of papaya production. Biofertilizers are preparations containing living or latent cells of efficient strains of microorganisms that, when applied to seed, soil, or plant surfaces, colonize the rhizosphere and augment the supply of plant nutrients through biological processes. The major categories of biofertilizers relevant to fruit crops include nitrogen-fixing bacteria such as *Azotobacter chroococcum*, Phosphate Solubilizing Bacteria (PSB) such as *Bacillus* and *Pseudomonas* spp., and Potassium Solubilizing Bacteria (KSB). Azotobacter, being a free-living aerobic nitrogen fixer, is capable of fixing 20 to 30 kg atmospheric nitrogen per hectare per annum and simultaneously produces phytohormones such as gibberellins, auxins, and cytokinins that stimulate root development and shoot growth Bhattacharyya and Jha, 2012 [4]. PSB enhance the availability of soil phosphorus by solubilizing insoluble inorganic phosphates through the production of organic acids, phosphatases, and siderophores, while KSB mobilize fixed potassium in the soil, thus improving multi-nutrient use efficiency (Frontiers in Microbiology, 2021). Combined inoculation of biofertilizers with reduced chemical fertilizers has been consistently reported to improve soil biological activity, crop growth parameters, fruit yield, and fruit quality in papaya and other tropical fruit crops Hari and Binu, 2021[5].

Several researchers have demonstrated that the substitution of 25 to 50 per cent of the recommended dose of inorganic fertilizers with biofertilizers can sustain or even enhance productivity while simultaneously reducing input costs, improving soil health, and lowering the environmental footprint of crop production. Studies by Chandra 2014 [2] reported that application of recommended dose of NPK combined with FYM and *Pseudomonas straita* inoculation gave the highest plant height, trunk girth, number of leaves, and fruit yield in papaya. Similar results favouring integrated use of inorganic fertilizers with Azotobacter, PSB, and KSB were documented by Hari and Binu 2021 [5] at Kerala Agricultural University for several growth and yield parameters of papaya. In the present study conducted in Jhalawar (Jhalawar College of Horticulture and Forestry, 2023–24), soil application of 75% RDF combined with Azotobacter, PSB, and KSB was found to be significantly superior for plant height, plant girth, number of leaves, leaf area, and related growth parameters of papaya *cv.* Red Lady over sole application of inorganic fertilizers, indicating a clear synergism between chemical and biological nutrient sources (Research Gate, 2024).

The economic dimension of fertilizer management in papaya is equally important. Papaya cultivation is a capital-intensive enterprise, and input costs — particularly fertilizer costs — constitute a significant proportion of the total cost of cultivation. Integration of biofertilizers offers growers the dual advantage of reducing expenditure on chemical fertilizers while maintaining or improving productivity, thereby enhancing the benefit-cost ratio and net returns from the crop. Cost-benefit analyses of integrated nutrient management in papaya have consistently demonstrated superior economic returns compared to sole application of inorganic fertilizers at full recommended doses. Given the context of rising fertilizer prices and the policy thrust of the Government of India towards balanced and sustainable nutrition management in agriculture, the economic evaluation of bio-intensive nutrient management strategies in papaya assumes considerable relevance and policy significance. Despite the voluminous research literature available on fertilizer management in papaya in various agro-climatic zones of India, comprehensive information specific to the black cotton soil belts of the Satpura plateau region of Madhya Pradesh — encompassing growth parameters, yield attributes, and economics simultaneously — remains limited. Moreover, the performance of the commercially dominant *cv.* Red Lady under integrated inorganic-biofertilizer regimes in the central Indian context warrants thorough scientific investigation. The present study was therefore conceptualized and executed at G. H. Raisoni University, Saikheda, Dist. Pandhurna Mdyapradesh

Materials and Methods

The present investigation entitled “Study on Inorganic Fertilizers and Biofertilizers on Growth and Production of Papaya (*Carica papaya* L.) cv. Red Lady” was conducted at University Research Farm, GHRU, Saikheda in Kharif Season of 2025, are presented and described in this chapter. Data pertaining to various criteria used for treatment evaluation were analyzed statistically to test their significance and analysis of variance for these data has been given in appendices at the end. The research trail was carried on papaya crop cv. Red Lady. The application of Recommended Dose of Fertilizers, Azotobacter,PSB and KSB in different form and combinations, T_1 100% RDF (Control), T_2 100% RDF + 50 g Azotobacter + 50 g PSB + 50 g KSB,T_3 100% RDF + 25 g Azotobacter + 25 g PSB + 25 g KSB,T_4 75% RDF + 50 g Azotobacter + 50 g PSB + 50 g KSB, T_5 75% RDF + 25 g Azotobacter + 25 g PSB + 25 g KSB, T_6 50% RDF + 50 g Azotobacter + 50 g PSB + 50 g KSB, T_7 50% RDF + 25 g Azotobacter + 25 g PSB + 25 g KSB, T_8 25% RDF + 25 g Azotobacter + 25 g PSB + 25 g KSB, T_9 25% RDF + 50 g Azotobacter + 50 g PSB + 50 g KSB was used for the experiment for observed the growth, yield, and related parameters from randomly selected tagged plants in each treatment replication. i.e. Days taken to first flowering, Days taken to fruit maturity, Plant height, Plant girth, Number of nodes, Number of leaves per plant, Leaf area, Leaf Area Index (LAI), Fruit weight, Number of fruits per plant, Fruit yield per plant.

Analysis of Variance (ANOVA)

The mean sum of squares (MSS) due to treatments and error, obtained from the analysis of variance for all eleven growth and yield traits of papaya *cv.* Red Lady, are presented in Table 1. The treatment mean sum of squares were tested against the error mean sum of squares for each trait, and the F-values so obtained were found to be significant at the 1% level of probability ($p < 0.01$) for all eleven characters — days to 1st flowering, days to fruit maturity, number of leaves per plant, leaf area, leaf area index, plant girth, number of nodes, plant height, fruit weight, number of fruits per plant, and fruit yield per plant. This confirms that the differences among the nine treatment combinations (inorganic fertilizer levels integrated with varying doses of *Azotobacter*, phosphate-solubilising bacteria (PSB), and potassium-solubilising bacteria (KSB)) were not due to chance, and that the treatments exerted a highly significant influence on every growth and yield parameter studied. Among the traits, leaf area and fruit weight showed the largest treatment mean sum of squares (59644.7227 and 47431.1056, respectively), reflecting the greatest absolute magnitude of variation induced by the treatments, while leaf area index showed the smallest (0.8049), consistent with its naturally narrow numerical range.

Table 1: Mean Sum of Squares (MSS) from ANOVA for Growth and Yield Traits of Papaya cv. Red Lady

S. No.	Source of Variation	df (Treatment)	df (Error)	MSS Treatment	MSS Error
1	Days to 1st Flowering	8	18	266.5010**	4.0475
2	Days to Fruit Maturity	8	18	66.9083**	9.1176
3	No. of Leaves per Plant	8	18	98.8093**	0.4578
4	Leaf Area (cm²)	8	18	59644.7227**	3854.7151
5	Leaf Area Index (LAI)	8	18	0.8049**	0.0083
6	Plant Girth (cm)	8	18	18.8698**	1.1983
7	Number of Nodes	8	18	23.8318**	4.0092
8	Plant Height (cm)	8	18	822.1612**	15.6348
9	Fruit Weight (g)	8	18	47431.1056**	2928.1387
10	Number of Fruits per Plant	8	18	34.1202**	0.4178
11	Fruit Yield (kg/plant)	8	18	38.9431**	0.1419

** Significant at $p < 0.01$ level of probability.
Degrees of freedom: Replications (r−1) = 2; Treatments (t−1) = 8; Error (r−1) (t−1) = 18.

Results and Discussion

Plant Girth (cm): Significant differences among treatments were observed for plant girth. Treatment T_4 (75% RDF + 50 g Azotobacter + 50 g PSB + 50 g KSB) registered the maximum plant girth of 32.21 cm, followed by T_2 (29.13 cm) and T_6 (28.92 cm). The minimum girth was recorded under T_1 (100% RDF — Control) at 23.04 cm. Treatments T_5, T_6, T_7, and T_9 were statistically at par with each other. The marked increase in stem girth under T_4 relative to T_1 (control) indicates that the 75% inorganic fertilizer dose combined with the maximum biofertilizer consortium dose improved the vasculature and structural biomass of the papaya stem considerably.

Number of Leaves per Plant: Significant differences were observed among treatments. Treatment T_4 (75% RDF + 50 g Azotobacter + 50 g PSB + 50 g KSB) recorded the maximum number of leaves per plant at 62.25, which was significantly superior to all other treatments. It was followed by T_2 (57.66), T_9 (54.78), and T_5 (54.38). The minimum number of leaves was recorded under T_1 (100% RDF — Control) with 41.06 leaves, which was significantly the lowest among all treatments. The trend clearly demonstrated that increasing both the biofertilizer dose and optimizing the inorganic fertilizer percentage together produced the maximum canopy leaf count in papaya.

Leaf Area (cm²): Significant differences were recorded among treatments for leaf area. T_4 (75% RDF + 50 g Azotobacter + 50 g PSB + 50 g KSB) produced the highest leaf area of 1912.04 cm², followed by T_2 (1867.08 cm²) and T_6 (1811.54 cm²). These three treatments did not differ significantly from each other but were significantly superior to the remaining treatments. The control treatment T_1 (100% RDF alone) recorded the minimum leaf area of 1453.55 cm², which was significantly the lowest among all treatments. The range of mean leaf area across all treatments was 1453.55 to 1912.04 cm².

Leaf Area Index (LAI): LAI showed highly significant differences among treatments. The highest LAI was recorded in T_2 (100% RDF + 50 g Azotobacter + 50 g PSB + 50 g KSB) at 5.00, which was statistically at par with T_4 (75% RDF + 50 g Azotobacter + 50 g PSB + 50 g KSB; LAI = 4.96). These were followed by T_6 (4.81) and T_9 (4.70). The minimum LAI was recorded in T_1 (100% RDF — Control) at 3.29, which was significantly lower than all other treatments. The close performance of T_2 and T_4 in LAI — despite T_4 using 25% less inorganic fertilizer than T_2 — is a particularly noteworthy finding, confirming that biofertilizer consortia can offset the reduction in chemical fertilizer dose in terms of leaf area deployment per unit ground area.

Number of Nodes: Significant differences among treatments were observed for number of nodes. T_4 (75% RDF + 50 g Azotobacter + 50 g PSB + 50 g KSB) recorded the maximum number of nodes at 71.21, which was significantly superior to all other treatments. It was followed by T_2 (68.00) and T_6 (66.06). The minimum number of nodes was recorded in T_1 (100% RDF — Control) with 61.47 nodes, which was the lowest among all treatments. The number of nodes is a direct function of the rate of node initiation at the shoot apical meristem and internode elongation, both of which are positively influenced by adequate nutrition.

Days to First Flowering: Highly significant differences were observed among treatments for days to first flowering. T_4 (75% RDF + 50 g Azotobacter + 50 g PSB + 50 g KSB) recorded the minimum days to first flowering of 140.14 days — the most desirable result. It was followed by T_5 (148.61 days) and T_9 (157.41 days). The maximum (most delayed) days to first flowering was recorded in T_1 (100% RDF — Control) at 169.93 days, which was significantly the highest among all treatments. T_3 (166.79 days) and T_2 (164.21 days) also showed delayed flowering compared to the biofertilizer-supplemented treatments at 75% and 50% RDF.

Days to Fruit Maturity: The results revealed highly significant differences among treatments. T_4 (75% RDF + 50 g Azotobacter + 50 g PSB + 50 g KSB) recorded the minimum days to fruit maturity of 199.37 days, which was significantly the lowest and most desirable among all treatments. It was followed by T_5 (207.83 days) and T_9 (208.55 days). The maximum days to maturity was recorded in T_3 (100% RDF + 25 g biofertilizers) at 215.68 days, followed by T_1 (213.79 days), which was the control treatment. This trend of earlier maturity in optimally integrated treatments mirrored the earlier flowering pattern, confirming that biofertilizer integration accelerates the entire reproductive development cycle in papaya.

Number of Fruits per Plant: The results revealed highly significant differences among treatments for number of fruits per plant. T_4 (75% RDF + 50 g Azotobacter + 50 g PSB + 50 g KSB) recorded the maximum number of fruits per plant at 32.78, which was significantly superior to all other treatments. It was followed by T_5 (29.14), T_6 (28.53), and T_7 (28.50). The minimum number of fruits per plant was recorded in T_1 (100% RDF — Control) at 22.05, which was significantly the lowest. Notably, T_4 recorded approximately 49% more fruits per plant compared to the control (T_1), demonstrating the profound advantage of integrating 75% RDF with a full biofertilizer consortium dose over exclusive inorganic fertilization.

Fruit Weight (g): The data revealed significant differences among treatments for fruit weight. T_4 (75% RDF + 50 g Azotobacter + 50 g PSB + 50 g KSB) recorded the highest average fruit weight of 1924.30 g, which was significantly superior to all other treatments. It was followed by T_7 (1783.87 g) and T_2 (1780.46 g), which were statistically at par with each other. The minimum fruit weight was recorded under T_8 (25% RDF + 25 g biofertilizers) at 1484.12 g, indicating that a severely reduced inorganic fertilizer dose — even when supplemented with biofertilizers — was insufficient for achieving optimal individual fruit size. T_1 (control; 100% RDF alone) recorded 1695.55 g, which was intermediate and significantly lower than T_4.

Fruit Yield per Plant (kg/plant)

The results showed highly significant differences among treatments for fruit yield per plant. T_4 (75% RDF + 50 g Azotobacter + 50 g PSB + 50 g KSB) recorded the maximum fruit yield of 31.60 kg/plant, which was significantly superior to all other treatments. It was followed by T_5 (30.06 kg/plant) and T_7 (28.14 kg/plant). The minimum fruit yield was recorded under T_1 (100% RDF — Control) at 20.41 kg/plant, which was significantly the lowest. T_4 recorded a 54.8% higher fruit yield than the sole inorganic fertilizer control (T_1), clearly demonstrating the transformative impact of integrating the optimum biofertilizer consortium with a reduced inorganic fertilizer dose. The overall order of fruit yield across treatments was: T_4 (31.60) > T_5 (30.06) > T_7 (28.14) > T_6 (26.77) > T_9 (25.64) > T_3 (23.93) > T_8 (24.56) > T_2 (22.37) > T_1 (20.41) kg/plant. The hierarchy clearly shows that 75% RDF treatments with biofertilizers (T_4 and T_5) outperformed even the 100% RDF + full biofertilizer treatment (T_2), indicating that 75% of the recommended inorganic dose is the optimal chemical input level when complemented with a full biofertilizer consortium.this all paramitars are table no 2.

Table 2: Effect of different nutrient and biofertilizer treatments on growth, flowering, fruiting and yield attributes of the crop

Sl. No.	Treatment	Days to 1st Flower (days)	Days to Fruit Maturity (days)	No. of Leaves/Plant	Leaf Area (cm²)	LAI	Plant Girth (cm)	No. of Nodes	Plant Height (cm)	Fruit Weight (g)	No. of Fruits/Plant	Fruit Yield (kg/plant)
1.00	T1	169.93	213.79	41.06	1453.55	3.29	23.04	61.47	191.60	1695.55	22.05	20.41
2.00	T2	164.21	211.45	57.66	1867.08	5.00	29.13	68.00	240.05	1780.46	23.10	22.37
3.00	T3	166.79	215.68	53.68	1686.31	4.40	26.81	64.25	216.33	1660.66	24.12	23.93
4.00	T4	140.14	199.37	62.25	1912.04	4.96	32.21	71.21	243.39	1924.30	32.78	31.60
5.00	T5	148.61	207.83	54.38	1741.66	4.53	28.05	64.75	219.67	1757.25	29.14	30.06
6.00	T6	152.93	209.32	56.57	1811.54	4.81	28.92	66.06	240.53	1741.15	28.53	26.77
7.00	T7	157.62	208.91	52.72	1651.03	4.30	27.39	63.92	214.40	1783.87	28.50	28.14
8.00	T8	162.43	212.96	51.63	1603.31	4.32	25.88	64.00	215.91	1484.12	27.51	24.56
9.00	T9	157.41	208.55	54.78	1754.43	4.70	28.37	64.26	226.57	1594.32	26.63	25.64
SE(m) ±		1.16	1.74	0.39	35.85	0.05	0.63	1.16	2.28	31.24	0.37	0.22
CD @ 5%		3.45	5.18	1.16	106.51	0.16	1.88	3.43	6.78	92.83	1.11	0.65
CV (%)		1.28	1.44	1.26	3.61	2.03	3.94	3.07	1.77	3.16	2.40	1.45

Economics

The data revealed wide variation in economic performance across treatments. The maximum total cost of cultivation was recorded under T_2 (100% RDF + 50 g *Azotobacter* + 50 g PSB + 50 g KSB; ₹2,24,729/ha), owing to the combined expense of the full inorganic fertilizer dose together with the maximum biofertilizer dose, while the minimum cost was recorded under T_1 (100% RDF — Control; ₹1,52,729/ha), which used no biofertilizer inputs at all. T_4 (75% RDF + 50 g Azotobacter + 50 g PSB + 50 g KSB) recorded the highest gross return (₹8,08,960/ha) and the highest net return (₹5,95,145/ha) of all nine treatments, but its B:C ratio (3.78) was not the highest in the trial, since it required a comparatively high investment (₹2,13,815/ha) to achieve this return. The single highest B:C ratio was instead recorded under T_5 (75% RDF + 25 g Azotobacter + 25 g PSB + 25 g KSB) at 4.33, achieved at a considerably lower cultivation cost (₹1,77,815/ha) while still securing a net return of ₹5,91,721/ha — only marginally below that of T_4. T_7 (50% RDF + 25 g Azotobacter + 25 g PSB + 25 g KSB) recorded the second-highest B:C ratio (4.32) at the lowest cost among the high-performing treatments (₹1,66,903/ha), with a net return of ₹5,53,481/ha, followed by T_8 (25% RDF + 25 g Azotobacter + 25 g PSB + 25 g KSB; B:C = 4.03). In contrast, T_2, despite recording a respectable gross return (₹5,72,672/ha), gave the lowest net return (₹3,47,943/ha) and the lowest B:C ratio (2.55) of all nine treatments — a direct consequence of its disproportionately high input cost relative to the yield advantage it produced. The control treatment T_1, while having the lowest cultivation cost, ranked eighth in net return (₹3,69,767/ha), confirming that sole reliance on inorganic fertilizer, although cheap, is not the most remunerative strategy. Thus, two distinct economic leaders emerge from the data: T_4 for the highest absolute net profit per hectare, and T_5 (closely followed by T_7) for the highest return per rupee invested.

Table 3: Economics of Papaya cv. Red Lady Cultivation as Influenced by Different Levels of Inorganic Fertilizers and Biofertilizers

Sl.	Treatment	Total Cost of Cultivation (₹/ha)	Gross Return (₹/ha)	Net Return (₹/ha)	B:C Ratio
1	T_1: 100% RDF	1,52,729	5,22,496	3,69,767	3.42
2	T_2: 100% RDF + 50g Azotobacter + 50g PSB + 50g KSB	2,24,729	5,72,672	3,47,943	2.55
3	T_3: 100% RDF + 25g Azotobacter + 25g PSB + 25g KSB	1,88,729	6,12,608	4,23,879	3.25
4	T_4: 75% RDF + 50g Azotobacter + 50g PSB + 50g KSB	2,13,815	8,08,960	5,95,145	3.78
5	T_5: 75% RDF + 25g Azotobacter + 25g PSB + 25g KSB	1,77,815	7,69,536	5,91,721	4.33
6	T_6: 50% RDF + 50g Azotobacter + 50g PSB + 50g KSB	2,02,903	6,85,312	4,82,409	3.38
7	T_7: 50% RDF + 25g Azotobacter + 25g PSB + 25g KSB	1,66,903	7,20,384	5,53,481	4.32
8	T_8: 25% RDF + 25g Azotobacter + 25g PSB + 25g KSB	1,55,990	6,28,736	4,72,746	4.03
9	T_9: 25% RDF + 50g Azotobacter + 50g PSB + 50g KSB	1,91,990	6,56,384	4,64,394	3.42

Gross Return (₹/ha) = Yield (kg/ha) × ₹16/kg; Net Return (₹/ha) = Gross Return − Total Cost of Cultivation; B:C Ratio = Gross Return ÷ Total Cost of Cultivation

Conclusion

- The analysis of variance revealed that the treatment effect was highly significant ($p < 0.01$) for all eleven growth and yield parameters studied, confirming that the integration of inorganic fertilizers with biofertilizers exerted a pronounced influence on the performance of papaya cv. Red Lady.
- Treatment T_4 (75% RDF + 50 g Azotobacter + 50 g PSB + 50 g KSB) recorded the maximum plant height (243.39 cm), which was statistically at par with T_6 (240.53 cm) and T_2 (240.05 cm), while the minimum plant height (191.60 cm) was recorded under T_1 (100% RDF, control).
- The maximum plant girth (32.21 cm) was recorded under T_4, while the minimum (23.04 cm) was recorded under the control treatment T_1.
- The maximum number of leaves per plant (62.25) was recorded under T_4, significantly superior to all other treatments, while the minimum (41.06) was recorded under T_1.
- The maximum leaf area (1912.04 cm²) was recorded under T_4, statistically at par with T_2 (1867.08 cm²) and T_6 (1811.54 cm²), while the minimum (1453.55 cm²) was recorded under T_1.
- The maximum Leaf Area Index (5.00) was recorded under T_2, statistically at par with T_4 (4.96), while the minimum (3.29) was recorded under T_1.
- The maximum number of nodes (71.21) was recorded under T_4, while the minimum (61.47) was recorded under T_1.
- The minimum (earliest) number of days to first flowering (140.14 days) was recorded under T_4, while the maximum (most delayed) flowering (169.93 days) was recorded under T_1.
- The minimum (earliest) number of days to fruit maturity (199.37 days) was recorded under T_4, while the maximum (215.68 days) was recorded under T_3.
- The maximum number of fruits per plant (32.78) was recorded under T_4 — approximately 49 per cent higher than the control — while the minimum (22.05) was recorded under T_1.
- The maximum fruit weight (1924.30 g) was recorded under T_4, while the minimum (1484.12 g) was recorded under T_8.
- The maximum fruit yield per plant (31.60 kg/plant) was recorded under T_4, representing a 54.8 per cent improvement over the control (T_1: 20.41 kg/plant). The overall ranking of treatments for fruit yield was $T_4 > T_5 > T_7 > T_6 > T_9 > T_8 > T_3 > T_2 > T_1$.
- Economic analysis revealed that T_4 recorded the highest gross return (₹8,08,960/ha) and the highest net return (₹5,95,145/ha) among all treatments, but its benefit-cost ratio (3.78) was exceeded by T_5 (4.33) and T_7 (4.32), both of which achieved comparable net returns at substantially lower cultivation costs. T_2 recorded the lowest benefit-cost ratio (2.55) of all treatments owing to its high input cost relative to yield advantage, while the control T_1 recorded the lowest cultivation cost but ranked eighth in net return.

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