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Evaluation of Bio-Stimulants for Active Growth, Yield and Shelf Life of Papaya cv. Red Lady

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Bio-stimulants, which are natural substances aiding plant growth and resilience, are comprised of various organic and mineral compounds, serving as eco-friendly tools for sustainable farming. The research study was conducted at the Horticulture Farm of Agriculture at Lovely Professional University in Phagwara, Punjab, during the years 2023-24. The study employed a randomized block design with seven treatments replicated three times. Bio-stimulants were sprayed at 60, 90, 120 and 150 days after planting (DAP) on papaya plants cv. Red Lady to evaluate its effect on various

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growth, quality and shelf-life parameters. Various growth parameters including plant height, stem girth, canopy spread, petiole length of leaves, as well as floral characteristics such as days taken for flowering, height at initial flowering, number of flowers per node, fruit set percentage and yield-related parameters were evaluated. The study found significant effects of different bio-stimulant applications on papaya growth, flower and fruit production, fruit quality and shelf-life. Treatment T_4 (RDF + Diatomaceous earth) showed notable improvements in growth parameters, while treatment T_5 (RDF + Panchgavya) resulted in enhanced productivity, fruit quality and shelf-life. Overall, the study suggests that the application of Diatomaceous earth alongside fertilizers promotes vegetative growth, while Panchgavya application enhances flowering, fruiting and quality attributes, offering insights for optimizing papaya cultivation practices for improved yield and quality.

Keywords: Papaya; red lady; bio-stimulants; panchgavya; growth; yield; quality and shelf-life.

1. INTRODUCTION

Papaya (*Carica papaya* L.) characterized as an herbaceous plant [1], exhibits a variable growth pattern depending on the specific variety, with some reaching heights of up to ten meters [2]. The leaves of papaya plants are palmately-lobed [3], featuring lengthy [4], hollow petioles and blades divided into 5-9 segments [5]. Flower buds develop at the axils of the leaves [6] and the fertilized fruit can contain up to 1000 seeds [5]. The fruit's skin transitions from green in its unripe stage to a vibrant yellow orange when it ripens [7]. In general, papaya plants have a lifespan ranging from five to ten years [2]. Papaya differs in its nutrient requirements as compared to other crops as flowering, fruit initiation and formation and fruit development is a continuous phenomenon. The source-sink interaction is also very prominent for this crop and such it responds very well to nutrient application whether basal or foliar [8].

Bio-stimulants refer to the formulations that reduce the dependency of plants on fertilizers [9]. These provide an impetus to the plant growth and provide a resistance mechanism to the plants against various abiotic stresses [10]. Although these are not comparable to the plant growth regulators, yet when applied in small concentrations, tend to streamline the plant physiological processes resulting in high yields and fairly good quality of fruits [11]. Application of plant bio-stimulants enhances the nutritional efficiency of the plant [12], plant morphological traits [13] resistance to abiotic stresses irrespective of the source of nutrients used [14]. Bio-stimulant compositions have varied ingredients such as humic acids, algal extracts, hormones and growth promoting bacteria for plants [15]. While they are not the same as fertilizers, they are seen as eco-friendly tools for sustainable farming, promoting healthier plant growth without harming the environment [11]. Bio-stimulant like Panchgavya is a form of organic liquid made purely from 5 organic ingredients like cowdung, cow urine, cow milk, curd and ghee [16]. All the five constituents are known to have medicinal properties and were used singly or in combination against many diseases. It is well documented that the organically produced fruits, vegetables and grains are more beneficial for human health [17] and contain higher hydrolysable polyphenols and higher soluble and hydrolysable antioxidant capacities [18]. Several studies indicated the positive effect of foliar application of panchagavya on food crops etc. [19,20].

Various other bio-stimulants like vermiwash, jeevamrutham and brassinosteriods have shown positive effect on the growth and development of fruit plants. The daily administration of panchgavya led in a considerable decrease in the time needed for first flowering, first fruiting, and the period between first flowering and fruit maturity in papaya cv Vinayak [21]. It is seen that application of brassinosteroids as a foliar spray in papaya boosted firmness, reduced physiological weight loss and lowered oxygen consumption, consequently enhancing fruit quality and extending its shelf life [22]. The application of Jeevamrutham in conjunction with the recommended dose of fertilizers in papaya cv Taiwan Red Lady cultivation in the Satpura plateau region of Madhya Pradesh resulted in significant enhancements in vegetative growth, yield, and fruit quality attributes [23]. It was observed that papaya plants exhibited superior growth parameters, including increased plant height, stem girth and petiole length, when treated with a blend of vermiwash and other organic supplements such as neem seed extract and cow urine within the framework of precision farming techniques [24]. This study was planned to evaluate the effect of foliar application of bio-

stimulants on growth, yield and shelf life of papaya cv. Red Lady.

2. MATERIALS AND METHODS

The current study was conducted at the Horticultural Farm and within the laboratories of the School of Agriculture, Lovely Professional University, located in Phagwara, Punjab, throughout the duration of 2023. Experimental site is located within the Doaba region of Punjab, situated at coordinates 31.25° N latitude and 75.70° E longitude, with an elevation of 249 meters above sea level. For this experiment, various bio-stimulants were employed across seven distinct treatments, alongside a control group. These bio-stimulants were administered through both foliar and soil applications. The experimental design adopted was a randomized block design, with three replications. The research was conducted in randomized block designs (RBD). Total number of treatments was 7 (T_1: Recommended dose of fertilizer (Conventional method), T_2: RDF + seaweed extract spray, T_3: RDF + Brassinosteroids, T_4: RDF + Diatomaceous earth, T_5: RDF + Panchagavya, T_6: RDF + Vermiwash, T_7: RDF + Jeevamrutham) having 3 replications (each replication had 2 plants per treatment) each with total number of plants 42 for papaya cv. Red Lady.

2.1 Observations Recorded

Every 30 days after spraying till the harvesting of fruits, vegetative parameters were recorded. Plant height was recorded using a graduated stick. Stem girth was recorded using a Vernier caliper. Number of leaves of selected plants from each replication were numerically counted, Petiole length was measured at 150 and 240 days of transplanting by taking three tagged leaf petioles from the top. It was measured with the help of measuring tape. Plant Spread was recorded using a measuring tape. Number of days taken from transplanting till the opening of first female/hermaphrodite flower was recorded to access days to flowering. Height of the plant from ground level to the node where first flower appeared was recorded. Number of flowers produced per node in each plant was recorded for three months, starting from first flowering. Number of fruits per plant, Fruit physical characters, Fruit yield per plant, Days taken for maturity were recorded as per standard methods. Fruit Acidity (%) and Ascorbic acid (mg/100g) was calculated as per the method given by Ranganna [25], Total sugars were estimated by the method given by Dar et al. [26], reducing sugars were recorded as per the method given by AOAC [27] and non-reducing sugar is computed by removing reducing sugar from total sugar and multiplying the result by 0.95. Shelf-life parameters were recorded at an interval of 4 days and were analyzed using standard methods of observations.

3. RESULTS AND DISCUSSION

3.1 Vegetative Parameters

The maximum plant height on 150th DAP was observed under T_4 (RDF+ Diatomaceous earth) having the value of 152.33cm followed by T_6 (RDF + Vermiwash) with 146.83 cm of plant height. Treatment T_4 was found significant for stem girth which recorded 8.11 cm of stem girth at 150th DAP followed by T_7 (RDF+ Jeevamrutham) with 8.01cm of stem girth. There was a notable difference in the treatment T_4 (RDF + Diatomaceous earth) which had the highest number of leaves (31) at 150th DAP followed closely by treatment T_5 (RDF + Panchagavya) with 30.67 leaves per plant. Treatment T_4 (RDF + Diatomaceous earth) resulted in maximum canopy spread (197.83 N-S; 203.33 E-W) followed by the treatment T_2 (RDF + Seaweed extract) with 195.33cm N-S; 198.83 cm E-W at 150th DAP. The findings at at 240 DAP revealed a substantial difference: the treatment T_4 had the longest petiole length of leaves (67.06cm) followed by the treatment T_3 (RDF + Brassinosteroids) resulted a petiole length of 66.50cm. The maximum chlorophyll index value of 35.90 was reported in the treatment T_4 (RDF + Diatomaceous earth) at 150th DAP followed by the treatment T_5 (RDF + Panchagavya). It is clear from the obtained data in Table 1 that spraying papaya cv. Red lady with diatomaceous earth along with recommended dose of fertilizers at 30, 60, 90 and 120 DAP significantly accompanied with enhancing plant height, stem girth, Leaf count per plant, Canopy spread, Petiole length and Chlorophyll index. These findings were similar with that of Abd El-Gawad [28] in Hindi Khasa mango, [29] in orange, [30] in Keitte mango. According to Satisha et al. [31], plants sprayed with silicon showed significantly greater absorption of nitrogen, potassium, phosphorus and zinc. The application of Diatomaceous Earth as a silicon source led to an increase in leaf chlorophyll content, which consequently reduced chlorophyll degradation, reported by Kalatippi [32] in Pomegranate var. Kesar.

Table 1. Effect of bio-stimulant administrations on Vegetative Parameters of Papaya cv. Red Lady at 150 Days after planting

Treatments	Plant height (cm)	Stem girth (cm)	No. of Leaves	Canopy spread (N-S)	Canopy spread (E-W)	Petiole length of leaves (cm) [150, 240 days]		Chlorophyll index of Leaves
T_1	138.5	7.34	28.67	179.67	170.33	56.33	63.72	32.95
T_2	139.5	7.8	29.5	195.33	198.83	60	64.78	33.27
T_3	144.67	7.95	30.17	185.67	192.5	65.39	66.5	34.27
T_4	152.33	8.11	30.5	197.83	203.33	65.72	67.06	35.9
T_5	139.33	7.89	31	188.83	188.67	59.33	64.67	35.9
T_6	146.83	7.91	30.67	194.5	174.5	62.67	64.39	35.07
T_7	142	8.01	29.17	194.17	173.5	61.17	64.5	34.72
S.Em (±)	4.5	0.31	0.8	6.23	8.87	1.73	1.36	0.74
C.D. at 5%	9.08	0.63	1.61	12.5	17.8	3.49	2.73	1.49

T_1= Recommended dose of fertilizer, T_2= RDF + Seaweed extract, T_3= RDF + Brassinosteroids, T_4= RDF + Diatomaceous earth, T_5 = RDF + Panchagavya, T_6 = RDF + Vermiwash, T_7 = RDF + Jeevamrutham.

3.2 Flower and Fruit Parameters

The treatment T_5 combining RDF with Panchagavya resulted in the increased number of flowers per node (6.33) at 150th DAP followed by the treatment T_7 (RDF + Jeevamrutham) which produced 5.33 flowers per node. The minimum days to flower opening was observed for the treatment T_5 (RDF + Panchagavya) with minimum of 99.67days to open flowers followed by the treatment T_7 (RDF + Jeevamrutham) with 103.67days. The maximum fruit set percentage of 70.35 was observed under the treatment T_5 followed by the treatment T_7 of about 69.85% of fruit set. Treatment T_5 demonstrated the superior performance with 36.83 fruits per plant, followed by the treatment T_3 (RDF + Brassinosteroids) with 34.83 fruits per plant. Statistical examination of data regarding fruit yield per plant and fruit yield per hectare as depicted in Table 2a & Table 2b reveals that the various treatments exerted a significant influence on fruit yield. The treatment T_5 recorded the higher fruit yield of 56.78 kg/plant and 83.83t/hectare followed by 44.83kg/plant and 83.10t/hectare with treatment T_7. The treatment T_5 (RDF + Panchagavya) resulted in the substantially highest length and width of fruits (24.2cm and 21.0cm), followed by the treatment T_7 (RDF+ Jeevamrutham) with the fruit length and width of about 21.26cm and 20.23cm. The minimum days taken for fruit maturity (197.6) was observed with the treatment T_5 (RDF + Panchagavya) followed by the treatment T_7 (RDF + Jeevamrutham) with minimum days of 198 for fruit maturity. Highest fruit weight was observed under the treatment T_5 (0.97 kg) followed by the treatment T_7 of about 0.96 kg. These readings were similar with that of Rana [33] in Bitter gourd, [34] in Capsicum.

3.3 Quality Parameters

The maximum pulp weight of 0.8kg was noticed under the treatment T_5 (RDF + Panchagavya) followed by the treatment T_7 (RDF + Jeevamrutham) having the pulp weight of 0.79kg. Treatment T_5 (RDF + Panchagavya) recorded the maximum peel weight and seed weight of 92.41g and 86.06g respectively followed by the treatment T_7 (RDF + Jeevamrutham) having the peel and seed weight of about 89.75g and 84.16g respectively. The finding of results depicted in Table 3a and Table 3b shows that minimum recorded acidity was found in the treatment T_5 having the value of 0.019% followed by the treatment T_7 with the acidity value of 0.02%. TSS concentration was notably highest in the treatment T_5 (RDF + Panchagavya) with a reading of 8.93°Brix, followed by treatment T_7 (RDF + Jeevamrutham) with 8.6°Brix. The maximum concentration of ascorbic acid was detected for the treatment T_5 (RDF + Panchagavya) of 41.91mg/100g, followed by treatment T7 (RDF + Jeevamrutham) of about 40.06mg/100g. The highest sugars% (reducing, Non-reducing and Total sugars) was observed under the treatment T_5 (RDF + Panchagavya) with the readings of 8.56%, 1.25% and 10.26% respectively followed by the treatment T_7 (RDF + Jeevamrutham) with the readings of 8.30%, 1.24% and 9.98%. Research by Tiwari et al. [35] indicates that the improved performance of plants treated with panchagavya can be attributed to its properties as a growth promoter and immunity booster, as well as its ability to mitigate common diseases. Similarly, [36] and [37] support these findings.

Table 2a. Effect of bio-stimulant administrations on flower and fruit parameters of Papaya cv. Red Lady

Treatments	No. of flowers/node	Days to flower opening	Fruit set percentage (%)	No. of fruits/plant	Fruit yield per plant (kg)
T_1	4.5	125.17	63.44	31.83	19.57
T_2	4.33	122.83	66.43	33.67	26.68
T_3	4.67	106.5	68.88	34.83	43.35
T_4	5	108.83	65.55	33.83	25.01
T_5	6.33	99.67	70.35	36.83	56.78
T_6	4.67	107.33	66.63	34.5	35.29
T_7	5.33	103.67	69.85	32.5	44.83
S.Em (±)	0.37	8.78	3.87	1.72	2.255
C.D. at 5%	0.73	17.7	7.79	3.46	7.02

T_1= Recommended dose of fertilizer, T_2= RDF + Seaweed extract, T_3= RDF + Brassinosteroids, T_4= RDF + Diatomaceous earth, T_5 = RDF + Panchagavya, T_6 = RDF + Vermiwash, T_7 = RDF + Jeevamrutham.

Table 2b. Effect of bio-stimulant administrations on flower and fruit parameters of Papaya cv. Red Lady

Treatments	Fruit yield per hectare (t)	Days taken for maturity	Fruit length (cm)	Fruit width (cm)	Fruit weight (Kg)
T_1	50.46	207.17	13	12.03	0.63
T_2	66.7	202.88	16.73	14.83	0.8
T_3	79.86	200.50	19.6	18.93	0.92
T_4	62.53	203.83	14.86	13.46	0.74
T_5	83.83	197.67	24.2	21	0.97
T_6	79.33	202.17	18.33	16.53	0.9
T_7	83.1	198	21.26	20.23	0.96
S.Em (±)	4.12	4.42	0.3	0.27	0.02
C.D. at 5%	12.83	1.42	0.94	0.85	0.063

T_1= Recommended dose of fertilizer, T_2= RDF + Seaweed extract, T_3= RDF + Brassinosteroids, T_4= RDF + Diatomaceous earth, T_5 = RDF + Panchagavya, T_6 = RDF + Vermiwash, T_7 = RDF + Jeevamrutham.

Table 3a. Effect of bio-stimulant treatments on quality parameters of Papaya cv. Red Lady

Treatments	Pulp weight (kg)	Peel weight (g)	Seed weight (g)	Titratable acidity (%)	Total soluble solids
T_1	0.48	74.11	69.76	0.027	6.6
T_2	0.63	83.56	77.46	0.025	6.77
T_3	0.76	88.06	81.98	0.021	7.96
T_4	0.58	78.86	74.3	0.026	6.78
T_5	0.8	92.41	86.06	0.019	8.93
T_6	0.72	86.11	78.56	0.024	7.43
T_7	0.79	89.75	84.16	0.02	8.6
S.Em (±)	0.02	0.55	2.55	0.001	0.41
C.D. at 5%	0.064	1.71	0.82	0.002	1.29

T_1= Recommended dose of fertilizer, T_2= RDF + Seaweed extract, T_3= RDF + Brassinosteroids, T_4= RDF + Diatomaceous earth, T_5 = RDF + Panchagavya, T_6 = RDF + Vermiwash, T_7 = RDF + Jeevamrutham

Table 3b. Effect of bio-stimulant treatments on quality parameters of Papaya cv. Red Lady

Treatments	Ascorbic acid (mg/100g)	Reducing sugars (%)	Non-reducing sugars (%)	Total sugars (%)
T_1	34.31	5.841	1.135	7.283
T_2	37.3	7.177	1.163	8.718
T_3	39.5	8.186	1.227	9.843
T_4	36.28	6.829	1.155	8.343
T_5	41.91	8.56	1.253	10.263
T_6	38.03	7.293	1.192	8.868
T_7	40.06	8.308	1.243	9.988
S.Em (±)	0.48	0.16	0.01	0.17
C.D. at 5%	1.51	0.5	0.04	0.53

T_1= Recommended dose of fertilizer, T_2= RDF + Seaweed extract, T_3= RDF + Brassinosteroids, T_4= RDF + Diatomaceous earth, T_5 = RDF + Panchagavya, T_6 = RDF + Vermiwash, T_7 = RDF + Jeevamrutham

Table 4. Effect of bio-stimulant treatments on shelf- life parameters of Papaya cv. Red Lady

Treatments	Physiological loss in weight (%)	Shelf life (days)
T_1	18.418	3.167
T_2	16.355	4.5
T_3	13.673	5.833
T_4	17.778	4.167
T_5	11.72	6.833
T_6	15.172	5.167
T_7	12.917	6.167
S.Em (±)	0.23	0.25
C.D. at 5%	0.73	0.79

T_1= Recommended dose of fertilizer, T_2= RDF + Seaweed extract, T_3= RDF + Brassinosteroids, T_4= RDF + Diatomaceous earth, T_5 = RDF + Panchagavya, T_6 = RDF + Vermiwash, T_7 = RDF + Jeevamrutham.

3.4 Shelf-Life Parameters

Physiological loss in weight was minimum with the treatment T_5 (RDF + Panchagavya) having the value 11.7%, followed by the treatment T_7 (RDF + Jeevamrutham) with the value 12.9%. The data of findings shows that maximum shelf life was noted in the treatment T_5 (RDF + Panchagavya) with maximum days of about 6.83 days followed by the treatment T_7 (RDF + Jeevamrutham) remain marketable for about 6.16 days. Treatments T_5 and T_7 were non-significant to each other. Similar findings were observed by Gajjela et al. [38] in bitter gourd and [39] in Tomato. Panchagavya has been found to contain growth regulators such as IAA, GA and cytokinin, as demonstrated by Sreethu and Singh [40]. Panchagavya harbours the highest populations of total bacteria, actinomycetes, phosphate solubilizers, fluorescent pseudomonads and nitrifiers among the microorganisms [39]. Dehydrogenase activity and microbial biomass were greater in Panchagavya treated plants [41]. The outcomes align with the findings presented by Senthilkumar et al. [42] in their research involving the strawberry cultivar Camarosa.

4. CONCLUSION

This study demonstrated that combining the recommended dose of fertilizers (RDF) with organic amendments such as Diatomaceous Earth, Panchagavya, and Jeevamrutham significantly improved the growth, yield and quality of papaya cv Red Lady in the Doaba region of Punjab. The treatment with RDF and Diatomaceous Earth (T_4) showed the best results for vegetative growth parameters, including plant height, stem girth, leaf count, canopy spread, petiole length and chlorophyll index. The treatment combining RDF with Panchagavya (T_5) excelled in reproductive and fruit quality traits, achieving the highest number of flowers per node, fruit set percentage, fruit yield, fruit size, weight and quality attributes such as TSS, ascorbic acid content and total sugars. Panchagavya also significantly enhanced the shelf life and reduced physiological weight loss of the fruits. These findings suggest that integrating

these organic treatments with RDF can greatly enhance papaya production.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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