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Research Article

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Influence of PGRs and Bio-inoculants on Seed Germination and Growth Characteristics of Papaya cv. Red Lady in Shade Net

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Abstract

Papaya farmers faces challenges such as slow, unreliable, and incomplete germination of seeds, as well as notable mortality among seedlings. As a result, the primary method of propagation for papaya is through seeds. Application of plant growth regulators (PGRs) and bio-inoculants have indeed played a crucial role in improving seed germination, growth, productivity, and quality of various fruit crops. The present research entitled "Influence of PGRs and bio-inoculants on seed germination and growth characteristics of papaya cv. Red Lady in shade net" was conducted. The study was conducted using a completely randomized design, which included 15 treatments with three replications. Results indicated that, GA_3 (Gibberellic acid) 120 ppm + PSB (Phosphorous solubilizing bacteria) 5 g, exhibited the shortest days for germination (19 days), highest germination percentage (91.11%), germination index (1.05), seed vigor index (4,781.03) and favorable growth parameters such as height of seedling (52.49 cm), stem girth (8.80 mm), number of leaves (11.22), shoot length (30.32 cm), root length (22.17 cm), root diameter (7.62 mm), fresh weight of shoot (15.57 gm), dry weight of shoot (2.27 g), fresh weight of root (6.73 gm) and dry weight of root (1.03 g). The maximum root:shoot ratio (0.63) was observed in GA_3 60 ppm + PSB 5 g. Overall, the findings indicate that the application of GA_3 120 ppm + PSB 5 g enhances seed germination and growth characteristics of the crop papaya cv. Red Lady.

Keywords

Seed germination, Growth characteristics, Plant growth regulators, Bio-inoculant, Gibberellic acid, NAA, Phosphorous solubilizing bacteria, *Azotobacter*

Introduction

Papaya, scientifically called as *Carica papaya* L., is a member of caricaceae family has 2n = 18 chromosomes. It holds a prominent position as a tropical herbaceous fruit crop. Often hailed as wonder fruit of the tropics. The fruit is native to Tropical America and commonly known as 'Pawpaw', 'Backyard Fruit', 'Tree Melon' and 'Breakfast Fruit' [1]. In India, it is the 7th most prominent fruit crop, following Mango, Citrus, Banana, Apple, Guava, and Sapota [2].According to the National Horticulture Board (2021-2022), papaya is grown across an area of 149,000 hectares and yields an annual production of 5,733.26 million metric tons [3]. It is a fast growing evergreen perennial plant with a softwood stem that is hallow, unbranched and can grow up to a height of 15-20 ft which may vary depending on the cultivar [4].

Seed quality plays a vital role in enhancing papaya productivity. Challenges faced in India include propagation difficulties, diverse sexual forms, waterlogging issues, waterborne diseases, and temperature sensitivity influenced by the current climate [5]. The gelatinous sarcotesta, which forms the outer seed coat of papaya, acts as a germination inhibitor [6] while aging rapidly reduces seed viability, re-

sulting in slow, erratic, and incomplete germination and high seedling mortality [7]. For successful nursery production of papaya, it is crucial to ensure efficient seed germination and robust seedling development [8]. So prior to planting, treatments like application of PGRs, growing media and bio-fertilizers are used in other fruit crops to enhance germination process and growth and growth of seedlings [9]. Similarly, in papaya, seed pre-treatment breaks dormancy, improves germination, reduces time, increases rates, and minimizes losses from late plantings [10].

PGRs led to remarkable advancements in improving seed germination, growth, productivity and quality of numerous fruit crops [11]. The growth regulators like GA_3, NAA, etc., are found to be very effective to enhance are to increase the quantity and quality of seedlings during germination. GA_3 has the capability to stimulate rapid growth of both stems and roots, stimulate the process of cell division in the leaf tissue of specific plant species, and enhance the rates of seed germination [12]. Seed dormancy can be broken with gibberellic acid. According to Mishra et al. [13] GA_3 is a powerful hormone known for its ability to stimulate the germination of fruit seeds, particularly papaya seeds, to germinate. Papaya seeds are treated with auxins (NAA), promote root growth and development. Increased auxin levels from NAA lead to a rise in root initiation, cell elongation, higher intake of nutrients, and increased tap root size, all of which increase the fresh and dry weight of roots [14].

Living microorganisms known as bio-inoculants or bio-fertilizers are capable of mobilizing nutrients from an unusable to useful state through biological processes. The use of bio-fertilizers, like *Azotobacter* and PSB, leads to enhanced nitrogen and phosphorus availability in the soil, produce growth hormones, antimicrobial substances, and siderophores, promoting improved nutrient accessibility for plant growth [15].

High-efficiency PSB can replace chemical fertilizers, reducing environmental pollution and restoring ecological balance [16]. Inoculants of *Azotobacter*, are used to crops as a seed treatment, seedling root dip, or soil treatment, adhere to seeds or roots, multiply near developing roots, and form a thick root sheath [17]. Therefore present study investigated the impact of GA_3, NAA, PSB, and *Azotobacter*, influence the germination of papaya seeds and their growth characteristics under shade net.

Materials and Methods

The current experiment was conducted during the year 2023 at Lovely Professional University, School of Agriculture, Phagwara (Punjab), under shade net conditions. The experiment followed a completely randomized design consist of fifteen (15) treatment combinations, with three replications. The papaya seeds were exposed to different pre-sowing treatments and were grown in poly-bags filled with vermin compost: FYM: vermiculite (2:1:1) and a thin layer cocopeat at the top, placed under a shade net during the growth period. Seeds were immersed in various concentrations of GA_3 and NAA solution i.e., 60 ppm and 120 ppm for 12 hours and Bio-inoculants like, PSB and *Azotobacter* 5 g are were applied to enhance seed germination and promote growth characteristics. The treatments are T0 - Control (Water), T1 - GA_3 60 ppm, T2 - GA_3 120 ppm, T3 - NAA 60 ppm, T4 - NAA 120 ppm, T5 - PSB (5 g), T6 - *Azotobacter* (5 g), T7 - GA_3 60 ppm + PSB (5 g), T8- GA_3 120 ppm + PSB (5 g), T9 - GA_3 60 ppm + *Azotobacter* (5 g), T10 - GA_3 120 ppm + *Azotobacter* (5 g), T11 – NAA 60 ppm + PSB (5 g), T12 -NAA 120 ppm + PSB (5 g), T13 - NAA 60 ppm + *Azotobacter* (5 g), T14 - NAA 120 ppm + *Azotobacter* (5 g). The following parameters were observed germination percentage (%), time taken to germination (days), germination index, seed vigor index, height of the seedling (cm), stem girth (mm), number of leaves, length of the shoot (cm), length of the root (cm), root diameter (mm), fresh weight of shoot (g), fresh weight of root (g), dry weight of shoot and root g and root:shoot ratio. To determine the root:-shoot ratio, the dry weight of roots we divided the dry weight of shoots for a random selection of five seedlings and the mean value was computed. The data obtained were analyzed using OPSTAT software, and treatment means were compared with the critical difference (C.D.) at a 5% significance level.

Results and Discussion

Germination percentage (%)

Figure 1 shows the influence of PGRs and bio-inoculants on germination percentage of papaya. The maximum germination was found in T8 (GA_3 120 ppm + PSB 5 g) with 91.11% followed by T10 (GA_3 120 ppm + *Azotobacter* 5 g) i.e., 88.88% and the minimum germination was noticed in T0 (Control) with a value of 60.00%.

GA_3 stimulates the germination process by promoting α-amylase activity, which transforms starch, which is insoluble into soluble sugars and removing metabolic barriers, as demonstrated by [9, 10] in studies on papaya. Additionally, PSB increases the levels of growth promoting substances, enhances availability of nutrients, including phosphorus and plays a crucial role in root initiation by encouraging cell division and energy transfer, in the form of ADP and ATP. These effects have been observed in studies conducted by Baghel et al. [18] in papaya.

Time taken to germination (days)

The treatment T8 (GA_3 120 ppm + PSB 5 gm) significantly took minimum days for germination, 19.00 days as given in the figure 1 followed by T10 ($GA_3$120 ppm + *Azotobacter* 5 g) with 20.13 whereas the treatment T0 (Control) took the maximum days of germination i.e., 25.33.

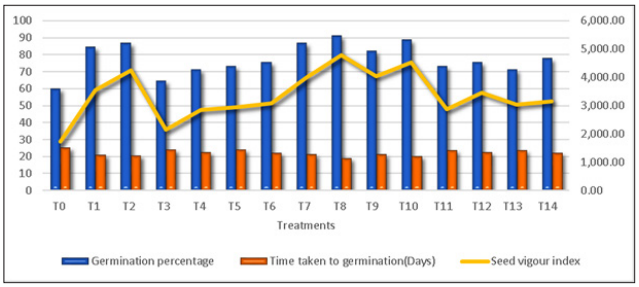

Figure 1: Effect of PGRs and bio-inoculants on germination (%), time taken (days) and seed vigor index of papaya.

There is a potential role of GA_3 in two stages of germination. Firstly, it may induce enzyme production, and secondly, it may deactivate the reserve food mobilizing system, leading to enhanced germination or overcoming physiological challenges linked to seeds that have impermeable seed coats and are in a state of dormancy. Similar studies on papaya conducted by [5, 19] support these findings. PSB increases plant growth regulators like auxins, promoting early completion of physiological processes for seed sprouting and root development by Hakim et al. [20] in pomegranate.

Seed vigor index

The results demonstrated in figure 1 indicate the treatment, T8 (GA_3 120 ppm + PSB 5 g) showed the maximum seed vigor index, 4,781.03 followed by T10 (GA_3 120 ppm + *Azotobacter* 5 g) with 4,521.53. Conversely, the control treatment (T0) have the minimum value 1,738.00.

The observed improvement in vigor index following GA_3 treatment is probably a result of its direct impact on promoting robust seedling growth, potentially by aiding in the increased mobilization of stored nutrient reserves towards the growing apices. These findings are consistent with the results reported by [21, 22] in Kagzi lime.

Height of the seedlings (cm)

The data presented in figure 2 shows the result obtained for height of plant, when different PGRs and bio-inoculants were applied. The maximum height of the seedling was observed in T8 (GA_3 120 ppm + PSB 5 g), 52.49 cm followed by T10 (GA_3 120 ppm + *Azotobacter* 5 g) i.e., 50.89 cm and the minimum height of the seedling is noticed in T0 (Control) which has a value of 28.97 cm.

The application of GA_3 could have stimulated growth by improving cell multiplication and elongation. This result shows extended internodal length and leading to a subsequent rise in plant height, contributing to overall better plant growth in papaya and [23-25] on acid lime. PSB biofertilizers boost plant growth by improving nitrogen fixation, phosphate solubilization, and phosphorus availability via organic acid, plant hormones, vitamins and extracellular phosphatase production in *Camellia oleifera* Abel [26].

Stem girth (mm)

Significance impact on stem girth of the papaya seedlings are presented in the figure 2. The Treatment T8 (GA_3 120 ppm + PSB 5 g) noticed the maximum stem girth of 8.80 mm followed by T10 (GA_3 120 ppm + *Azotobacter* 5 g) with 8.76 mm. The minimum stem girth is found in T0 (control) i.e., 4.547 mm.

The application of GA_3, enhances the uptake of nutrients by the somatic cells, thereby promoting cell division and elongation in stem region. The increase in the diameter of stem is due to the activation of the cambium and its direct cell progeny, as noticed in studies conducted by [8, 13] in papaya. PSB played a role in enhancing nutrient accessibility, resulting in increased production of photosynthetically functional leaves and ultimately leading to improved seedling girth. Similar findings have been reported by Vaka et al. [27] in custard apple.

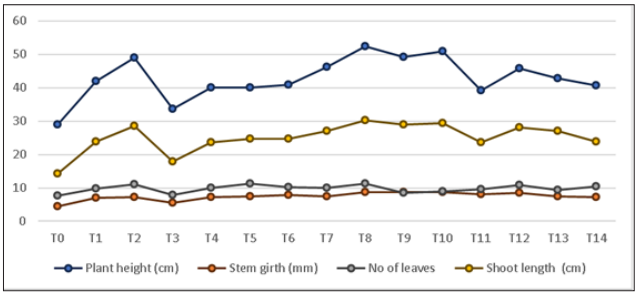

Figure 2: Effect of PGRs and bio-inoculants on plant height (cm), stem girth (cm), no. of leaves and shoot length (cm) of papaya.

No. of leaves

Figure 2 shows the significance difference in no. of leaves among different treatments. As per the analysis of the data, maximum no. of leaves are was noticed in T8 (GA_3 120 ppm + PSB 5 g) i.e., 11.22, followed by T5 (PSB 5 g) i.e., 11.22. The minimum no. of leaves are found in the T0 (Control) with 7.68.

From a physiological standpoint, leaves are crucial photosynthetic sites in plants as they provide energy for metabolic activities. The application of GA_3 aids in cell division and elongation, leading to an increased no. of leaves per seedling and enhanced nutrient availability, which in turn leads to a higher production of leaves capable of photosynthesis. These results align with research carried out by Mewada and Bakshi [12] in papaya and by Yadav et al. [28] in Jatti Katti. By the application of PSB similar observations regarding the no. of leaves have been reported by Vanrajsinh et al. [29] in custard apple.

Shoot length (cm)

Data presented in figure 2 showed significant difference in shoot length among different treatments. According to the analysis of data figure 2 shows the maximum shoot length (30.32 cm) was observed in the treatment T8 (GA_3 120 ppm + PSB 5 g) followed by T10 (GA_3 120 ppm + *Azotobacter* 5 g) i.e., 29.37 cm. The minimum shoot length was observed in the treatment T0 (Control) i.e., 14.37 cm.

GA_3 helps in increasing the shoot length by the absorption of nutrients through osmosis facilitates cell elongation, subsequently leading to longer internodal length, resulting in enhanced shoot and length of seedlings. This finding aligns with the studies conducted by Sejal et al. [30] in Khirni, by Desai et al. [31] in papaya. PSB biofertilizers enhance biological nitrogen fixation, increase phosphorus availability, promote cell elongation, and division through the production of growth substances like IAA and GA_3 [32] in strawberry.

Root length

The results presented in figure 3, demonstrate the root length of different treatments. Among the treatments, T8 (GA_3 120 ppm + PSB 5 g) displayed the highest root length, 22.17 cm followed by T10 (GA_3 120 ppm + *Azotobacter* 5 g) 21.53 cm and the control treatment (T0) exhibited the lowest root length, 14.60 cm.

GA_3 treatment could be attributed to the stimulation of growth of shoot leading to the generation of photosynthates. These photosynthates are then transported through the phloem to the root area, potentially leading to an expansion in root length. These findings are in align studies conducted on papaya by Dhorajiya et al. [33], and on Kagzi lime by Panda et al. [34]. The biofertilizers can increase phosphorus availability in the root zone, encouraging the initiation of roots, facilitating nutrient absorption, and promoting root elongation, consequently resulting in greater tap root length. Similar results have been observed in studies on pomegranate by Solanki et al. [35].

Root diameter

The data presented in figure 3, has shown the significance influence of PGRs and bio-inoculants on root diameter of the papaya seedlings. The maximum root diameter (7.62 mm) was recorded in treatment T8 (GA_3 120 ppm + PSB 5 g) followed by T10 (GA_3 120 ppm + *Azotobacter* 5 g) 7.29 mm respectively. The minimum root diameter was observed in T0 (Control) i.e., 4.15 mm.

GA_3 promotes cell elongation in sub-apical region of roots, which may contribute, an increase in root diameter. Similar results have been observed in studies on Ber (*Indian jujube*) by [36]. PSB biofertilizer enhances rooting in pomegranate, increasing root number, length, diameter, and fresh weight [37]. This is attributed to the combined action of growth-promoting substances from PSB and increased phosphorus availability in the rhizosphere.

Fresh weight of shoot (gm)

The results in figure 4, indicate the influence of different treatments on fresh weight of shoot. The maximum shoot fresh weight were noticed in T8 (GA_3 120 ppm + PSB 5 g) 15.57 gm, followed by T10 (GA_3 120 ppm + *Azotobacter* 5 g) with 13.13 g. The minimum fresh weight of shoot was observed in the treatment T0 (Control) with the value 7.47 g.

GA_3 affects different metabolic pathways such as photosynthesis, respiration, and nutrient uptake, which ultimately result in enhanced shoot growth and fresh weight. This effect has been observed in studies conducted on Tamarind and Jamun by [38, 39] respectively. PSB biofertilizers enhance nutrient availability by converting insoluble phosphorus into soluble forms and fixing atmospheric nitrogen. This improved nutrient uptake promotes shoot growth and biomass accumulation. Similar results were reported in studies on papaya by Singh and Tripathi [15].

Dry weight of shoot

Based on the analysis of the data indicated in the figure 4, the maximum dry weight of the shoot was noticed in T8 (GA_3 120 ppm + PSB 5 g), 2.27 gm followed by T10 (GA_3 120 ppm + *Azotobacter* 5 g) with 1.70. The minimum shoot dry weight (0.90 g) observed in T0 (Control).

GA_3 promotes shoot growth and carbohydrate accumulation, resulting in increased dry matter production. Similar outcomes were reported by Choudhary et al. [23] in his studies on papaya. PSB biofertilizer improve nutrient absorption and utilization, ultimately leading to increased shoot growth and increased dry weight of the shoot. Similar effects were observed on chili and maize plants [40].

Fresh weight of root (gm)

Figure 4 shown the significance in fresh weight of the root among different treatments of PGRs and bio-inoculants given to papaya seeds. According to the analysis of data, the highest fresh weight of root was noticed in the treatment T8 (GA_3 120 ppm + PSB 5 g) i.e., 6.73 g followed by T10 (GA_3 120 ppm + *Azotobacter* 5 g) 6.30 g. The lowest fresh weight of root is in T0 (Control) 3.03 g.

GA_3 influences various plant parts, increases cell division, elongation, auxin metabolism, alterations in cell wall and changes in membrane permeability, resulting in enhanced growth and increased fresh root weight. Similar effect has been observed on rough lemon by Arghistani et al. [41] and Khirni by Rai et al. [42]. Biofertilizers (PSB) application increased enzyme activities and enhanced rhizosphere activity, which, in turn, improved nutrient uptake which have a positive impact on the fresh weight and dry weight of root biomass. This finding is consistent with the study conducted on pomegranate by Simpi [43].

Dry weight of root (g)

Figure 4 indicate the highest dry weight of root was noticed in the treatment T8 (GA_3 120 ppm + PSB 5 g) 1.03 g followed by T10 (GA_3 120 ppm + *Azotobacter* 5 g) i.e., 0.90 g The lowest dry weight of root was noticed in T0 (Control) 0.37 g.

GA_3 boosts auxin levels in roots, stimulating encourages the initiation of roots, enhances nutrient absorption, and promotes root elongation. As a result, it leads to the development

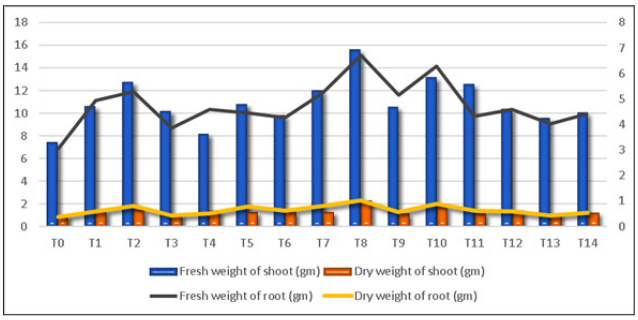

Figure 3: Effect of PGRs and bio-inoculants on fresh and dry weight of shoot (g), fresh and dry weight of root (g) in papaya.

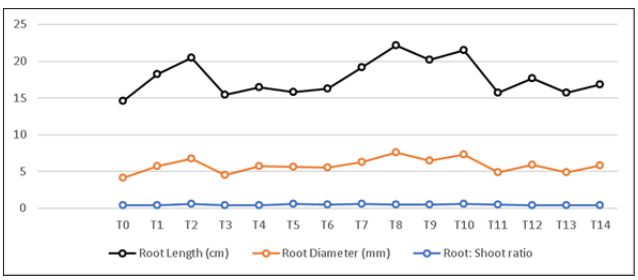

Figure 4: Effect of PGRs and bio-inoculants on root length, diameter, and root:shoot ratio of papaya.

of longer taproots, many secondary and fibrous roots, and an increase in root weight, ultimately contributing to higher fresh and dry root weights. Similar findings were observed in studies on papaya by Pratibha et al. [44] and Rangpur lime by Dilip et al. [45]. PSB improves soil fertility, increasing fresh and dry weights of plant parts by enhancing nutrient availability for plant growth. This was shown in a study on Aonla by Chiranjeevi et al. [46].

Root:shoot ratio

The data shown in figure 3 shows the maximum root: shoot ratio was observed in T7 (GA_3 60 ppm + PSB 5 g) i.e., 0.63 followed by T5 (PSB 5 g) i.e., 0.60. The minimum root: shoot ratio was noticed in T0 (Control) i.e., 0.37.

GA_3 + PSB treatment increases the root:shoot ratio by facilitating faster water and nutrient transport. This promotes higher photosynthetic product production, which is then distributed throughout the plant. As a result, seedling growth improves, leading to increased fresh and dry weights. Similar findings were reported in studies on papaya by Sharma et al. [47].

Conclusion

The research study, concluded that the combined application of GA_3 and PSB significantly influenced the seed germination and growth characteristics of papaya cv. Red Lady. The treatment GA_3 120 ppm + PSB 5 g consistently showed the most favorable outcomes across multiple parameters. It enhanced germination percentage, reduced germination time, improved seed vigor index, and promoted significant increase in the plant height, stem girth, no. of leaves, petiole length, leaf area index, shoot length, fresh weight of shoot, length of root, root diameter, fresh weight of root, dry weight of root, and the root:shoot ratio was found in GA_3 60 ppm + PSB 5 g. These findings highlight the potential of using GA_3 and PSB bio-inoculant for enhancing papaya cultivation. The findings from this research offer valuable insights for papaya growers and researchers aiming to enhance farming techniques or cultivation practices and meet market demand for this popular fruit.

Acknowledgements

None.

Conflict of Interest

None.

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