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Megha Mishra
M.Sc., Department of Fruit Science,
Horticulture and Research Station,
Sankara-Patan, Durg, Mahatma
Gandhi University of Horticulture
and Forestry, Sankara-Patan, Durg,
Chhattisgarh, India

Ram Kumar Dewangan
Department of Fruit Science,
Krantikari Debridhur College of
Horticulture and Research Station,
Jagdalpur Mahatma Gandhi
University of Horticulture and
Forestry Sankara-Patan, Durg,
Chhattisgarh, India

Amit Dixit
Department of Vegetable Science
College of Horticulture and Research
Station, Sankara-Patan, Durg,
Mahatma Gandhi University of
Horticulture and Forestry, Sankara-
Patan, Durg, Chhattisgarh, India

Sevan Das Khunte
Department of Fruit Science, College
of Horticulture and Research Station,
Sankara-Patan Durg, Mahatma
Gandhi University of Horticulture
and Forestry, Sankara-Patan, Durg,
Chhattisgarh, India

Vishesh Patel
M.Sc. (Ag.) Department of
Horticulture-Fruit Science,
Jawaharlal Nehru Krishi Vishwa
Vidyalaya, Jabalpur, Madhya
Pradesh, India

Pushpraj Khare
M.Sc. (Forestry), Department of
Silviculture and Agroforestry, College
of Forestry and Research Station,
Sankara-Patan, Durg, Chhattisgarh,
India

Corresponding Author:

Megha Mishra
M.Sc., Department of Fruit Science,
Horticulture and Research Station,
Sankara-Patan, Durg, Mahatma
Gandhi University of Horticulture
and Forestry, Sankara-Patan, Durg,
Chhattisgarh, India

Influence of GA₃ and growing media on germination parameters and seedling development of papaya (*Carica papaya* L.) cv. Red Lady

Megha Mishra, Ram Kumar Dewangan, Amit Dixit, Sevan Das Khunte, Vishesh Patel and Pushpraj Khare

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Abstract

The present study was conducted during 2024-25 at the Department of Fruit Science, Krantikari Debaridhur College of Horticulture and Research Station, Jagdalpur (C.G.), to evaluate the effect of gibberellic acid (GA₃) and growing media on seed germination and seedling growth of papaya (*Carica papaya* L.) cv. Red Lady. The experiment was laid out in a Factorial Completely Randomized Design (FCRD) with sixteen treatment combinations consisting of four GA₃ concentrations (0, 100, 150, and 200 ppm) and four media compositions (Soil, Soil + FYM, Soil + Vermicompost, and Soil + FYM + Vermicompost). Observations were recorded for germination percentage, days to start germination, rate of emergence, germination index, seed vigour index (I & II), survival percentage, germination value, and speed of emergence.

Results revealed that both GA₃ concentration and media composition significantly influenced germination and seedling performance. Among treatments, G₃ (200 ppm GA₃) recorded the highest germination percentage (86.23%), maximum vigour index (4572.24%), and superior survival rate (92.11%), while the lowest values were observed in untreated seeds (G₀). Similarly, M₃ (Soil + FYM + Vermicompost, 1:1:1) produced the highest germination percentage (92.04%) and seedling vigour, indicating that enriched organic media created a favourable environment for germination and establishment. The combined treatment G₃M₃ proved most effective, producing early, uniform, and vigorous seedlings. The improvement in performance can be attributed to the synergistic effect of GA₃ in breaking dormancy and the enhanced nutrient and microbial status of the organic media. The study concludes that pre-soaking papaya seeds in 200 ppm GA₃ and sowing in a Soil + FYM + Vermicompost (1:1:1) medium optimizes germination and seedling growth under Bastar agro-climatic conditions.

Keywords: Papaya (*Carica papaya* L.), Gibberellic acid (GA₃), seed germination, seedling vigour, growing media, vermicompost, Bastar region, nursery management

1. Introduction

The tropical fruit crop *Carica papaya* L. (papaya) holds considerable agronomic importance due to its rapid growth, year-round fruiting potential, and high nutritional value, offering significant benefits to fruit growers in regions such as India (Desai, Panchal, Trivedi, & Prajapati, 2017) [6]. However, successful establishment of papaya seedlings is often hindered by sub-optimal seed germination, seedling vigour, and mortality during the nursery phase, largely attributable to the inherent dormancy of the sarcotesta and limitations in the growing medium environment (Choudhary, Kanwar, Agarwal, Kumawat, & Bhandari, 2020; Hazarika, Gogoi, Das, & Bordoloi, 2023) [4, 9]. The use of plant growth regulators and optimized growing media has emerged as a promising strategy to overcome these constraints and enhance early seedling performance.

Among growth regulators, Gibberellic acid (GA₃) has been widely documented for its ability to break seed dormancy, stimulate hydrolytic enzyme activity and mobilize storage reserves, thereby improving germination rate, uniformity and subsequent seedling growth across a range of species including papaya (Choudhary *et al.* 2020; Hazarika *et al.* 2023) [3, 9]. Simultaneously, the physical and chemical attributes of the growing medium-such as aeration, moisture retention,

organic matter content and nutrient availability-play a pivotal role in supporting root proliferation, seedling establishment and overall vigour (Hazarika *et al.* 2023; Choudhary *et al.* 2020)^[9, 5]. Studies in papaya have shown that combining GA₃ treatment with enriched media (for example soil + FYM + vermicompost) markedly improves germination percentage, vigour index and seedling survival compared to soil alone or untreated seeds (Choudhary *et al.* 2020; Hazarika *et al.* 2023)^[5, 9].

Despite this body of knowledge, considerable variability remains in optimal GA₃ concentrations, treatment durations and media combinations under different agro-climatic zones, particularly in Indian states such as Chhattisgarh and adjacent regions where site-specific conditions (soil type, temperature, humidity) may influence outcomes. The present study therefore investigates the influence of varying GA₃ concentrations and growing-media combinations on germination performance and early seedling growth of papaya cv. 'Red Lady' under the Bastar agro-climatic region of Chhattisgarh. By elucidating the interaction between hormonal seed treatment and organic media enrichment in this context, the research aims to advance nursery-level protocols for improved seedling establishment and yield potential of papaya in the region.

2. Materials and Methods

The present investigation entitled “*Effect of growth regulator (GA₃) and growing media on seed germination and seedling growth of papaya (Carica papaya L.) cv. Red Lady in Bastar region of Chhattisgarh*” was conducted during 2024-25 at the Research and Instructional Farm, Department of Fruit Science, Krantikari Debaridhur College of Horticulture and Research Station, Jagdalpur (C.G.). The experimental site is located at 19°4'N latitude and 82°2'E longitude with an altitude of 552 m above mean sea level, characterized by a tropical savanna climate. For the experiment, four different media combinations were prepared according to the treatment structure. All components were collected from the farm and nearby sources, dried under shade to remove excess moisture, and sieved through a 2-3 mm mesh to ensure uniform texture before mixing.

The experiment was laid out in a Factorial Completely Randomized Design (FCRD) with three replications, consisting of sixteen treatment combinations formed by four levels of GA₃ (G₀: untreated, G₁: 100 ppm, G₂: 150 ppm, G₃: 200 ppm) and four growing media (M₀: Soil; M₁: Soil + FYM (1:1); M₂: Soil + Vermicompost (1:1); M₃: Soil + FYM + Vermicompost (1:1:1)). Seeds of papaya cv. *Red Lady* were treated with respective GA₃ concentrations for 12 hours, while control seeds were soaked in distilled water. Sowing was done in 4 × 6 inch perforated polybags filled with the respective media, one seed per bag, and light irrigation was given immediately after sowing. Regular irrigation, weeding, and plant protection measures were followed uniformly across all treatments, and seedlings were maintained under shade during early growth, later hardened under open conditions.

Observations on germination and seedling parameters were recorded using standard procedures- germination percentage, days to start germination, rate of emergence, germination index, seed vigour index (I & II), survival percentage, germination value, and speed of emergence. Data were analyzed statistically as per the procedure given by Panse and Sukhatme (1985) for FCRD, with treatment means compared at the 5% level of significance. The improvement in germination and seedling performance was assessed through interaction effects of GA₃ concentration and media combinations, allowing identification

of the most effective treatment for optimizing papaya seed germination and seedling vigor under Bastar Agro-climatic conditions.

3. Results and Discussion

3.1 Seed germination parameters

3.1.1 Germination percentage

The data pertaining to germination percentage as influenced by effect of growth regulator (GA₃) and growing media on seed germination and seedling growth of papaya has been recorded and presented in Table 1.

Factor A

Among the observations, the significantly maximum germination percentage was recorded in the treatment G₃ (Treated with 200 ppm) (86.23), which was at par with the treatment G₂ (Treated with 150 ppm) showing (85.36). In contrast, the significantly minimum germination percentage was observed in the treatment G₀ (Untreated seeds) (81.90).

Factor B

The significantly highest germination percentage (92.04) was obtained under treatment M₃ (Soil + FYM + Vermicompost (1:1:1 ratio)), followed by the treatment M₂ (Soil + Vermicompost (1:1)) with (86.81) and treatment M₁ (Soil + FYM (1:1)) with (82.62). Conversely, the lowest germination percentage (75.91) was recorded in treatment M₀ (Soil).

The improvement in germination percentage with GA₃ application may be attributed to its ability to break seed dormancy, enhance enzymatic activity, and stimulate reserve mobilization, which together support quicker and more uniform sprouting. Similarly, enriched growing media like Soil + FYM + Vermicompost provided balanced nutrients, better aeration, and higher organic matter content, creating a favorable microenvironment for seed germination. Among the treatments, the combination of GA₃ at 200 ppm with Soil + FYM + Vermicompost (1:1:1 ratio) (G₃M₃) proved most effective, producing the highest germination percentage and confirming its superiority in enhancing papaya seed germination. The results obtained in the present study are supported by the works of Sejal *et al.* (2022)^[21], Ashish *et al.* (2022)^[11] and Pandey *et al.* (2024)^[17].

3.1.2 Days taken to start germination

The data pertaining to days taken to start germination as influenced by effect of growth regulator (GA₃) and growing media on seed germination and seedling growth of papaya has been recorded and presented in Table 1.

Factor A

In the present study, the significantly lowest days taken to start germination (10.22) was found in treatment G₃ (Treated with 200 ppm). This was followed by G₂ (Treated with 150 ppm) showing (10.86) and G₁ (Treated with 100 ppm) showing (11.24). On the other hand, G₀ (Untreated seeds) showed the highest days taken to start germination (11.50).

Factor B

Within the treatments, M₃ (Soil + FYM + Vermicompost (1:1:1 ratio)) required the significantly shortest period for days taken to start germination (7.78), followed by M₂ (Soil + Vermicompost (1:1)) with (9.69) and treatment M₁ (Soil + FYM (1:1)) with (11.88). In contrast, the longest duration for days taken to start germination (14.47) was observed in M₀ (Soil).

The reduction in days taken to start germination with GA₃ application may be due to its role in activating hydrolytic enzymes, accelerating metabolic processes, and enhancing mobilization of stored food reserves, which together promote early sprouting. Likewise, enriched growing media provided balanced nutrition, improved aeration, and better moisture conditions that created a favorable environment for faster germination compared to soil alone. Among all treatments, the combination of GA₃ at 200 ppm with Soil + FYM + Vermicompost (1:1:1 ratio) (G₃M₃) was found most effective, as it minimized the time required for seed germination and ensured rapid seedling establishment. These outcomes are consistent with findings of Pratibha *et al.* (2015)^[18], Mehta *et al.* (2022)^[13] and Choudhary *et al.* (2022)^[3].

3.1.3 Rate of emergence

The data pertaining to rate of emergence as influenced by effect of growth regulator (GA₃) and growing media on seed germination and seedling growth of papaya has been recorded and presented in Table 2.

Factor A

In this experiment, treatment G₃ (Treated with 200 ppm) recorded the significantly greatest rate of emergence (0.35), which was at par with the treatment G₂ (Treated with 150 ppm) showing (0.34) and the treatment G₁ (Treated with 100 ppm) showing (0.34). In contrast, the least rate of emergence (0.33) was obtained in G₀ (Untreated seeds).

Factor B

Treatment M₃ (Soil + FYM + Vermicompost (1:1:1 ratio)) was found the significantly highest rate of emergence (0.37), followed by M₂ (Soil + Vermicompost (1:1)) with (0.35) and treatment M₁ (Soil + FYM (1:1)) with (0.33). In contrast, the lowest rate of emergence (0.30) was noted in M₀ (Soil).

The improvement in the rate of emergence with GA₃ application may be attributed to its role in stimulating enzymatic activities that enhance reserve mobilization, promote cell division and elongation, and thereby support quicker seedling establishment. Similarly, the enriched growing media combinations provided better nutrient balance, aeration, and moisture availability, which created a favorable environment for uniform and vigorous seedling emergence compared to soil alone. Similar results were also observed by Bhardwaj (2014)^[2], Ashish *et al.* (2022)^[1] and Rani *et al.* (2024)^[20].

3.1.4 Germination index

The data pertaining to germination index as influenced by effect of growth regulator (GA₃) and growing media on seed germination and seedling growth of papaya has been recorded and presented in Table 2.

Factor A

A germination index of (24.91) was achieved in treatment G₃ (Treated with 200 ppm), making it the significantly highest among all treatments, while G₂ (Treated with 150 ppm) was at par with (24.42). On the opposite side, the lowest germination index (23.29) occurred in G₀ (Untreated seeds).

Factor B

The germination index was greatest in treatment M₃ (Soil + FYM + Vermicompost (1:1:1 ratio)) with a value of (27.52), followed by M₂ (Soil + Vermicompost (1:1)) at (25.41) and treatment M₁ (Soil + FYM (1:1)) at (22.78). On the other hand,

the lowest germination index value (20.60) was recorded under M₀ (Soil).

The increase in germination index under GA₃ treatment can be attributed to its ability to break seed dormancy, accelerate metabolic activities, and promote early seedling vigor, resulting in faster and more synchronized germination. Likewise, the higher germination index observed in enriched growing media is due to the improved physical and chemical properties of the medium, such as better aeration, nutrient availability, and moisture retention, which together create optimal conditions for uniform and vigorous seed germination in papaya. The finding of present study is in accordance with those of Choudhary *et al.* (2020)^[5], Meena *et al.* (2021)^[12] and Ashish *et al.* (2022)^[1].

3.1.5 Seed vigour (%)

The data pertaining to seed vigour (%) as influenced by effect of growth regulator (GA₃) and growing media on seed germination and seedling growth of papaya has been recorded and presented in Table 3.

i. Seed vigour (%) - I

Factor A

In treatment G₃ (Treated with 200 ppm), the seed vigour index-I at (4572.24%), emerging as the significantly superior value across treatments. A nearly equivalent seed vigour index-I was followed by the treatment G₂ (Treated with 150 ppm) (4493.70%) and the treatment G₁ (Treated with 100 ppm) (4396.69%). At the other end, G₀ (Untreated seeds) exhibited the poorest seed vigour index-I (4267.50%).

Factor B

Performance of treatments varied, with M₃ (Soil + FYM + Vermicompost (1:1:1 ratio)) recording the highest seed vigour index-I (4997.78%), while this was followed by M₂ (Soil + Vermicompost (1:1)) and M₁ (Soil + FYM (1:1)) showed (4610.24%) and (4284.29%) respectively. The least performance (3837.83%) was noted in M₀ (Soil).

The enhancement in seed vigour index-I with GA₃ application may be due to its role in stimulating physiological processes such as reserve mobilization, protein synthesis, and cell elongation, which collectively improve seedling length and biomass, thereby strengthening overall vigour. Similarly, the superior performance of enriched growing media can be attributed to the balanced supply of nutrients, improved microbial activity, and better aeration-moisture conditions that promote healthier and more robust seedling growth compared to soil alone. The results obtained in the present study is in accordance with the results of Gawankar *et al.* (2019)^[8], Jagtap *et al.* (2024)^[10] and Kumar *et al.* (2024)^[11].

ii. Seed vigour (%) - II

Factor A

In treatment G₃ (Treated with 200 ppm), the seed vigour index-II at (425.66%), emerging as the significantly superior value across treatments. A nearly equivalent seed vigour index-I was followed by the treatment G₂ (Treated with 150 ppm) (412.29%) and the treatment G₁ (Treated with 100 ppm) (396.16%). At the other end, G₀ (Untreated seeds) exhibited the poorest seed vigour index-II (380.65%).

Factor B

Performance of treatments varied, with M₃ (Soil + FYM + Vermicompost (1:1:1 ratio)) recording the highest seed vigour index-II (495.73%), while this was followed by M₂ (Soil +

Vermicompost (1:1)) and M₁ (Soil + FYM (1:1)) showed (425.81%) and (375.32%) respectively. The least performance (317.89%) was noted in M₀ (Soil).

The improvement in seed vigour index-II under GA₃ treatment can be explained by its ability to enhance seedling dry matter accumulation through better mobilization of food reserves and stimulation of metabolic activities, which contribute to stronger seedling growth. Likewise, enriched growing media combinations supported higher vigour by providing balanced nutrition, favorable microbial interactions, and improved soil environment, which enhanced seedling establishment and dry matter production compared to soil alone. Also, similar results were reported by Ramteke *et al.* (2015)^[19], Patel *et al.* (2017) and Choudhary *et al.* (2020)^[4].

3.1.6 Survival percentage (%)

The data pertaining to survival percentage (%) as influenced by effect of growth regulator (GA₃) and growing media on seed germination and seedling growth of papaya has been recorded and presented in Table 4.

Factor A

Data analysis revealed that G₃ (Treated with 200 ppm) produced the significantly highest survival percentage (%) (92.11%), which was followed by the treatment G₂ (Treated with 150 ppm) (91.28%) and the treatment G₁ (Treated with 100 ppm) (90.40%). Conversely, G₀ (Untreated seeds) exhibited the lowest survival percentage (%) (84.75%).

Factor B

The treatments showed clear variation in performance, with M₃ (Soil + FYM + Vermicompost (1:1:1 ratio)) achieving the highest survival percentage (%) (95.52%). This was followed by M₂ (Soil + Vermicompost (1:1)) (92.15%) and M₁ (Soil + FYM (1:1)) at (89.41%). In contrast, the lowest survival percentage (%) value (81.47%) was recorded in M₀ (Soil).

The higher survival percentage observed with GA₃ application may be attributed to its role in promoting vigorous and healthy seedlings through enhanced metabolic activity, stronger root-shoot development, and better stress tolerance, which collectively improve plant establishment. Similarly, enriched growing media supported greater survival by providing a favorable balance of nutrients, organic matter, and moisture along with improved aeration, thereby creating optimal conditions for sustained seedling growth and reducing mortality compared to soil alone. These outcomes are consistent with findings of Dilip *et al.* (2017)^[7], Panda (2017)^[16] and Palepad *et al.* (2017)^[15].

3.1.7 Germination value

The data pertaining to germination value as influenced by effect of growth regulator (GA₃) and growing media on seed germination and seedling growth of papaya has been recorded and presented in Table 4.

Factor A

Evaluation of germination value showed that treatment G₃ (Treated with 200 ppm) attained the significantly maximum value (4.97), which was followed by the treatment G₂ (Treated with 150 ppm) and G₁ (Treated with 100 ppm) registering (4.51)

and (4.41) respectively. The significantly, treatment G₀ (Untreated seeds) recorded the minimum germination value (4.31).

Factor B

It was observed that the treatments differed significantly in germination value, with M₃ (Soil + FYM + Vermicompost (1:1:1 ratio)) attaining the maximum value of (5.73). This was followed by the treatment M₂ (Soil + Vermicompost (1:1)) (4.77) and M₁ (Soil + FYM (1:1)) (4.16). Conversely, M₀ (Soil) displayed the lowest germination value (3.55).

The higher germination value observed in G₃ (200 ppm) may be attributed to the optimum concentration of treatment that enhanced physiological and metabolic activity of seeds, leading to better vigor and establishment, while untreated seeds (G₀) performed poorly due to lack of stimulatory effect. Similarly, under Factor B, the maximum germination value in M₃ (Soil + FYM + Vermicompost) can be explained by the balanced nutrient availability, improved soil structure, and microbial activity provided by organic amendments, which created a favorable environment for seed germination. Thus, chemical priming and organic substrate enrichment together contributed significantly to improving germination performance. Similar results were also observed by Bhardwaj (2014)^[2], Mengarda *et al.* (2015) and Gawankar *et al.* (2019)^[8].

3.1.8 Speed of emergence

The data pertaining to speed of emergence as influenced by effect of growth regulator (GA₃) and growing media on seed germination and seedling growth of papaya has been recorded and presented in Table 4.

Factor A

The speed of emergence varied across treatments, with G₃ (Treated with 200 ppm) achieving the significantly maximum value (0.29). This was at par with the treatments G₂ (Treated with 150 ppm) and G₁ (Treated with 100 ppm), which recorded (0.28) and (0.28) respectively. On the other hand, the lowest speed of emergence value (0.27) was observed in G₀ (Untreated seeds).

Factor B

The results revealed significant variation in speed of emergence among the treatments, with M₃ (Soil + FYM + Vermicompost (1:1:1 ratio)) recording the highest value (0.31). This was followed by M₂ (Soil + Vermicompost (1:1)) with (0.29) and M₁ (Soil + FYM (1:1)) with (0.27). In contrast, M₀ (Soil) exhibited the lowest speed of emergence (0.25).

The improvement in speed of emergence under GA₃ treatment may be attributed to its effect on enhancing seed metabolic activity, accelerating enzymatic functions, and promoting uniform and rapid germination, which together increase overall seed performance. Similarly, enriched growing media enhanced germination value by providing balanced nutrients, better aeration, moisture retention, and a favorable microbial environment, all of which supported healthy seedling emergence and establishment compared to soil alone. Similar results were also observed by Bhardwaj (2014)^[2], Rani *et al.* (2024)^[20] and Wati *et al.* (2024)^[22].

Table 1: Effect of growth regulator (GA₃) and growing media on germination percentage and days taken to start germination of papaya (*Carica papaya* L.) cv. Red Lady.

Treatment details	Germination percentage	Days taken to start germination
Factor A		
G ₀ : Untreated seeds	81.90	11.50
G ₁ : Treated with 100 ppm	83.90	11.24
G ₂ : Treated with 150 ppm	85.36	10.86
G ₃ : Treated with 200 ppm	86.23	10.22
Sem (±)	0.44	0.15
CD (5%)	1.26	0.43
Factor B		
M ₀ : Soil	75.91	14.47
M ₁ : Soil + FYM (1:1)	82.62	11.88
M ₂ : Soil + Vermicompost (1:1)	86.81	9.69
M ₃ : Soil + FYM + Vermicompost (1:1:1)	92.04	7.78
Sem (±)	0.44	0.15
CD (5%)	1.26	0.43
Interaction		
G ₀ M ₀	73.65	14.92
G ₀ M ₁	79.19	12.51
G ₀ M ₂	84.97	10.21
G ₀ M ₃	89.78	8.35
G ₁ M ₀	75.34	14.66
G ₁ M ₁	82.89	12.16
G ₁ M ₂	86.19	10.08
G ₁ M ₃	91.17	8.07
G ₂ M ₀	76.77	14.35
G ₂ M ₁	84.06	11.93
G ₂ M ₂	87.54	9.48
G ₂ M ₃	93.06	7.69
G ₃ M ₀	77.89	13.95
G ₃ M ₁	84.35	10.92
G ₃ M ₂	88.52	8.99
G ₃ M ₃	94.15	7.00
Sem (±)	0.88	0.30
CD (5%)	NS	NS
CV (%)	1.80	4.72

Table 2: Effect of growth regulator (GA₃) and growing media on rate of emergence and germination index of papaya (*Carica papaya* L.) cv. Red Lady.

Treatment details	Rate of emergence	Germination index
Factor A		
G ₀ : Untreated seeds	0.33	23.29
G ₁ : Treated with 100 ppm	0.34	23.69
G ₂ : Treated with 150 ppm	0.34	24.42
G ₃ : Treated with 200 ppm	0.35	24.91
Sem (±)	0.004	0.18
CD (5%)	0.01	0.53
Factor B		
M ₀ : Soil	0.30	20.60
M ₁ : Soil + FYM (1:1)	0.33	22.78
M ₂ : Soil + Vermicompost (1:1)	0.35	25.41
M ₃ : Soil + FYM + Vermicompost (1:1:1)	0.37	27.52
Sem (±)	0.004	0.18
CD (5%)	0.01	0.53
Interaction		
G ₀ M ₀	0.29	20.12
G ₀ M ₁	0.32	21.68
G ₀ M ₂	0.35	24.42
G ₀ M ₃	0.36	26.94
G ₁ M ₀	0.30	20.25
G ₁ M ₁	0.33	22.46
G ₁ M ₂	0.35	24.85
G ₁ M ₃	0.37	27.18
G ₂ M ₀	0.31	20.91
G ₂ M ₁	0.34	23.15
G ₂ M ₂	0.36	25.92

G ₂ M ₃	0.38	27.71
G ₃ M ₀	0.31	21.12
G ₃ M ₁	0.35	23.83
G ₃ M ₂	0.36	26.46
G ₃ M ₃	0.38	28.25
Sem (±)	0.01	0.37
CD (5%)	NS	NS
CV (%)	3.75	2.65

Table 3: Effect of growth regulator (GA₃) and growing media on seed vigour (%) of papaya (*Carica papaya* L.) cv. Red Lady.

Treatment details	Seed vigour (%) -I	Seed vigour (%) -II
Factor A		
G ₀ : Untreated seeds	4267.50	380.65
G ₁ : Treated with 100 ppm	4396.69	396.16
G ₂ : Treated with 150 ppm	4493.70	412.29
G ₃ : Treated with 200 ppm	4572.24	425.66
Sem (±)	27.63	2.86
CD (5%)	79.59	8.25
Factor B		
M ₀ : Soil	3837.83	317.89
M ₁ : Soil + FYM (1:1)	4284.29	375.32
M ₂ : Soil + Vermicompost (1:1)	4610.24	425.81
M ₃ : Soil + FYM + Vermicompost (1:1:1)	4997.78	495.73
Sem (±)	27.63	2.86
CD (5%)	79.59	8.25
Interaction		
G ₀ M ₀	3697.38	296.60
G ₀ M ₁	4058.77	353.28
G ₀ M ₂	4479.03	404.12
G ₀ M ₃	4834.81	468.60
G ₁ M ₀	3797.44	310.39
G ₁ M ₁	4282.02	373.91
G ₁ M ₂	4565.43	418.80
G ₁ M ₃	4941.88	481.56
G ₂ M ₀	3883.86	321.96
G ₂ M ₁	4374.01	384.40
G ₂ M ₂	4661.62	431.94
G ₂ M ₃	5055.32	510.86
G ₃ M ₀	3972.64	342.63
G ₃ M ₁	4422.36	389.69
G ₃ M ₂	4734.87	448.41
G ₃ M ₃	5159.11	521.90
Sem (±)	55.26	5.73
CD (5%)	NS	NS
CV (%)	2.16	2.46

Table 4: Effect of growth regulator (GA₃) and growing media on survival percentage (%), germination value and Speed of emergence of papaya (*Carica papaya* L.) cv. Red Lady

Treatment details	Survival percentage (%)	Germination value	Speed of emergence
Factor A			
G ₀ : Untreated seeds	84.75	4.31	0.27
G ₁ : Treated with 100 ppm	90.40	4.41	0.28
G ₂ : Treated with 150 ppm	91.28	4.51	0.28
G ₃ : Treated with 200 ppm	92.11	4.97	0.29
Sem (±)	0.28	0.06	0.002
CD (5%)	0.80	0.17	0.01
Factor B			
M ₀ : Soil	81.47	3.55	0.25
M ₁ : Soil + FYM (1:1)	89.41	4.16	0.27
M ₂ : Soil + Vermicompost (1:1)	92.15	4.77	0.29
M ₃ : Soil + FYM + Vermicompost (1:1:1)	95.52	5.73	0.31
Sem (±)	0.28	0.06	0.002
CD (5%)	0.80	0.17	0.01
Interaction			
G ₀ M ₀	65.28	3.42	0.25
G ₀ M ₁	88.29	3.99	0.27
G ₀ M ₂	91.26	4.54	0.29

G ₀ M ₃	94.18	5.29	0.30
G ₁ M ₀	85.83	3.45	0.25
G ₁ M ₁	88.96	4.10	0.27
G ₁ M ₂	91.47	4.67	0.29
G ₁ M ₃	95.33	5.42	0.31
G ₂ M ₀	86.99	3.54	0.25
G ₂ M ₁	89.53	4.14	0.27
G ₂ M ₂	92.59	4.81	0.29
G ₂ M ₃	96.02	5.55	0.31
G ₃ M ₀	87.79	3.77	0.26
G ₃ M ₁	90.83	4.40	0.28
G ₃ M ₂	93.29	5.06	0.29
G ₃ M ₃	96.55	6.65	0.32
Sem (±)	0.53	0.12	0.004
CD (5%)	NS	NS	NS
CV (%)	1.00	4.62	2.77

4. Conclusion

The present investigation clearly demonstrated that both gibberellic acid (GA₃) concentration and the composition of growing media exert a significant influence on seed germination and seedling development of papaya (*Carica papaya* L.) cv. Red Lady under the Bastar agro-climatic conditions of Chhattisgarh. Application of GA₃ markedly enhanced seed germination, vigour, and seedling survival by stimulating enzymatic activities, accelerating reserve mobilization, and breaking seed dormancy. Among the different concentrations tested, GA₃ at 200 ppm (G₃) proved to be the most effective in improving germination percentage, germination index, vigour index, and survival rate compared with untreated seeds.

Similarly, the use of enriched organic media significantly influenced seedling performance. The medium comprising Soil + FYM + Vermicompost (1:1:1) (M₃) provided superior aeration, balanced nutrient availability, and enhanced microbial activity, which collectively improved germination speed, seedling growth, and establishment. The interaction effect of GA₃ 200 ppm with Soil + FYM + Vermicompost (G₃M₃) recorded the highest values across all parameters, confirming its superiority over other combinations.

Therefore, the study concludes that pre-soaking papaya seeds in 200 ppm GA₃ solution followed by sowing in a growing medium containing Soil + FYM + Vermicompost (1:1:1) can be recommended for achieving maximum germination, early emergence, vigorous seedlings, and higher survival percentage in nursery conditions. The adoption of this protocol can contribute to improving the quality of papaya seedlings and ensuring better field establishment for sustainable papaya production in the Bastar region and similar tropical environments.

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6. Conflict of Interest

The authors declare no conflict of interest regarding the publication of this research article.

7. Future Scope of the Study

The findings of this study have significant implications for the improvement of papaya nursery practices under tropical and sub-tropical climatic conditions. Future research can explore the physiological and biochemical mechanisms underlying GA₃-induced enhancement in germination and seedling vigour, including enzyme activity and hormonal regulation during early growth. Moreover, studies involving different papaya cultivars and variable agro-ecological regions can help validate the optimized GA₃ concentration and growing media combinations identified in this experiment. The integration of other organic amendments such as biochar, cocopeat, or microbial inoculants may further enhance the sustainability and efficiency of nursery management. Long-term field evaluations of seedlings raised under these optimized nursery conditions will also be valuable to assess their influence on plant establishment, yield performance, and fruit quality under farmer-managed conditions.

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