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Effect of Different Plant Growth Regulators on Seed Germination, Seedling Growth and Establishment of Papaya (*Carica papaya* L.) c.v. Taiwan-7

Abhishek [a++*], Samir E. Topno [a#] and Annjoe V Joseph [a#]

[a] Department of Horticulture, Naini Agricultural Institute, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj. 211007 (U.P.), India.

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

An experiment was conducted at the Department of Horticulture, Sam Higginbottom University of Agriculture, Technology & Sciences, Prayagraj (U.P)-211007, India during year 2023-24. The experiment was laid out in Randomized Design (RBD). There were Ten treatments including control replicated three times in which growing media such as pond soil, vermicompost, and Plant growth

[++] M.Sc. Scholar (Fruit Science),
[#] Assistant Professor;
**Corresponding author: E-mail: abhishekgodara9119@gmail.com;*

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regulators mixed in various percentages. The different levels of plant growth regulators Such as GA3, NAA and BA with different compositions in different combinations showed positive responses on the physical quality attributes of the papaya plant. The maximum values of physical quality characteristics of papaya plant like Survival percentage (90.68) number of germination days (10.01), germination percentage (90.01), number of leaves (10.46), plant height (12.76 cm), leaf area (38.4 cm2) and chlorophyll content (52.84), Number of primary roots (10.46), number of secondary roots(27.68) and stem diameter (3.85 cm) were recorded in T3 (GA3 with 150 ppm) and followed by the treatment T6 (NAA with 150 ppm) while, minimum values of these characters maximum value of physical parameter was recorded in control treatment (T0). From the present investigation it is concluded that treatment (T3) Performed best in terms of growth parameters followed by (T6) and (T9). The maximum B:C ratio (2.02) was also observed in the same treatment i.e. (T3).

Keywords: Plant growth regulators; vermicompost; Taiwan-7; GA3; NAA.

1. INTRODUCTION

Papaya (*Carica papaya* L.): A tropical fruit crop with rapid growth, continuous fruiting cycle, and evergreen nature. It is an exceptionally wholesome, refreshing, and delicious tropical fruit that belongs to the Caricaceae family. Native to tropical America, papaya is also known by the names papaw or pawpaw. It stands as an ideal fruit choice for cultivation in various settings, including kitchen gardens, residential backyards, fields, and even orchards as a filler plant. Its proximity to urban areas makes it a convenient choice for cultivation, and its nutritional richness further contributes to its popularity [1].

Nutritional Value and Richness: Papaya stands out as a nutritional powerhouse, offering a plethora of health benefits. It contains approximately 2500 International Units (IU) of vitamin A and around 85 milligrams of vitamin C per 100 grams of its succulent pulp [2]. These vitamins are essential for maintaining healthy skin, boosting the immune system, and supporting overall well-being. In addition, papaya is notably rich in calcium and a range of other essential minerals that contribute to bone health, nerve function, and more. Medicinal Significance: Beyond its delectable taste and nutritional bounty, papaya holds high medicinal value. The extraction of papain from the dried latex of immature papaya fruits serves a variety of applications. Papain, a proteolytic enzyme, is used to tenderize meat, manufacture chewing gum, create cosmetics, degum natural silk, and enhance the shrink resistance of wool. The diverse utility of papain highlights its significance in industries beyond the culinary realm. Anticancer Potential: Recent research has uncovered another facet of papaya's potential health benefits. Papaya juice has demonstrated an *in vitro* antiproliferative effect on liver cancer cells [3-5]. This effect is believed to be attributed to compounds like lycopene present in papaya. The promising findings suggest that papaya may have a role to play in promoting health and potentially combating certain diseases [6].

Soil Requirements and Climatic Considerations: The optimal Soil Conditions: Papaya thrives in well-drained and fertile soils, which provide the ideal foundation for its growth and development. Well-drained soils prevent waterlogging, which can be detrimental to the root system. Fertile soils offer the necessary nutrients for papaya plants to flourish [7].

The soil structure should allow for efficient root penetration, promoting healthy root growth and nutrient absorption. Climatic Preferences and Protection: Papaya plants have specific climatic preferences that contribute to their successful cultivation. They thrive in sheltered environments that offer protection against adverse wind conditions. While papaya requires abundant sunlight for growth, exposure to strong winds can damage the plants and hinder their development. By choosing a sheltered location with ample sunlight, cultivators can provide the optimal climatic conditions for papaya to thrive. Seedling Raising Time and Challenges: Best Raising Time: Optimal seedling raising time for papaya is June to September, with an alternative window of February to May in North India due to frost [8]

Naphthalene Acetic Acid (NAA) is a synthetic plant growth regulator with significant effects on plant growth and development: Root Development: NAA promotes the formation and growth of roots. It stimulates cell elongation and division in root tissues, leading to the development of a robust root system. Lateral

Root Formation: NAA is involved in the initiation and development of lateral roots, which branch from the primary root. This branching increases the root surface area, enhancing nutrient and water absorption. Fruit Growth: NAA can influence fruit development by preventing premature fruit drop and enhancing fruit growth. Its application can lead to increased fruit size and yield in specific crops

Gibberellic Acid (GA) is a plant growth regulator with diverse roles in influencing plant development: Stem Elongation: GA stimulates cell division and elongation in the internodes, leading to increased stem length and overall plant height. Seed Germination: GA breaks seed dormancy and promotes germination by activating enzymes that degrade stored nutrients, facilitating embryo growth. Flowering Induction: GA interacts with other hormones and environmental cues to influence flowering. It's widely used in horticulture to trigger flowering in certain plants [9].

The Taiwan-7 papaya variety, scientifically known as *Carica papaya* L., is characterized by its distinct features: Fruit Color: The standout feature of this variety is its vibrant red-orange flesh, setting it apart from traditional yellow or orange varieties. Flavor and Taste: "Taiwan-7" papaya is known for its sweet and tropical flavor, making it a favorite for consumption. Fruit Size: The fruits of this variety are medium to large, making them suitable for both individual consumption and commercial use. Yield Potential: This variety boasts high yield potential, making it an attractive option for farmers seeking productive cultivars.

2. MATERIALS AND METHODS

2.1 Geographical Location of the Experimental Site

The experimental site is located at a latitude of 25.41º North and longitude of 81.84 ºEast, with an altitudeof98meters above the mean sea level (MSL) of prayagraj.

2.2 Climatic Conditions of the Experimental Area

The area of Prayagraj comes under a humid sub-tropical climate, which experiences warm humid monsoon, hot dry summer and cold dry winter. The annual mean temperature is 26.1ºC while monthly mean temperatures are 18-29ºC. The daily average maximum temperature is about 22ºC and the minimum temperature is 9ºC. The average annual rainfall received is 1042.2 mm. At this location, the temperature reaches up to 46ºC-48ºC and the minimum temperature recorded is 4ºC-5ºC. The relative humidity ranges in this location ranges between 20-94%.

Table 1. Treatment Details

Treatment	Treatments
T_0	Control (Unsprayed)
T_1	GA3@50ppm
T_2	GA3@100ppm
T_3	GA3@150ppm
T_4	NAA@50ppm
T_5	NAA@100ppm
T_6	NAA@150ppm
T_7	BA@50ppm
T_8	BA@100ppm
T_9	BA@150ppm

3. RESULTS AND DISCUSSION

a) Number of days to germination

The minimum for Number of days required for initiation of germination was recorded in the treatment T3 (GA3 @ 150 ppm) at 10.01 followed by 10.68 with T6 (NAA @ 150 ppm) and the maximum days for initiation of Germination at 12.68 was recorded in the T0 control.

“Maximum number of days to germination was recorded when seeds soaked in GA3 might be due to the fact that GA3 involved in the activation of cytological enzymes which stimulates α–amylase enzyme that converts insoluble starch into soluble sugars and it also initiates the radical growth by removing some metabolic blocks” [10].

b) Number of leaves per plant

At 45 DAT the maximum Number of leaves per plant was recorded in the treatment T4 (GA3 @ 150 ppm) at 10.46 followed by 10.40 with T6 (NAA @ 150 ppm) and the minimum Number of leaves per plant at 8.36 was recorded in the T0 control.

“Number of leaves/plant was noticed in seed treated with GA3 - 200 ppm. This may be due to GA3 are used for weakening of the seed coat so that the emergence of radical and plumule is positively influenced for root and shoot initiation. Beside this, GA3 also helps in cell expansion and

its elongation resulting better root and shoot growth, which supports and encourage better survival of the seedlings" [11].

c) Height of seedling

At 45 days the maximum height of the seedling was recorded in the treatment T4 (GA3 @ 150 ppm) at 12.76 cm followed by 12.00 cm with T6 (NAA @ 150 ppm) and minimum height of seedling at 9.96 cm was recorded in the T0 control.

"Height of seedling was noticed in seed treated with GA3 - 200 ppm. This may be due to GA3 are used for weakening of the seed coat so that the emergence of radical and plumule is positively influenced for root and shoot initiation. Beside this, GA3 also helps in cell expansion and its elongation resulting better root and shoot growth, which supports and encourage better survival of the seedlings" [12].

d) Stem Diameter

The maximum stem Diameter was recorded in the treatment T3 (GA3@ 150 ppm) at 3.85 mm followed by 3.67 mm with T6 (NAA @ 150 ppm) and the minimum stem Diameter at 3.37 mm was recorded in T0 control.

"Stem diameter was noticed in seed treated with GA3 - 200 ppm. This may be due to GA3 are used for weakening of the seed coat so that the emergence of radical and plumule is positively influenced for root and shoot initiation. Beside this, GA3 also helps in cell expansion and its elongation resulting better root and shoot growth, which supports and encourage better survival of the seedlings" [13].

e) Fresh weight of shoot (g)

At 45 DAT the maximum Fresh weight of shoot (g) was recorded in the treatment T4 (GA3@ 150 ppm) at 5.05 g followed by 4.60 g with T6 (NAA @ 150 ppm) and the minimum Fresh weight of shoot (g) at 3.98 was recorded in T0 control.

"Fresh weight of shoot (g)was noticed in seed treated with GA3 - 200 ppm. This may be due to GA3 are used for weakening of the seed coat so that the emergence of radical and plumule is positively influenced for root and shoot initiation. Beside this, GA3 also helps in cell expansion and its elongation resulting better root and shoot growth, which supports and encourage better survival of the seedlings" s14].

f) Fresh weight of root (g)

Fresh weight of root (g) of four tagged seedlings was measured by metric scale at 45 days and average value was Calculated. The maximum Fresh weight of root (g) was recorded in the treatment T4 (GA3 @ 150 ppm) at 1.26 g followed by 1.09 g with T6 (NAA @ 150 ppm) and minimum days for Fresh weight of shoot (g) at 0.60 was recorded in T0 control.

"Fresh weight of root (g)was noticed in seed treated with GA3 - 200 ppm. This may be due to GA3 are used for weakening of the seed coat so that the emergence of radical and plumule is positively influenced for root and shoot initiation. Beside this, GA3 also helps in cell expansion and its elongation resulting better root and shoot growth, which supports and encourage better survival of the seedlings" [15].

g) Leaf area

The maximum Leaf Area was recorded in the treatment T4 (GA3 @ 150 ppm) at 38.40 cm^2 / plant followed by 38.21 cm^2 / plant with T8 (NAA @ 150 ppm) and the minimum Leaf Area at 33.69 cm^2 / plant was recorded in T0 control.

"Leaf area was noticed in seed treated with GA3 - 200 ppm. This may be due to GA3 are used for weakening of the seed coat so that the emergence of radical and plumule is positively influenced for root and shoot initiation. Beside this, GA3 also helps in cell expansion and its elongation resulting better root and shoot growth, which supports and encourage better survival of the seedlings" [16].

h) Survival percentage of papaya seedling

The maximum Survival percentage of papaya seedling was recorded in the treatment T4 (GA3 @ 150 ppm) at 90.86 % followed by 87.98% with T6 (NAA @ 150 ppm) and the minimum Survival percentage of papaya seedling at 77.79% was recorded in T0 control.

"Maximum survival was noticed in seed treated with GA3 - 200 ppm. This may be due to GA3 are used for weakening of the seed coat so that the emergence of radical and plumule is positively influenced for root and shoot initiation. Beside this, GA3 also helps in cell expansion and its elongation resulting better root and shoot growth, which supports and encourage better survival of the seedlings" (Ramteke, 2015).

Table 2. Effect of PGRs on germination percentage, days to germination, plant height (cm) and survival percentage in papaya

Treatment (No.)	Treatment	Germination Percentage	Number of Days of Germination	Survival Percentage (%)	Plant Height (cm)
T_0	Control	60.01	12.68	77.79	9.96
T_1	GA3@50ppm	68.34	11.34	84.34	10.23
T_2	GA3@100ppm	73.34	11.01	87.01	10.46
T_3	GA3@150ppm	90.01	10.01	90.68	12.76
T_4	NAA@50ppm	66.68	12.34	82.34	10.03
T_5	NAA@100ppm	70.01	11.01	85.72	10.3
T_6	NAA@150ppm	86.68	10.68	87.98	12
T_7	BA@50ppm	61.13	12.68	81.34	10
T_8	BA@100ppm	68.34	11.34	85.01	10.06
T_9	BA@150PPM	75.01	10.70	87.68	11.16
F test		S	S	S	S
SE(m)		3.11	0.29	1.18	0.31
C.D. at 5%		1.56	0.14	0.59	0.15
C.V		13.67	8	4.4	9.08

Table 3. Effect of PGRs on Stem diameter (mm), Leaf area and number of leaves in papaya

Treatment (No.)	Treatment	Number of leaves	Stem Diameter (mm)	Chlorophyll (SPAD Value)	Leaf Area(cm²)
T_0	Control	8.36	3.37	45.17	33.69
T_1	GA3@50ppm	9.33	3.46	49.24	36.28
T_2	GA3@100ppm	10.26	3.66	49.77	37.61
T_3	GA3@150ppm	10.46	3.85	52.84	38.4
T_4	NAA@50ppm	9.06	3.41	48.67	34.87
T_5	NAA@100ppm	9.5	3.54	49.25	37.38
T_6	NAA@150ppm	10.4	3.67	51.82	38.21
T_7	BA@50ppm	8.76	3.41	47.8	34.25
T_8	BA@100ppm	8.83	3.51	49.46	36.35
T_9	BA@150PPM	10.3	3.65	50.54	37.95
F test		S	S	S	S
SE(m)		0.25	0.05	0.67	0.54
C.D. at 5%		0.12	0.02	0.33	0.27
C.V		8.2	3.53	4.27	4.69

Table 4. Effect of PGRs on root and shoot value of different term in papaya

Treatment	Treatment	Fresh weight of shoot (g)	Fresh weight of roots (g)	Root to shoot ratio
T_0	Control	3.98	2.12	0.54
T_1	GA3@50ppm	4.16	2.24	0.55
T_2	GA3@100ppm	4.33	2.62	0.61
T_3	GA3@150ppm	5.05	2.9	0.58
T_4	NAA@50ppm	4.26	2.23	0.53
T_5	NAA@100ppm	4.31	2.18	0.52
T_6	NAA@150ppm	4.6	2.21	0.49
T_7	BA@50ppm	4.03	2.14	0.54
T_8	BA@100ppm	3.85	2.1	0.55
T_9	BA@150PPM	4.12	2.12	0.52
F test		S	S	S
SE(m)		0.11	0.08	0.01
C.D. at 5%		0.05	0.04	0.01
C.V		8.12	12.18	6.26

Table 5. Economics of different treatment

Treatment	Cost of cultivation	Gross Return	Net Return	B:C Ratio
T_0	13100	35000	21900	1.68
T_1	13130	37000	23870	1.82
T_2	13150	38500	25350	1.93
T_3	13220	40000	26780	2.02
T_4	13120	37000	23880	1.82
T_5	13130	37500	24370	1.86
T_6	13140	39000	25860	1.97
T_7	13120	37000	23880	1.83
T_8	13140	38000	24860	1.9
T_9	13160	38800	25640	1.95

i) Germination Percentage

The germination percentage was worked out after the final germination, i.e., after stoppage of germination. It was calculated by dividing to total number of seeds sown with the number of seeds germination and germination percent was calculated.

The maximum Germination Percentag**e** was recorded in the treatment T3 (GA3 @ 150 ppm) at 90.01 % and the minimum Germination Percentage at 60.01% was recorded in T0 control.

"Maximum germination percentage was recorded when seeds soaked in GA3 might be due to the fact that GA3 involved in the activation of cytological enzymes which stimulates α–amylase enzyme that converts insoluble starch into soluble sugars and it also initiates the radical growth by removing some metabolic blocks" [17].

j) Chlorophyll content

Chlorophyll content of four tagged seedlings was measured with the help of spectrophotometric ally. An average value was calculated. The maximum Chlorophyll Content was recorded in the treatment T4 (GA3 @ 150 ppm) at 52.84 µm/g followed by 51.82 µm/g with T8 (NAA @ 150 ppm) and the minimum Chlorophyll Content at 45.17 µm/g was recorded in T0 control.

k) Shoot: ratio

Aperusal of data given in Table 4 revealed that use of different plant growth regulators brought out perceptible variation in shoot: root ratio of papaya seedlings at 45 days after sowing. Maximum and significantly higher shoot: root ratio (0.61) was observed in treatment T_2 and it was statistically at par with treatment T_4, T_5, T_8 and T_9 during the course of experimentation. However, minimum shoot: root ratio (0.54) was found in treatmentT_6.

"Fresh weight and dry weight of roots recorded significantly increase with treatment GA3 - 200 ppm. This seems to be the effect of mobilization of water and nutrients transported at higher rate which might have promoted more production of photosynthetic product and translocated them to various plant parts which might have resulted in better growth of the seedlings and hence more fresh and dry weight" as suggested by Desai et al., [18].

l) Economics of papaya

It is evident from the data (Table 5) that plant growth regulators GA 3@ 150 ppm had maximum and significantly higher net returns in papaya seedlings (26780 per 1000 seedlings) over rest of the treatments except T8, T5, T6 and T2 which were found at par. Further, the minimum net return (21900 per 1000 seedlings) was recorded under the treatment T0 [19].

4. CONCLUSION

Growing media and growth regulators are being commonly used nowadays to get a high germination percentage in a short period. From this paper we can conclude that using GA3 with a combination of different types of growing media resulting in effective seed germination and good seedling vigor. The resulted high survival % of seedlings in papaya seeds is attributed to GA3 which in turn catalyzes the starch conversion into simple carbohydrates by participating in the activity of alpha-amylase which liberates chemical energy for the activation of the embryo. On the other hand, growing media helps the germination by providing adequate cation-exchange for holding nutrients and also having good water holding capacity and sufficiently porous structure that permits adequate moisture and exchange of gases between the growing media and the embryo which is important for fast and invariant germination of seeds.

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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