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Effects of Different Plant Growth Regulators on Seed Germination, Seedling Growth and Establishment of Papaya (*Carica papaya*) Cv. Pusa Nanha

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

Papaya (*Carica papaya* L.) is an economically significant tropical fruit, but its cultivation is often hindered by low seed germination rates and poor seedling vigor. The present study aims to investigate the effects of different Plant Growth Regulator on seed germination, seedling growth and establishment of papaya (*Carica papaya*) Cv. Pusa Nanha. at The Department of Horticulture, Sam Higginbottom University of Agriculture, Technology and Sciences, Allahabad, during the period

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2023-24. The experiment was laid in completely randomized block design with three replications and ten treatment combinations. viz, T0 (Control), T1 (NAA 100ppm), T2 (NAA 150ppm), T3 (NAA 200ppm), T4 (GA3 100ppm), T5 (GA3 150ppm),T6 (GA3 200 ppm), T7 (IAA 100ppm), T8 (IAA 150ppm), T9 (IAA 200ppm). Seeds were soaked in respective PGR solutions for 12 hours before sowing and various parameters related to Germination Parameters, Growth Parameters, Survival and Establishment were evaluated. On the basis of present experimental findings, it is concluded that treatmentT6(GA3 200ppm) performed best in term of Germination percentage (100%), Seedling vigour index (823.33), Number of leaves (10.00), Plant height (16.83 cm), Chlorophyll content (41.30 SPAD value) and stem girth (0.56 cm) Whereas T2 (NAA 150ppm) performed best in term of Leaf length (8.83 cm), Leaf width (8.50 cm), Leaf area (59.53 cm^2) and Establishment Percentage (82.20%). The lowest observation was recorded in T0 (Control). These findings suggest that specific PGR treatments can substantially enhance the germination and growth parameters of papaya seedlings, potentially leading to improved crop yields.

Keywords: GA3; NAA; IAA; PGRs; seed germination; seedling growth; establishment; papaya var.; pusa nanha.

1. INTRODUCTION

“The papaya, also known as *Carica papaya* L. in botanical terms, is a member of the Caricaceae family and is both a genus and a species of Carica. Chromosome no. (2n=18). One of the world's top crops is grown in tropical and subtropical areas” [1].

“Papaya (*Carica papaya*) is a tropical fruit having commercial importance because of its high nutritive and medicinal value. Papaya cultivation had its origin in South Mexico and Costa Rica. Total annual world production is estimated at 6 million tonnes of fruits. India leads the world in papaya production with an annual output of about 3 million tonnes. Other leading producers are Brazil, Mexico, Nigeria, Indonesia, China, Peru, Thailand and Philippines. The papaya is believed to be native to southern Mexico and neighboring Central America. It is currently cultivated in Florida, Hawaii, Eastern British Africa, South Africa,Sri-Lanka, India, Canary Islands, Malaysia and Australia. It is now present in every tropical and subtropical country” [1].

“Papaya is a rich source of vitamin A and C. It has a high nutritive and medicinal value. Papaya trees can grow up to 30 feet tall, and the fruit typically weighs between 1 and 10 pounds. The fruit has a greenish yellow skin when unripe, and turns yellow or orange as it ripens. The flesh of the papaya is orange or pink, and is soft and juicy with small black seeds in the center. Papain prepared from dried latex of its immature fruits is used in meat tenderizing, manufacture of chewing gum, cosmetics, for degumming natural silk and to give shrink resistance to wool. Papaya fruits can be eaten ripe or unripe and prepared as vegetables. The ripe fresh fruits are used to make jam, syrup, crystallized fruits, ice cream flavoring, and soft beverages. Papain, an enzyme used in meat tenderizing preparations, is made from the dried latex of unripe fruits. It works in a similar manner as pepsin” [2].

Papaya is primarily propagated by seed, yet low germination and weak seedling vigor occur from early seed degeneration after harvest. In the pursuit of improving these essential attributes, the application of growth regulators and the selection of appropriate propagation media have gathered significant attention among researchers and horticulturists.

Therefore, the present study was designed to investigate the impact of growth regulators on the germination, growth, and overall vigour of papaya seedling. Understanding how these variables influence the early stages of papaya growth is pivotal for enhancing the quality and yield of papaya crops, and ultimately contribute to the advancement of sustainable agriculture and the production of nutritious fruits. It has been reported that the germination of seeds of papaya is slow, erratic and incomplete [3] which is mainly due to the accumulation of inhibitors in the sarcotesta, resulting in subsequent decrease in seed germination during storage [4]. Sarcotesta, a gelatinous substance around the seeds that contains germination inhibitors was found to not only impede germination but also the subsequent emergence of seedlings. It has been found to stop oxygen from reaching the seed and impeding the germination process.

The application of growth regulators and other compounds to seeds, improves their germination

and vigour through modifications to the respiratory metabolism and promoter-inhibitor balance. Pre-soaking of papaya seeds in GA3 and NAA (1-Naphthalene acetic acid) presents a promising approach for nursery and agricultural practices aimed at achieving higher germination rates and healthier seedlings, ultimately contributing to improved papaya crop yields [5].

Overall, PGRs serves as a valuable tool for papaya growers aiming to cultivate healthier and more productive papaya seedlings [6].

2. MATERIALS REQUIRED

The present study was carried out during 2023-2024 at the experimental orchard of Department of Horticulture, Naini Agricultural Institute, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj. which is located in the south-east part of Uttar Pradesh India. Prayagraj falls under agroclimatic zone IV which is named as “trans Jamuna plains” the site of experiment is located at 25.57º N latitude 81.51º E longitude and 98 meter above the sea level the temperature falls down as low as 4-5ºc during winter, the average rainfall in this area is around 798.900 mm annually with maximum concentration during July to September with few showers and drizzles in winter also. The experiment was arranged in a randomized block design (RBD) with three replications and ten treatments. Each treatment consisted of different concentrations of three growth regulators (GA3, NAA, IAA) and a control (zero dose). The treatments were: T0 (Control), T1 (NAA 100ppm), T2 (NAA 150ppm), T3 (NAA 200ppm), T4 (GA3 100ppm), T5 (GA3 150ppm), T6 (GA3 200 ppm), T7 (IAA 100ppm), T8 (IAA 150ppm), T9 (IAA 200ppm). The papaya seed of the variety Pusa Nanha was procured from Head, Division of Fruits and Post Harvest Technology, IARI New Delhi, ensuring its seed quality and varietal purity. The PGR solutions were prepared as follows:

- GA3: Concentrations of 100 ppm, 150 ppm, and 200 ppm were prepared by weighing 100 mg, 150 mg, and 200 mg of GA3, respectively.
- NAA: Concentrations of 100 ppm, 200 ppm, and 300 ppm were prepared by weighing 100 mg, 200 mg, and 300 mg of NAA, respectively.
- IAA: Concentrations of 100 ppm, 150 ppm, and 200 ppm were prepared by weighing 100 mg, 150 mg, and 200 mg of IAA, respectively.

Each weighed amount was dissolved in 10 ml of ethyl alcohol to ensure complete dissolution. The solution was then diluted to a final volume of one liter with distilled water. The seeds were soaked in these PGR solutions for 12 hours to facilitate the absorption of the growth regulators.

All the treated seeds were sown in the poly bag (1 kg capacity) in the evening. The seeds are sown in each treatment (18 seeds) and irrigated immediately. Optimum moisture of media was maintained during the period of seed germination. Each treatment was clearly labeled with tags for easy identification. In order to evaluate the effect of plant growth regulators on growth parameters of papaya (*Carica papaya* L.) cv. “Pusa Nanha”, a method and algorithms were used to compute different statistical parameters. The Analysis of Variance (ANNOVA) method was used to compare the means of the attributes and necessary periodical observations were also recorded. A methodology of individual aspect is briefly described in the following parameters and have been presented below under the following headings.

2.1 Observations Recorded

The following observations were recorded and average was computed at growing successive stages.

2.1.1 Germination (%)

The germination percentage refers to the proportion of seeds that successfully sprout and begin to grow under specific conditions. It is commonly expressed as a percentage and is calculated by dividing the number of germinated seeds by the total number of seeds tested, then multiplying by 100. Here's the formula:

Germination percentage =

$$\frac{\text{Number of germinated seeds}}{\text{Total number of seeds}} \times 100$$

2.1.2 Plant height (cm)

A measuring scale was used to measure the height of the plant from ground level to the tip of the seedling at different intervals i.e. 15, 30, 45 Days after germination and 30 days after transplanting.

2.1.3 Numbers of leaves per seedling

Total number of leaves was counted from tagged plants in each replication at 15, 30, 45 DAS and at 30 DAT expressed as average number of leaves per plant.

2.1.4 Leaf length (cm)

Leaf length was measured using a measuring scale. For that, the scale was aligned along the midrib of the leaf, starting from the base to the tip, and the measurement was recorded in centimeters (cm) at different intervals i.e. 15, 30, 45 Days after germination and 30 days after transplanting.

2.1.5 Leaf width (cm)

For leaf width, the scale was placed perpendicular to the midrib, at the widest point of the leaf, and the measurement was taken in cm at different intervals i.e. 15, 30, 45 Days after germination and 30 days after transplanting.

2.1.6 Seedling vigour index

Seed vigour index was calculated by multiplying germination (%) and seedling length (cm) at 45 days after germination. The treatment showing the higher seed vigour index is considered to be more vigorous . It provides an indication of the overall vigor and health of the seedlings.

2.1.7 Stem girth (cm)

Girth of the stem was measured with the help of digital vernier calliper at 45 Days after germination and 30 days after transplanting.

2.1.8 Chlorophyll Content (SPAD Value)

The chlorophyll content of a plant is an important indicator of its photosynthetic capacity and overall health. Chlorophyll content was measured after 45 days after germination with the help of SPAD meter.

2.1.9 Leaf Area (sq. cm)

Leaf area refers to the total surface area of all the leaves on a plant. It is an important parameter in plant physiology and agronomy, as it directly influences the plant's ability to photosynthesize and produce energy. Placed the leaf flat on a piece of graph paper (which provides a grid of known dimensions) and traced the outline of the leaf onto the graph paper using a pen or pencil then counted the number of full squares (both complete and partial) enclosed by the leaf outline and each square represents a known area (e.g., 1 square centimeter). Finally, Multiplied the total number of squares by the known area represented by each square to obtain the total leaf area.

2.1.10 Establishment (%)

The establishment percentage is calculated by dividing the number of plants that have successfully established themselves by the total number of seeds or seedlings planted, then multiplying by 100 to express the result as a percentage. Here's the formula:

$$\text{Establishment percentage} = \frac{\text{Number of established plants}}{\text{Total number of seeds or seedlings planted}} \times 100$$

3. RESULTS AND DISCUSSION

The mean data on germination and seedling growth parameters, as influenced by different plant growth regulators, were recorded during the experimentation and are presented below.

Among different PGRs, T6 {GA3 200ppm} recorded maximum germination (%) of 100 % whereas minimum germination (%) of 55.53 % was recorded in T0 (Control). Seeds of papaya when treated with GA3@200ppm for 12hrs resulted in high % of germination and vigour index as GA3 activated cytological enzymes by increasing cell wall plasticity and provided better water absorption, promoted seed germination by producing α-amylase enzyme which converted insoluble starch into soluble sugars and initiated the radical growth by removing some metabolic blocks [7] .

Among different PGRs, T6 {GA3 200ppm} recorded maximum plant height (cm) of 3.47cm (15DAS), 6.53cm (30 DAS), 8.23cm (45 DAS) and 16.83cm(30DAT) whereas minimum plant height (cm) of 2.63cm (15DAS), 4.77cm (30 DAS), 6.83cm (45 DAS) and 13.37cm (30DAT) was recorded in T0 (Control). Maximum plant height in GA might have occurred due to cell division and cell elongation, which in turn would have increased the internodal length. The observations are in agreement with the findings of Deb et al. [8] in papaya seeds.

Among different PGRs, T6 {GA3 200ppm} recorded maximum number of leaves per plant of 2.53 (15DAS), 4.40 (30 DAS), 6.60 (45 DAS) and 10.00(30DAT) whereas minimum number of leaves of 2.00 (15DAS), 3.33 (30 DAS), 5.43 (45 DAS) and 8.50 (30DAT) was recorded in T0 (Control). A plant with more leaves per plant may have more vigorous physiological processes and be stimulated by GA3 to produce new leaves more quickly. This increased vegetative growth may have resulted in increased growth, higher metabolic activities, and increased production of carbohydrates. The results are in conformity of Sen et al. [9] in papaya seeds and Kalalbandi et al. [10] in kagzi lime.

Among different PGRs, T2 {NAA 150ppm} recorded maximum leaf length(cm) of 1.90cm (15DAS), 3.30cm (30 DAS), 4.57cm (45 DAS) and 8.83cm (30DAT) whereas minimum leaf length (cm) of 1.50cm (15DAS), 2.63cm (30 DAS), 4.03cm (45 DAS) and 8.07cm (30DAT) was recorded in T0 (Control).

Among different PGRs, T2 {NAA 150ppm} recorded maximum leaf width (cm) of 0.87cm (15DAS), 2.57cm (30 DAS), 3.77cm (45 DAS) and 8.50cm (30DAT) whereas minimum leaf width (cm) of 0.57cm (15DAS), 1.80cm (30 DAS), 2.73cm (45 DAS) and 7.37cm (30DAT) was recorded in T0 (Control). 53

Among different PGRs, T6 {GA3 200ppm} recorded maximum seedling vigour index of 823.33 whereas minimum seedling vigour index of 382.07 was recorded in T0 (Control). “The highest seedling vigour in GA3 was attributed to enlarged embryos, higher rate of metabolic activity and respiration, better utilization and mobilization of metabolites to growth points and higher activity of enzymes. Enzymatic and hormonal mechanism stimulate metabolic process such as sugar mobilization, protein hydrolysis, oxidation” [11], which leads to increase in root length, shoot length and seedling dry weight, in turn increase in seedling vigour. The present results are in conformity with the results of Gurung et al. [12].

Among different PGRs, T6 {GA3 200ppm} recorded maximum chloropyll content (SPAD value) of 41.30 whereas minimum chlorophyll content (SPAD value) of 33.63 was recorded in T0 (Control). This may have been due to growth regulators and agrochemicals causing decreased chlorophyll degradation, and increased chlorophyll synthesis. Growth regulator application delayed leaf senescence which could also be attributed to higher chlorophyll content. Similar results were reported by Shinde and Jadhav[13] in cowpea and Sai Sankar [14] in mung bean and the application of gibberellins increased the chlorophyll and protein content in the wax apple fruits [15].

Among different PGRs, T6 {GA3 200ppm} recorded maximum stem girth(cm) of 0.38 cm (45 DAS) and 0.56cm (30DAT) whereas minimum stem girth (cm) of 0.21cm (45 DAS) and 0.35cm (30DAT) was recorded in T0 (Control). It is revealed that stem diameter of papaya significantly increased under T6 (200ppm GA3). Increase in girth of stem may be possible due to stimulation of cambium and its immediate cell progeny, as observed. Dhankhar and Singh [16] and Gholap et al. [17] in Anola (*Phyllantus emblica* L.) and Deb et al. [8] in papaya.

Among different PGRs, T6 {NAA 200ppm} recorded maximum leaf area (cm^2) of 43.83cm (45 DAS) and 59.53cm (30DAT) whereas minimum leaf area (cm) of 19.90cm (45 DAS) and 35.10cm (30DAT) was recorded in T0 (Control). Increased amylase in the seed's aleurone tissue may have resulted from increased NAA availability. This would have improved the seed's ability to convert complex starches into simple sugars, which would have provided growth energy. Leaf area increased over time to a maximum that corresponded with peak growth and then steadily declined at later stages. Similar results were also reported by Ram. Asrey et al. [18] in musk melon.

Among different PGRs, T6 {NAA 150ppm} recorded maximum Establishment (%) of 82.20 % whereas minimum Establishment (%) of 61.07 % was recorded in T0 (Control) In the present study it is noted that the treatment with NAA at 150 ppm concentration gave the maximum survival percentage (82.20%) among all other treatments. This could be the result of longer roots, the maximum number of primary roots, early sprouting, and thicker roots. It could also be the result of the ability to regenerate more fibrous roots from the main roots, which likely absorb more water and nutrients from the soil with minimal transpirational losses. Similar results were also reported by Singh and Bahadur [19] and Singh et al. [20] in phalsa.

Table 1. Effects of different Plant growth regulators on plant height, number of leaves, leaf length, leaf breadth

Treatment Notion	Treatment details	Germin ation %.	Plant Height (cm) 30 DAT	Number of leaves 30 DAT	Leaf Length (cm) 30DAT	Leaf Width (cm) 30 DAT
T0	Control	55.53	13.37	8.50	8.07	7.37
T1	NAA@100ppm	77.73	15.03	8.57	8.70	8.27
T2	NAA@150ppm	94.43	16.03	9.00	8.83	8.50
T3	NAA@200ppm	88.87	16.17	9.07	8.67	8.23
T4	GA3@100ppm	88.87	13.40	9.33	7.23	5.93
T5	GA3@150ppm	100.00	15.47	9.60	8.40	7.93
T6	GA3@200ppm	100.00	16.83	10.00	8.37	7.83
T7	IAA@100ppm	83.30	15.03	9.07	7.77	7.73
T8	IAA@150ppm	72.17	14.67	9.30	8.07	7.40
T9	IAA@200ppm	94.43	14.73	9.40	8.30	7.47
F-Test		**S**	**NS**	**NS**	**NS**	**S**
S.Ed (+)		**10.56**	**1.29**	**0.41**	**0.70**	**0.58**
C.D. at 5%		**22.19**	**2.71**	**0.86**	**1.47**	**1.22**
C.V		**15.12**	**10.49**	**5.47**	**10.41**	**9.28**

Table 2. Effects of different plant growth regulators on seed vigour index, leaf area (cm^2), Chlorophyll content (SPAD Value), stem girth (cm), establishment %

Notion	Treatments	SPAD value.	Seedling vigour index	Leaf Area (cm^2).	Stem Girth (cm).	Establishment %.
T0	**Control**	33.63	382.07	35.10	0.35	61.07
T1	**NAA@100ppm**	38.63	601.87	56.97	0.46	80.53
T2	**NAA@150ppm**	35.87	673.17	59.53	0.45	82.20
T3	**NAA@200ppm**	39.87	683.17	54.47	0.50	80.53
T4	**GA3@100ppm**	39.90	680.93	44.17	0.48	80.53
T5	**GA3@150ppm**	34.13	760.00	47.50	0.51	72.17
T6	**GA3@200ppm**	41.30	823.33	55.00	0.56	77.73
T7	**IAA@100ppm**	38.87	603.00	46.47	0.47	67.20
T8	**IAA@150ppm**	35.67	665.37	45.97	0.41	76.67
T9	**IAA@200ppm**	36.50	703.23	52.73	0.43	76.63
F- Test		**NS**	**S**	**S**	**S**	**NS**
S.Ed (+)		**2.66**	**90.30**	**4.39**	**0.03**	**7.84**
C.D. at 5%		**5.59**	**189.71**	**9.23**	**0.06**	**16.47**
C.V		**8.71**	**16.82**	**10.81**	**7.92**	**12.71**

4. CONCLUSION

On the basis of present experimental findings, it is concluded that treatment T6 (GA3 200ppm) performed best in term of Germination percentage, Seedling vigour index, Number of leaves, Plant height, Chlorophyll content and stem girth Whereas T2 (NAA 150ppm) performed best in term of Leaf length, Leaf width, Leaf area and Establishment Percentage.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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