The Pharma Innovation Journal 2023; 12(11): 2387-2391

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2023; 12(11): 2387-2391

www.thepharmajournal.com
Received: 11-08-2023
Accepted: 17-09-2023

**Binita Hazarika**
Department of Horticulture, Assam Agricultural University, Jorhat, Assam, India

**Sailen Gogoi**
Department of Horticulture, Assam Agricultural University, Jorhat, Assam, India

**Reecha T Das**
Department of Horticulture, Assam Agricultural University, Jorhat, Assam, India

**Aradhana Bordoloi**
Department of Horticulture, Assam Agricultural University, Jorhat, Assam, India

**Corresponding Author:**
**Binita Hazarika**
Department of Horticulture, Assam Agricultural University, Jorhat, Assam, India

# Studies on seed germination, growth and vigour of papaya seedlings cv. 'Sapna' as influenced by growth regulators and propagation media

**Binita Hazarika, Sailen Gogoi, Reecha T Das and Aradhana Bordoloi**

## Abstract
An experiment entitled "Studies on seed germination, growth and vigour of papaya seedlings cv. 'Sapna' as influenced by growth regulators and propagation media" was conducted at Horticultural Experimental Farm, Department of Horticulture, Assam Agricultural University, Jorhat to find out suitable hormone and propagation medium for seedling growth of papaya. The experiment was laid out in Completely Randomized Design with 11 different treatments comprising of two growth hormones of $GA_3$ (200 ppm and 500 ppm) and NAA (200 ppm and 500 ppm) and two combinations of growing media [garden soil + sand + FYM + Cocopeat (1:1:1:1) and garden soil + sand + vermicompost + cocopeat (1:1:1:1)] and was compared with the recommended media mix of garden soil + sand + FYM (1:1:1). The results indicated that combination of 500 ppm $GA_3$ with garden soil + sand + vermicompost + cocopeat in the ratio of 1:1:1:1 was most effective for better germination percentage, germination index, seed vigour index I, seed vigour index II, seedling length, plant fresh weight, plant dry weight, and highest number of primary roots, in papaya cv. 'Sapna' under Assam condition. However, increased number of leaves, length of taproot, survival percentage and stem diameter was recorded with the combination of 500 ppm NAA + Garden soil + vermicompost + cocopeat (1:1:1:1). It was concluded that seeds treated with 500 ppm $GA_3$ planted in the media mix of garden soil + sand + vermicompost + cocopeat in the ratio of 1:1:1:1 was found most suitable for enhanced seedling growth and higher vigour in papaya.

**Keywords:** Cocopeat, gibberelic acid, sarcotesta, vermicompost, vigour index

## Introduction
Papaya (*Carica papaya* L.) is an important tropical fruit crop that holds significant importance in agriculture, particularly in regions with warm climates. It belongs to family Caricaceae and has a chromosome number of 18. Due to its quick growing habit, minimal input requirement and multipurpose uses, papaya has gained considerable popularity. Also it is a highly remunerative crop and has high cost- benefit ratio (Sharma and Zote, 2010) [26]. In India, it is grown luxuriantly in Tamil Nadu, Karnataka, Kerala Andhra Pradesh states, Maharashtra, Madhya Pradesh, Gujarat, Bihar, Uttar Pradesh, Assam and West Bengal. The area and production of papaya cultivation in India is 146 thousand ha and 5540000MT respectively (NHB, 2023) [17]. 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 and various propagation media 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 (Chako and Singh 1966) [9] which is mainly due to the accumulation of inhibitors in the sarcotesta, resulting in subsequent decrease in seed germination during storage (Reyes *et at.*, 1980) [22]. 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 (Malo and Campbell, 2001) [13]. It has been found to stop oxygen from reaching the seed and impeding the germination process. By washing fresh seeds in water followed by drying under shade removes the sarcotesta and improves seed germination (Sipple and Claassen 1993) [27].

In addition, 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. Among the growth hormones, $GA_3$ (Gibberellic acid) a naturally occurring plant hormone, plays a crucial role in regulating various physiological processes in plants, including seed germination. When applied to papaya seeds, $GA_3$ has been found to significantly improve germination rates. It achieves this by breaking seed dormancy and promoting a quicker and more uniform germination process. Moreover, $GA_3$ treatment has been reported to increase shoot and root growth in papaya seedlings, resulting in improved vigour of plants. Pre-soaking of papaya seeds in $GA_3$ 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 (Mishra *et al*., 2017) [15].

NAA, a synthetic plant growth regulator from the auxin family, improves germination rates, stimulates root development, and encourages shoot growth. This leads to more robust and uniform seedling growth, ultimately establishing a solid foundation for successful papaya cultivation. However, it is essential to follow recommended concentrations and procedures to avoid its over use, which could have adverse effects. Overall, NAA serves as a valuable tool for papaya growers aiming to cultivate healthier and more productive papaya seedlings (Rana *et al*., 2020) [21].

The germination of seeds is also greatly influenced by the propagation medium. Media serve both as a growing environment and a source of nutrients for plant development. Vermicompost provides sufficient nutrients to plants and have good water holding potentiality. FYM besides having good water holding capacity also has sufficient porosity, thus permitting adequate moisture and exchange of gases between the germination growth media and the embryo of seed (Anjanawe *et al.,* 2013) [3]. Cocopeat is also considered as a good growing media component because of its acceptable pH, electrical conductivity and other chemical attributes (Abad *et al.,* 2002) [1]. This study therefore, aimed to determine the combined effect of propagation media and growth regulators $GA_3$ and NAA that had a positive effect on germination and initial growth of papaya seedlings.

## Materials and Methods

The experiment was conducted in the Experimental Farm, Department of Horticulture, Assam Agricultural University, Jorhat during 2022-23. The experiment was laid out in completely randomized design (CRD) with three replications in polybags. It was undertaken with two doses of $GA_3$ (200ppm and 500ppm and two doses of NAA (200ppm and 500ppm) along with two different growing media combinations consisting of garden soil + sand + FYM + cocopeat (1:1:1:1) and garden soil + sand + vermicompost + cocopeat (1:1:1:1) which was compared with the recommended media mix of garden soil + sand + FYM (1:1:1). Treatment details of the experiment are as follows:

1. $T_1$-200ppm $GA_3$ + garden soil + sand + FYM + cocopeat (1:1:1:1)
2. $T_2$-200ppm $GA_3$ + garden soil + sand + vermicompost + cocopeat (1:1:1:1)
3. $T_3$-500ppm $GA_3$ + garden soil + sand + FYM + cocopeat (1:1:1:1)
4. $T_4$-500ppm $GA_3$ + garden soil + sand + vermicompost + cocopeat (1:1:1:1)
5. $T_5$-200ppm NAA + garden soil + sand + FYM + cocopeat (1:1:1:1)
6. $T_6$-200ppm NAA + garden soil + sand + vermicompost + cocopeat (1:1:1:1)
7. $T_7$-500ppm NAA + garden soil + sand + FYM + cocopeat (1:1:1:1)
8. $T_8$-500ppm NAA + garden soil + sand + vermicompost + cocopeat (1:1:1:1)
9. $T_9$- garden soil + sand + FYM + cocopeat (1:1:1:1)
10. $T_{10}$- garden soil + sand + vermicompost + cocopeat (1:1:1:1)
11. $T_{11}$-(control) - garden soil + sand + FYM (1:1:1).

Seeds of the cv. ‘Sapna’ were collected from the market. Stock solution of growth regulators were prepared and required quantity of plant growth regulators were taken for seed treatment. Fifty seeds were used for each treatment. The seeds were soaked before sowing in the aqueous solution of plant growth regulator for 12 hours as per the treatments. The seeds were then sown in the pre-filled polybags of desired growing medium at a depth of 1 cm. Watering was done immediately after sowing and repeated everyday till the final emergence of seedlings. After final emergence the bags were irrigated after every 2 days on a regular basis with a rose can till the time of transplanting (45 days after sowing) and plant protection measures were implemented when required. The germinating seeds were observed daily and the day on which the first germination of seed was initiated from the date of sowing was considered as days taken to first germination. For seedling growth parameters five seedlings were randomly selected and tagged for recording observations at 45 DAS. Length of seedling was measured from the root tip to growing tip of shoot with the help of a scale. For total dry matter of seedling, seedlings were chopped and oven dried at 60 ± $2^0$C temperature till a constant weight was obtained. The weight was taken with the help of electronic balance and average value was computed. Stem diameter was measured 1 cm above from the base of the stem using Vernier Caliper. Length of taproot was measured by destructive method of uprooting the plant and taking measurement by standard method.

Germination percentage was calculated by using the formula given below:

$$\text{Germination percentage} = \frac{\text{Number of seeds germinated}}{\text{Total number of seeds sown}} \times 100$$

Seedling vigour was calculated using the formulae given by Bewley and Black, 1982 as follows:

Vigour index I = Percent germination x Length of seedling

Vigour index II = Percent germination x Total dry weight of seedlings

Survival percentage was recorded in 45 DAS by using the following formula:

$$\text{Survival percentage} = \frac{\text{Total survived seedlings}}{\text{Total germinated seeds}} \times 100$$

Germination index was calculated as described in the Association of Official Seed Analysis (1983) using the following formula:

$$\text{Germination index} = \left[\frac{\text{No. of germinating seeds}}{\text{Days of first count}} \times \frac{\text{No. of germinating seeds}}{\text{Days of final or last count}}\right]$$

All data were subjected to analysis of variance (ANOVA) to determine significant differences and comparison of mean at a significant level of 5%.

**Results and Discussion**

From the findings it was evident that there were significant differences among the treatments for all the characters studied (Tables 1&2). Highest germination percentage (80.11%), germination index (8.03), seed vigour index I (1451.80), seed vigour index II (170.39), seedling length (18.37cm), plant fresh weight (4.25g), plant dry weight (2.12g), and highest number of primary roots (31) was observed in $T_4$ (500ppm $GA_3$ + garden soil +sand + FYM+ cocopeat (1:1:1:1). Lowest germination percentage (59.75%), germination index (2.07), seed vigour index I (305.30), seed vigour index II (20.52), seedling length (6.31cm), plant fresh weight (2.05g), plant dry weight (0.30g), and lowest number of primary roots (8) was observed in was recorded in $T_{11}$ (Garden soil: sand: FYM = 1:1:1) i.e. in the control. The highest germination percentage exhibited in $T_4$ might be due to presoaking of the seeds in 500 ppm $GA_3$, which is an effective growth regulator for seed germination (Choudhary *et al*., 2022) [10]. Gibberellic acid plays a significant role in stimulating hydrolytic enzymes such as α-amylase and protease. These enzymes are responsible for nourishing the plant's growth and development by breaking down starch, consequently reducing the time needed for the germination process (SR *et al*., 2022) [28]. High germination index in $GA_3$ treated seeds might be attributed to its impact on early seed germination, leading to a higher rate of successful germination. These outcomes aligned with the findings reported by Rajamanickam and Anbu (2001) [19] in aonla. The enhanced elongation of seedlings treated with gibberellic acid ($GA_3$) may be attributed to $GA_3$'s influence on augmenting the osmotic uptake of nutrients, leading to cellular elongation, as evidenced by an increase in internodal length. Ultimately, this phenomenon contributes to an overall increase in plant height (Patel *et al*., 2022) [18]. These findings align with the observations reported by Barche *et al*. (2010) and Babu *et al*. (2010) [30] in papaya. The vigour index I of seedlings is directly dependent on germination percentage and seedling length. The observed increase in the vigor index of seeds treated with $GA_3$ can likely be attributed to its direct impact on promoting substantial seedling growth, possibly by enhancing the mobilization of stored nutrients toward the growing apices (Patel *et al*., 2022) [18]. The heightened vigor index II observed in papaya plant seedlings of $T_4$ could be attributed to an elevated seedling dry weight resulting from the application of gibberellic acid treatment. This current finding aligns closely with the outcomes reported by Sen *et al*. (2003) [25] in Kagzi lime. Higher fresh and dry weight in $GA_3$ treated seedlings may have resulted from the increased mobilization of water and nutrients, leading to a higher rate of transport. Further, this heightened transport may have facilitated greater production of photosynthetic products, subsequently translocated to different plant organs, thereby contributing to enhanced seedling growth and, consequently, greater fresh and dry biomass (Ramteke *et al*., 2015) [20]. These findings align with the research findings of Dhankhar and Singh (1996) [12] conducted in aonla. Increased number of primary roots in $GA_3$ treated seedlings could be attributed to the fact that accelerated root growth induced by gibberellic acid ($GA_3$) potentially leading to increased photosynthetic product production and enhanced transport of these products through the phloem to the root region. This, in turn, may account for the observed enhancement in root growth (Choudhary *et al*., 2022) [10]. Similar findings were also reported in aonla by Dhankhar *et al*. (1997) [11]. Media combination of garden soil + sand + vermicompost + cocopeat (1:1:1:1) along with 500 ppm $GA_3$ was found to be best for germination and root growth of papaya. Bhardwaj (2013) [7] also reported accelerated growth of papaya seedlings using similar media combination (pond soil + sand + vermicompost + 2cm cocopeat) due to the high organic matter content of the medium thereby enhancing the physical characteristics and water retention capacity and promoting the potential for germination. Similar finding was also reported by Ramteke *et al*. (2015) [20] in papaya. Combined utilization of vermicompost and cocopeat in $T_4$ had a notable and beneficial impact on germination, seedling growth, and plant biomass. This positive effect is likely attributed to a synergistic interaction between these components, enhancing the physical characteristics of the growth medium and supplying essential nutrients (Sahni *et al*., 2008) [23]. Vermicompost is recognized for containing bioactive compounds that promote root growth, root initiation, germination, and overall plant development (Bachman and Metzger, 2008) [5]. Moreover, it possesses a well-balanced nutrient composition (Zaller, 2007) [29]. When mixed with garden soil, vermicompost influences the physical, chemical, and biological properties of the soil by serving as a binding agent for soil aggregation and a source of soil nutrients. This improvement in soil aggregation enhances permeability and airflow within the polybags, ultimately leading to increased percentages of seed germination, seed vigor, germination indices, germination values, root growth, and fresh and dry weights of seedlings.

Number of leaves (9), length of taproot (14.19cm) and stem diameter (3.38cm) was found to be highest in $T_8$, which is the combination of 500ppm NAA and garden soil + sand + vermicompost + cocopeat (1:1:1:1). The increased number of leaves could be attributed to the fact that NAA aids in the invigoration of the plant's physiological processes and the stimulatory action of chemicals in the formation of new leaves at a faster rate. Biswas *et al.* (1988) [8] also reported that the application of NAA tended to increase the number of leaves produced per plant in papaya. Therefore NAA (500 ppm) can also be an effective growth regulator for seedling growth of papaya under Assam condition, which was also reported by Naithani (2018) [16] under Valley Condition of Garhwal Himalaya. The NAA treatment resulted in elevated auxin levels in the roots, which led to enhanced processes such as increased root initiation, improved nutrient absorption, and elongation of root cells. As a consequence, this promoted the development of a more extensive taproot as reported by SR *et al*. (2022) [28]. Length of taproot was found to have higher influence on length of papaya seedlings.It was observed that among all the treatments, treatment consisting of 500ppm NAA and garden soil + sand + vermicompost + cocopeat (1:1:1:1) exhibited highest survivality of seedlings (92.10%) and lowest survivality of seedlings was observed in control (70.58%). The findings are in conformity with the findings of Meena *et al*., (2022) [14] who observed that seed soaking with NAA @ 50 ppm in combination with Soil +

Vermicompost (2:1) exhibited significantly highest survival percentage of seedlings. Abirami *et al.*, (2010) [2] also reported that good physical and biological conditions in vermicompost and cocopeat had positive effect on root development, which is helpful in increased survival percentage of seedling. Increase in the girth of seedling might be due to the fact that application of NAA increases the synthesis of protein in plants, which was indirectly exhibited by increase in size of different plant parts including stem diameter (Sahoo, 2015) [24].

**Table 1:** Effect GA3 and NAA in combination with different growing media on germination percentage, germination index, seedling vigour index I, seedling vigour index II, fresh weight of plant, dry weight of plant in papaya cv. 'Sapna'

| Treatments | Germination percentage (%) | Germination index | Seedling vigour index I | Seedling vigour index II | Plant fresh weight (g) | Plant dry weight (g) |
|---|---|---|---|---|---|---|
| $T_1$ | 70.19 | 6.52 | 710.68 | 68.31 | 2.40 | 0.97 |
| $T_2$ | 75.47 | 7.10 | 1019.33 | 14.09 | 2.95 | 0.18 |
| $T_3$ | 71.69 | 6.25 | 728.34 | 32.03 | 2.44 | 0.44 |
| $T_4$ | 80.11 | 8.03 | 1451.80 | 170.39 | 4.25 | 2.12 |
| $T_5$ | 69.25 | 6.11 | 650.73 | 24.01 | 2.16 | 0.34 |
| $T_6$ | 68.16 | 5.02 | 812.85 | 36.91 | 2.90 | 0.52 |
| $T_7$ | 70.20 | 7.81 | 790.45 | 33.70 | 2.53 | 0.48 |
| $T_8$ | 79.03 | 7.18 | 1112.54 | 95.10 | 3.17 | 1.20 |
| $T_9$ | 62.09 | 4.85 | 315.04 | 21.32 | 2.22 | 0.34 |
| $T_{10}$ | 64.44 | 3.97 | 495.50 | 22.77 | 2.35 | 0.35 |
| $T_{11}$ | 59.45 | 2.07 | 305.30 | 20.52 | 2.05 | 0.30 |
| SEd (±) | 0.32 | 0.17 | 57.69 | 3.28 | 0.06 | 0.04 |
| C.D. (5%) | 0.68 | 0.36 | 120.35 | 6.84 | 0.13 | 0.09 |

**Table 2:** Effect $GA_3$ and NAA in combination with different growing media on survival percentage, seedling length, number of leaves, stem diameter, length of taproot and number of primary roots in papaya cv. 'Sapna'

| Treatments | Survival percentage | Seedling length (cm) | Number of leaves | Stem diameter (cm) | Length of taproot (cm) | Number of primary roots |
|---|---|---|---|---|---|---|
| $T_1$ | 80.20 | 10.12 | 6 | 2.43 | 7.68 | 15 |
| $T_2$ | 85.63 | 13.50 | 8 | 2.77 | 10.02 | 13 |
| $T_3$ | 81.24 | 10.16 | 6 | 3.23 | 8.20 | 29 |
| $T_4$ | 90.09 | 18.37 | 8 | 2.44 | 11.25 | 31 |
| $T_5$ | 78.58 | 9.40 | 5 | 2.50 | 6.99 | 14 |
| $T_6$ | 77.60 | 11.93 | 8 | 2.24 | 9.83 | 19 |
| $T_7$ | 82.13 | 11.26 | 7 | 2.32 | 9.13 | 19 |
| $T_8$ | 92.10 | 13.88 | 9 | 3.38 | 14.19 | 22 |
| $T_9$ | 73.13 | 7.07 | 4 | 1.78 | 6.28 | 10 |
| $T_{10}$ | 75.37 | 8.10 | 5 | 2.33 | 6.99 | 8 |
| $T_{11}$ | 70.58 | 6.31 | 5 | 1.71 | 6.14 | 8 |
| SEd | 0.26 | 0.46 | 0.08 | 0.30 | 0.06 | 0.22 |
| C.D. (5%) | 0.54 | 0.95 | 0.17 | 0.63 | 0.13 | 0.45 |

## Conclusion
On the basis of the findings of the study, it was observed that the growth regulators and growth media significantly influenced the seed germination and seedling growth in papaya. The treatment combination $T_4$ [500 ppm $GA_3$ with growing media combination garden soil + sand + vermicompost + cocopeat (1:1:1:1)] was found to be most effective in improving germination percentage, germination index, seed vigour index I, seed vigour index II, seedling length, plant fresh weight, plant dry weight, and highest number of primary roots, in papaya cv. 'Sapna' and therefore, can be recommended for application in papaya to achieve better growth and vigour of seedlings under Jorhat, Assam conditions.

## Acknowledgement
The authors express their gratitude to the Department of Horticulture, Assam Agricultural University for providing the necessary facilities to carry out the experiment and for the help and assistance in successful completion of the study undertaken.

## References
1. Abad M, Noguera P, Puchades R, Maquieira A, Noguera V. Physico-chemical and chemical properties of some coconut dusts for use as a peat substitute for containerized ornamental plants. Bioresearch Technology. 2002;82:241-245.
2. Abirami K, Rema PA, Mathew. Effect of different propagation media on seed germination, seedling growth and vigour of nutmeg. Journal of Medicinal plants Research. 2010;4(19):2054-2058.
3. Anjanawe SR, Kanpure RN, Kachouli BK, Mandloi DS. Effect of plant growth regulators and growth media on seed germination and growth vigour of papaya. Annals of Plant Soil Research. 2013;15(1):31-34.
4. AOSA. Seed vigour testing handbook, (Contribution No. 32). Association of Official Seed Analysis, Ithaca, USA; c1983. p. 45.
5. Bachman GR, Metzger JD. Growth of bedding plants in commercial potting substrate amended with vermicompost. Bioresource Technology. 2008;99:3155-3161.

6. Bewley JD, Black BM. Germination of seeds. In: Physiology and Biochemistry of Seed Germination. Ed: Khan, A.A., Springer Verlag, New York; c1982. p. 40-80.
7. Bhardwaj RL. Effects of nine different propagation media on seed germination and the initial performance of papaya (*Carica papaya* L.) seedlings. The Journal of Horticultural Science and Biotechnology. 2013;88(5):531-536
8. Biswas B, Sen SK, Maity SC. Effect of chemicals on growth, flowering and fruiting in papaya. Indian Agriculturist. 1988;32(1):47-53
9. Chacko EK, Singh RN. The effect of GA on the germination of papaya seeds and subsequent seedling growth. Tropical Agriculture (Trin). 1966;43:341-346.
10. Choudhary RC, Kanwar J, Singh P. Effect of gibberellic acid (GA3) and growing media on seedling growth parameters of papaya (*Carica papaya* L.) cv. Pusa nanha. The Pharma Innovation Journal. 2022;11(1):247-251.
11. Dhankhar DS, Shah PM, Joshi KI. Seed germination and seedling growth in Aonla (*Phyllanthus emblica* L.) as influenced by gibberellic acid and thiourea. Journal of Horticulture. 1997;3:93-97.
12. Dhankhar DS, Singh M. Seed germination and seedling growth in aonla (*Phyllanthus emblica* Linn.) as influenced by gibberellic acid and thiourea. Crop Research. 1996;12(3):363-366.
13. Malo EA, Campbell CW. Papaya: A potential annual crop under middle gorgia conditions. Journal of America Society of Horticultural Science. 2001;115(3):426-438.
14. Meena S, Garhwal OP, Meena A, Bhadala K, Diwaker P. Effect of growth media and plant growth regulators on growth parameters of papaya (*Carica papaya* L.). The Pharma Innovation Journal. 2002;11(1):38-42.
15. Mishra U, Bahadur V, Prasad VM, Verty P, Singh AK, Mishra S, *et al*. Influence of $GA_3$ and Growing Media on Growth and Seedling Establishment of Papaya (*Carica papaya* L.) cv. 'Pusa Nanha'. International Journal of Current Microbiology and Applied Sciences; c2017. https://doi.org/10.20546/ijcmas, 611.048
16. Naithani DC. Effect of Bioregulators and Chemical on Seed Germination and Seedling Growth in Papaya (*Carica papaya* L.) cv. 'Pusa Nanha' under Valley Condition of Garhwal Himalaya. International Journal of Pure and Applied Bioscience. 2018;6(1):1116-1121.
17. NHB. 2$^{nd}$ Advanced estimate of area and production of horticultural crops; c2023. Available at www.nhb.gov.in.
18. Patel D, Panigrahi HK, Tani M. Studies on the influence of plant growth regulators and bio-inoculants on seed germination and seedling growth of papaya (*Carica papaya* L.) cv. Red Lady under net tunnel. The Pharma Innovation Journal. 2022;11(9):1980-1985.
19. Rajamanickam C, Anbu S. Effect of bio-fertilizers and growth regulators on seed germination and seedling vigor in amla. Madras Agricultural Journal. 2001;88(4/6):295-297.
20. Ramteke V, Paithankar D, Kamatyanatt M, Baghel MM, Chauhan J, Kurrey V. Seed germination and seedling growth of papaya as influenced by $GA_3$ and propagation media. International Journal of Farm Sciences. 2015;5(3):74-81.
21. Rana G, Deb P, Dowarah B, Kanne S. Effect of Seed pre-treatment on Seed Germination and Seedling Growth of Papaya. International Journal of Current Microbiological and Applied Science. 2020;9(4):1066-1071.
22. Reyes MN, Perez A, Cuevas J. Detecting endogenous growth regulators of Sarcotesta, Scleroterta, endosperm and embryo by paper chromatography in fresh and edged seeds of two varieties of papaya. Journal of Agricultural University, Puerto Rico. 1980;45:188-90.
23. Sahni S, Sharma BK, Singh DP, Singh HB, Singh KP. Vermicompost enhances performance of plant growth promoting rhizobacteria in *Cicer arietinum* rhizosphere against *Sclerotium rolfsii*, Crop Protection. 2008;27:369-376.
24. Sahoo A. Effect of different plant growth regulators on seedling growth of acid lime. Research in environment and life sciences. 2015;8:725-728.
25. Sen SK, Shukla M, Singh J, Namdeo KN, Ahirwae MK. Effect of growth regulators and fungicide on seed germination and seedling vigour of kagzi lime. Annals of Plant Soil and Research. 2003;14(2):175-176.
26. Sharma SK, Zote KK. Effect of adoption of papaya ring spot virus management technology on economic of papaya cultivation. Indian Journal of Horticulture. 2010;67:456-462.
27. Sippel AD, Claassen NJP. The effect of different seed treatments on germination of *Carica papaya* L. cv. Sunrise Solo seeds. Inltgtingsbulletin· Institiel· vir-Trop/ese·en. Subtropiese-Oewasse. 1993;250:16-19.
28. SR V, Singh J, Jayarajan S. Effect of growth regulator and growing media on seed germination of papaya: A review. The Pharma Innovation Journal. 2022;11(4):1121-1124.
29. Zaller JG. Vermicompost as a substitute for peat in potting media: Effects on germination, biomass allocation, yields and fruit quality of three tomato varieties. Scientia Horticulturae. 2007;112:191-199.
30. Babu B, Wu JT. Production of phthalate esters by nuisance freshwater algae and cyanobacteria. Science of the total environment. 2010 Oct 1;408(21):4969-4975.