International Journal of Advanced Biochemistry Research

ISSN Print: 2617-4693
ISSN Online: 2617-4707
NAAS Rating (2025): 5.29
IJABR 2025; SP-9(8): 29-33
www.biochemjournal.com
Received: 02-06-2025
Accepted: 05-07-2025

Tarun Sonkar
Department of Fruit Science, CoA, IGKV, Raipur, Chhattisgarh, India

Ghanshyam Sahu
Department of Fruit Science, CoA, IGKV, Raipur, Chhattisgarh, India

HK Panigrahi
Department of Fruit Science, CoA, IGKV, Raipur, Chhattisgarh, India

Tekesh Sahu
Department of Fruit Science, CoA, IGKV, Raipur, Chhattisgarh, India

Yogesh Kumar Chandrakar
Department of Fruit Science, CoA, IGKV, Raipur, Chhattisgarh, India

Gajanand Sahu
Department of Fruit Science, CoA, IGKV, Raipur, Chhattisgarh, India

Saurabh Samdarshi
Senior Research Fellow, Division of Genetics, Indian Agriculture Research Institute, New Delhi, India

Corresponding Author:
Tarun Sonkar
Department of Fruit Science, CoA, IGKV, Raipur, Chhattisgarh, India

Investigations into the impact of various pre-sowing treatments on the germination of seeds and root growth parameters of Jamun (*Syzygium cuminii* L.) in Raipur

Tarun Sonkar, Ghanshyam Sahu, HK Panigrahi, Tekesh Sahu, Yogesh Kumar Chandrakar, Gajanand Sahu and Saurabh Samdarshi

DOI: https://www.doi.org/10.33545/26174693.2025.v9.i8Sa.5086

Abstract
The present investigation was carried out during 2024-25 at the Precision Farming Development Centre, Department of Fruit Science, IGKV, Raipur (C.G.), to evaluate the effects of various pre-sowing treatments on the seed germination and root growth performance of Jamun (*Syzygium cuminii* L.). A total of 13 treatments, including control, water soaking durations, gibberellic acid (GA_3) at 150 ppm and 200 ppm, thiourea, potassium nitrate (KNO_3), cow urine, and Panchagavya at varying concentrations, were applied using a Completely Randomized Design with three replications. Among all treatments, GA_3 at 200 ppm (T_4) demonstrated the most significant enhancement in germination parameters. It resulted in the earliest initiation of germination (8.10 days), shortest time to achieve 50% germination (13.10 days), the highest germination percentage (93.00%), and maximum survival rate (86.96%). This treatment also yielded the longest tap root (35.42 cm), highest fresh root weight (2.33 g), and maximum root dry weight (0.54 g), signifying improved seedling vigor. The positive effect is attributed to GA_3's role in promoting the production of hydrolytic enzymes, mobilising food reserves, and enhancing cellular expansion and nutrient translocation. Economically, the GA_3 150 ppm treatment (T_3) yielded the highest benefit: cost (B:C) ratio (3.96), closely followed by GA_3 200 ppm (3.88). Organic treatments like 20% cow urine (T_{10}) also showed notable improvement across parameters, although they remained less effective than GA_3 treatments. The study concludes that seed treatment with GA_3 at 200 ppm significantly improves the germination rate, root development, and economic viability of Jamun seedlings under shade net conditions. These findings underscore the potential of pre-sowing chemical treatments in enhancing propagation efficiency and establishing healthy rootstock for successful orchard establishment.

Keywords: Jamun seed germination, *Syzygium cuminii*, seedling vigor, gibberellic acid

Introduction
Jamun (*Syzygium cuminii* L.) is a perennial and versatile tree species. It holds significance as an underexploited fruit crop. Belonging to the Myrtaceae family (2n = 40), which encompasses 75 species, it originates from India. Common names include Humble fruit, Black Plum, Java Plum, Indian blackberry, and Jambolan. In India, Jamun trees are characteristically tall and extensively branched, yielding edible fruits of considerable value. Native to Indonesia and India, it is now widespread across Southern Asia (Periyathambi, 2007) [1], adapting well to varied climates and thriving in tropical and subtropical zones, including Himalayan foothills and the Southern Nilgiris, up to 1200 meters elevation. It is predominantly cultivated in India, Malaysia, Myanmar, Pakistan, Afghanistan, and Bangladesh. This evergreen species can grow between 15 and 30 meters in height. In India, it is grown widely for fruit, shade, firewood, timber, and as natural windbreaks.

Globally, Jamun production is around 13.5 million tonnes, with India contributing 15.4%, ranking second globally (Singh *et al.*, 2011) [2]. Maharashtra is the leading Indian producer, followed by Uttar Pradesh, Tamil Nadu, Gujarat, and Assam.

The fruit offers nutritional and medicinal value, particularly in diabetes management. It is rich in protective compounds like sugars, minerals, iron, and proteins. Sucrose and fructose are the main sugars present in ripened fruit.

Seeds contain jambolin or antimallin glycoside and jambosin alkaloid, known to inhibit enzymatic carbohydrate breakdown. Essential oils from seeds are used in treating diabetes, and also heart and liver ailments. Its antioxidant properties are credited to high phenolic content. It is also used in making jams, jellies, squashes, wine, pickles, and vinegar. Ripe fruit is highly palatable and seasonal demand is strong. Unripe jamun vinegar has carminative, diuretic, stomachic, and cooling effects (Thaper, 1958) [3].

Recently, the crop has gained recognition not only for its resilience but for its outstanding health and nutritional benefits. The fruit is rich in iron, minerals, sugar, and protein. On average, the edible portion contains 83.70-85.80 g of moisture, 0.70-0.13 g protein, 0.15-0.30 g fat, 0.30-0.90 g crude fiber, 14.00 g carbohydrates, 0.32-0.40 g ash, 8.30-15.00 mg calcium, 35.00 mg magnesium, 15.00-16.20 mg phosphorus, 1.20-1.62 mg iron, 26.20 mg sodium, 55.00 mg potassium, 0.23 mg copper, 13.00 mg sulfur, 8.0 IU vitamin A, 0.01-0.03 mg thiamine, 0.009-0.01 mg riboflavin, 0.20-0.29 mg niacin, 5.70-18.00 mg ascorbic acid, 7.00 mg chlorine, and 3.00 mg folic acid per 100 g (Baliga *et al.*, 2011) [4]. All parts of the tree, especially the seeds, are used for therapeutic purposes, notably for diabetes (Giri *et al.*, 1985; Sagrawat *et al.*, 2006) [5, 6].

Jamun trees require dry weather during flowering and fruiting. Flowering begins in early March and ends by early April. The flowers are aromatic, hermaphrodite, and approximately 5 mm in diameter. The tree bears fruit annually. The berries, which start off green, progress to pink, crimson, and eventually black upon ripening. These fruits are sweet-tart and favored for fresh consumption and processing into vinegar, jams, squashes, jellies, and wine (Warrier *et al.*, 1996) [7].

Various parts of Jamun are recognized for their antioxidant, anti-inflammatory, neuroprotective, antimicrobial, antifungal, anti-HIV, anti-leishmanial, and ulcer-preventive properties (Thaper, 1958) [3]. It is also useful for treating diarrhea, stomach disorders, and dysentery (Namasivayam *et al.*, 2008) [8], and has radio-protective potential.

The plant is extensively valued for its fruit, seeds, and leaves, which are beneficial in treating diabetes, dysentery, diarrhea, edema, ringworm, and fever. Additionally, Jamun seeds are used in cattle feed owing to their high protein, carbohydrate, and calcium content (Hayes, 1960) [9].

As a result, vegetative propagation has become common to preserve elite seedling lines. However, Jamun seedlings may require up to a year to reach graftable size and are prone to high mortality, making healthy seedling maintenance costly and labor-intensive (Llanes *et al.*, 2005) [10]. Research on seed storage and pre-sowing treatments specific to Jamun is limited. Yet, in many fruit species, seed germination and early root development are significantly impacted by pre-sowing treatments. To minimize the grafting timeline, it is essential to accelerate seedling growth through improved germination. Strategies such as chemical and hormonal treatments (GA_3, Thiourea, KNO_3), and organic priming agents like cow urine and Panchagavya, have been tested with varied results. This study aims to identify optimal pre-sowing treatments to promote seed germination and ensure standardized practices for Jamun seedling production.

Materials and Methods

Experimental site: The present experiment was conducted during the year 2024-25 at the Precision Farming Development Center (PFDC), Department of Fruit Science, College of Agriculture, IGKV, Raipur (C.G.).

Experiment material: Experiment was arranged in a completely randomized design (CRD) and three replications. In this experiment, Jamun seeds were soaked separately in water soaking 12 hours, water soaking 24 hours, GA_3 150 ppm, GA_3 200 ppm, Thiourea 1.0%, Thiourea 1.5%, KNO_3 1.0%, KNO_3 1.5%, Cow urine 10% and Cow urine 20%, Panchagavya 10% and Panchagavya 20%. Growing medium for all the treatments are composed of soil, vermicompost and sand in the ratio of 2:1:1.

Treatment detail: The experiment was carried out using a completely randomized design and included three replications. The treatments were *viz*. T_0-Control, T_1-Water soaking 12 hours, T_2-Water soaking 24 hours, T_3-GA_3 150 ppm, T_4-GA_3 200 ppm, T_5-Thiourea 1.0%, T_6-Thiourea 1.5%, T_7-KNO_3 1.0%, T_8-KNO_3 1.5%, T_9-Cow urine 10%, T_{10}-Cow urine 20%, T_{11}-Panchagavya 10% and T_{12}-Panchagavya 20%.

Results and Discussion

Germination attributes

The earliest average duration in days for the onset of seed germination (8.10 days) was observed under the treatment T_4 (GA_3 200 ppm), was followed statically *at par* with treatment T_8 (KNO_3 1.5%) having 8.43 days. Moreover, the treatment T_3 & T_7 and T_9 & T_{12} and T_1 & T_6 having respective values of 9.33 & 9.67 and 10.33 & 993 and 11.67 & 11.86 days were also observed statistically *at par* with each other at the 5% level of significance. The maximum number of days taken to initiate seed germination (13.67 days) was recorded for treatment T_0 (control) under the present study. The minimum number of days taken to achieve 50% seed germination (13.10 days) was recorded under treatment T_4 (GA_3 200 ppm), which was followed by treatment T_3 (GA_3 150 ppm) having 16 days in the present trial. However, the treatments T_8 & T_{10} and T_7, T_{12} & T_9, and T_{11} & T_2 had respective values of 18.10 & 19 and 19.34, 19.37 & 19.70 and 20.33 & 21 days, respectively, the differences between them were not significant at the 5% significance level. The maximum number of days taken for 50% of seed germination (31.67 days) was recorded under treatment T_0 (control). The treatment GA_3 200 ppm (T_4) registered the maximum germination percentage (93%), which found statically *at par* with T_3 (GA_3 150 ppm), which had a germination percentage of 89.33% under the present investigation. Although, the treatments T_9, T_{12} & T_7 and T_6, T_2, & T_1 having respective values of 75, 74.40 & 74.34 and 71, 70.67 and 69 were found non significance differences among each other. Whereas, the minimum germination percentage (64 %) was recorded under the treatment T_0 (control). The treatment T_4 (GA_3 200 ppm) retained the maximum survival percentage (86.96%), was found significantly excellent from rest of the other treatments tested under the present trial and followed by the treatments T_3 (GA_3 150 ppm) having survival percentage of 83.15% under the present investigation. Moreover, the treatments T_1, T_2 & T_5 and T_6 & T_{12} and T_7 & T_9 with respective survival percentage of 57.97, 58.33 & 60.61 and 66.20 & 65.71 and 68.92 & 69.33 were found statistically non significance differences among each other. However, the minimum survival percentage (54.69%) was observed under treatment T_0 (control) in the present trial.

The earliest germination of seed, 50% seed germination and maximum germination percentage might be due to removal of hard seed coat which increase the permeability of water and gases through seed which cause early germination. Priming with GA_3 and hydro-priming both improved germinations. The sharp increase in the germination percentage by GA_3 it is likely that during the germination process, gibberellic acids stimulate the creation of hydrolytic enzymes, including α-amylase and proteases. These enzymes are responsible for breaking down the stored food reserves located in the seed's endosperm or embryo. By converting complex carbohydrates and storage proteins into simple sugars, they facilitate the transfer of energy reserves from the endosperm to the developing regions, thereby supplying the embryo with the essential nutrients and energy needed to enhance germination. (Hota *et al.*, 2018) [11]. Gibberellins (GA_3) are also reported to have activated the embryonic vegetative growth, weaken the endosperm layer that hinders the embryo's growth, and activate the energy reserves within the endosperm (Taiz and Zeiger, 2006) [12]. Also, the reduction in the days taken to initiation of germination this reduction in germination time could be due to the rapid mobilization of energy, resulting in active and faster embryo growth facilitated by GA_3, indicating its stimulatory effect on the speed of germination. The results also showed that increasing concentrations of GA_3 further enhanced these characteristics by invigorating physiological processes (Gurung *et al.*, 2014) [19]. It was noted that treating seeds with a GA_3 solution at 200 ppm significantly improved the survival rate of custard apple seedlings. This enhancement in survival rates may result from an increase in seedling dry weight attributed to GA_3, which facilitates cell expansion and elongation, leading to improved root and shoot development that ultimately boosts seedling survival. Similar findings observed by Patil *et al.* (2018) [13], Mali *et al.* (2021) [14] and Hota *et al.* (2018) [11] in jamun seed germination

Table 1: Effect of seed treatments on days taken to initiation of seed germination, days taken to 50% of seed germination, germination percentage and survival percentage of Jamun

Notations	Treatments	Days taken to initiation of seed germination (Days)	Days taken to 50% of seed germination (Days)	Germination percentage (%)	Survival percentage (%)
T_0	Control	13.67^{i}	31.67^{k}	64.00^{a}	54.69^{a}
T_1	Water soaking for 12 hr	11.67^{g}	22.00^{g}	69.00^{bc}	57.97^{b}
T_2	Water soaking for 24 hr	12.00^{g}	21.00^{f}	70.67^{cd}	58.33^{b}
T_3	GA_3 (150 ppm)	9.33^{cd}	16.00^{b}	89.33^{f}	83.15^{g}
T_4	GA_3 (200 ppm)	8.10^{a}	13.10^{a}	93.00^{f}	86.96^{h}
T_5	Thiourea 1.0%	12.53^{h}	24.20^{j}	66.67^{ab}	60.61^{b}
T_6	Thiourea 1.5%	11.86^{g}	23.20^{i}	71.00^{c}	66.20^{c}
T_7	$KNO_3$1.0%	9.67^{de}	19.34^{d}	74.34^{d}	68.92^{de}
T_8	KNO_3 1.5%	8.43^{ab}	18.10^{c}	78.67^{e}	70.51^{ef}
T_9	Cow urine 10%	10.33^{f}	19.70^{de}	75.00^{d}	69.33^{de}
T_{10}	Cow urine 20%	8.74^{bc}	19^{cd}	80.00^{e}	72.50^{f}
T_{11}	Panchagavya 10%	9.00^{c}	20.33^{ef}	71.08^{c}	67.57^{cd}
T_{12}	Panchagavya 20%	9.93^{ef}	19.37^{d}	74.40^{d}	65.71^{c}
	SE.(m)±	0.17	0.31	1.02	0.9
	C.D. at 5%	0.50	0.93	3.00	2.70

Note: The superscript letters denote that treatment means marked with the same letters are comparable at the 5% significance level, whereas those with differing letters exhibit significant differences at this level. These letters have been assigned following the comparison of the CD values of the treatment means.

Root Paramters

The treatment T_4 (GA_3 200 ppm) retained the maximum root length (35.42 cm), which was followed by the treatments T_3 having root length of 31.88 cm under the present trial. Moreover, the treatments T_1, T_9 & T_2 and T_{12}, T_6, & T_{11} with respective root length of 22.18, 22.25 & 22.77 and 24.91, 25.03 & 23.71 cm no significant differences were observed among them at the 5% significance level. The treatment T_4 (GA_3 200 ppm) maximum fresh weight of roots (2.33 g), was found statistically similar with the treatments T_3 having fresh weight of roots of 2.29 g under the present trial. Besides, the treatments T_1 & T_2 and T_{11}, T_9 & T_{10} and T_6 & T_7 with respective fresh weight of roots of 0.79 & 0.87 and 1.17, 1.19 & 1.24 and 1.59 & 1.65 g no significant differences were observed among them at the 5% significance level. The treatment T_4 (GA_3 200 ppm) retained the maximum root dry weight (0.54 g), which was observed statistically superior from all other treatments tested in the present investigation and followed by the treatment T_3 (GA_3 150 ppm) having dry weight of roots of 0.50 g under the present trial. Furthermore, the treatments T_1, T_5, T_9 & T_2 and T_{12}, T_6, & T_7 with respective dry weight of roots of 0.29, 0.30, 0.30 & 0.32 and 0.36, 0.37 & 0.39 were found non significance differences among each other.

The application of GA_3 activates gluconeogenic enzymes during the initial phases of seed germination, potentially leading to improved germination and vigor, as evidenced by the increased length of the roots. The significant rise in biomass, reflected in the fresh and dry weights of roots and shoots can be linked to the influence of GA_3, which enhances cell division, cell elongation, auxin metabolism, cell wall flexibility, and cell membrane permeability, thereby fostering growth. The increase in the dry weight of various plant components might result from the improved nutrient mobilization facilitated by GA_3 application, which supports plant growth and development. (Hota *et al.*, 2018 and Mane *et al.*, 2018) [11, 15]. This enhancement in dry weight of roots may resulted from the significant role of GA_3 (gibberellic acid), the increased dry weight of the root might be the result of better nutrient mobilization that is caused by the use of gibberellic acid, which encourages the growth and development of plants. These findings align closely with those reported by Hota *et al.* (2018) [11] and Patil *et al.* (2018) [13] in jamun, Pandit *et al.* (2001) [16] and Anjanawe *et al.* (2013) [17] in papaya, Singh *et al.* (2003) [18] in ber and Gurung *et al.* (2014) [19] in passion fruit.

Benefit cost ratio

The highest benefit: cost ratio (3.96) was observed under the superiority of T_3 (GA_3 150 ppm), which was closely followed by the treatment T_4 (GA_3 200 ppm) having the benefit: cost ratio of 3.88. However, the minimum benefit-cost ratio (2.20) was registered under the control (T_0). Yet,, the treatments *i.e.* T_1, T_2, T_5, T_6, T_7, T_8, T_9, T_{10}, T_{11} & T_{12} with respective benefit: cost ratio of 2.75, 2.84, 2.83, 2.87, 3.30, 3.45, 3.52, 3.62 & 3.56 showed nearly similar variations among each other under the present study. The treatment T_3 (GA_3 150 ppm) recorded the highest benefit: cost ratio (3.88); however, the lowest benefit: cost ratio (2.20) was observed in T_0 (control). The highest benefit: cost ratio registered in the treatment T_3 (GA_3 150 ppm) might be due to the highest gross returns and net returns. These results align closely with findings from Barche *et al.* (2010) [20] in papaya, Thorat *et al.* (2018) [21] in custard apple and Rawat *et al.* (2023) [22] in sweet orange.

Table 2: Effect of seed treatments on length of longest tap-root (cm), fresh weight of root (gm), dry weight of root (gm) of Jamun.

Notations	Treatments	Length of longest tap root (cm)	Root fresh weight (g)	Root dry weight (g)	B:C ratio
T_0	Control	19.99^{a}	0.69^{a}	0.28^{a}	2.20
T_1	Water soaking for 12 hr	22.18^{b}	0.79^{b}	0.29^{ab}	2.75
T_2	Water soaking for 24 hr	22.77^{bc}	0.87^{b}	0.32^{b}	2.84
T_3	GA_3 (150 ppm)	31.88^{g}	2.29^{i}	0.50^{f}	3.96
T_4	GA_3 (200 ppm)	35.42^{h}	2.33^{i}	0.54^{g}	3.88
T_5	Thiourea 1.0%	23.61^{c}	1.50^{e}	0.30^{ab}	2.83
T_6	Thiourea 1.5%	25.03^{de}	1.59^{f}	0.37^{cd}	2.87
T_7	KNO_3 1.0%	26.11^{e}	1.65^{f}	0.39^{cd}	3.30
T_8	KNO_3 1.5%	29.10^{f}	1.78^{g}	0.44^{e}	3.45
T_9	Cow urine 10%	22.25^{b}	1.19^{d}	0.30^{b}	3.52
T_{10}	Cow urine 20%	26.00^{de}	1.24^{d}	0.39^{d}	3.62
T_{11}	Panchagavya 10%	23.71^{de}	1.17^{cd}	0.39^{d}	3.56
T_{12}	Panchagavya 20%	24.91^{d}	1.09^{c}	0.36^{c}	3.41
	SE.(m)±	0.73	0.10	0.01	
	C.D. at 5%	2.17	0.28	0.03	

Note: The superscript letters denote that treatment means marked with the same letters are comparable at the 5% significance level, whereas those with differing letters exhibit significant differences at this level. These letters have been assigned following the comparison of the CD values of the treatment means.

Conclusion

The present study clearly demonstrated that pre-sowing treatments significantly influence the germination behavior, seedling vigor, and root development of Jamun (*Syzygium cuminii* L.). Among all treatments evaluated, GA_3 at 200 ppm (T_4) proved to be the most effective in enhancing seed germination parameters, including the earliest germination initiation, shortest time to reach 50% germination, highest germination percentage, and superior survival rate. It also yielded the most favorable root growth metrics, such as longest tap root, and maximum fresh and dry root weights. Economically, the highest benefit:cost (B:C) ratio was observed in the GA_3 150 ppm (T_3) treatment, closely followed by GA_3 200 ppm, making these treatments not only agronomically but also economically advantageous for nurseries and orchard establishment. Among organic treatments, 20% cow urine (T_{10}) showed relatively better results, though not as significant as chemical treatments, indicating some potential for eco-friendly alternatives. In conclusion, the application of GA_3, particularly at 200 ppm, is highly recommended as a standard pre-sowing treatment for Jamun seeds to improve germination efficiency, promote early seedling establishment, and ensure higher survival and vigor under shade net conditions. These findings offer practical implications for enhancing nursery productivity and supporting large-scale propagation of this nutritionally and medicinally valuable fruit crop.

References

1. Periyathambi R. Jamun-the potential untapped. Kerala Callin. 2007 Feb;:30-2.
2. Singh S, Singh AK, Singh HP, Bagle BG, More TA. Jamun. New Delhi: Indian Council of Agricultural Research; 2011. 46 p.
3. Thaper AR. Farm Bulletin No. 42. New Delhi: ICAR; 1958.
4. Baliga M, Bhat P, Baliga B. Phytochemistry, traditional uses and pharmacology of *Eugenia jambolana* L. (Black Plum): A review. Food Res Int. 2011;44(7):1776-89.
5. Giri J, Sathidevi T, Dushyanth N. Effect of jamun seed extract on alloxan-induced diabetes in rats. J Diabetic Assoc India. 1985;25(1):115-9.
6. Sagrawat H, Mann A, Kharya M. Pharmacological potential of *Eugenia jambolana*: a review. Pharmacogn Mag. 2006;2(2):96-104.
7. Warrier P, Nambiar V, Ramankutty C. Indian Medical Plants. Vol. 5. Hyderabad: Orient Longman Ltd.; 1996. p. 225-8.
8. Namasivayam R, Ramachandrani B, Deecaraman M. Effect of aqueous extract of *Syzygium cumini* pulp on antioxidant defense system in streptozotocin-induced diabetic rats. Int J Post Harvest Technol. 2008;7:137-45.
9. Hayes WB. Fruit Growing in India. Allahabad: Kitabistan; 1960. p. 389-94.
10. Llanes A, Reinoso H, Luna V. Germination and early growth of *Prosopis strombulifera* seedlings in different saline solutions. World J Agric Sci. 2005;1(2):120-8.
11. Hota SN, Karna AK, Jain PK, Dhakad B. Effect of gibberellic acid on germination, growth and survival of

jamun (*Syzygium cumini* L.). Pharma J. 2018;7(8):323-6.
12. Taiz L, Zeiger E. Plant Physiology. 3rd ed. Porto Alegre: Artmed; 2006. p. 719.
13. Patil H, Tank RV, Bennurmath P, Patel M. Effect of seed treatment on germination and seedling growth of jamun (*Syzygium cuminii* L.). Int J Curr Microbiol Appl Sci. 2018;7(2):2654-9.
14. Mali H, Jain MC, Yadav RK, Sharma P, Singh K. Effect of seed treatment on germination and seedling growth of jamun (*Syzygium cuminii* L.). Int J Curr Microbiol Appl Sci. 2021;10(1):3392-400.
15. Mane SB, Naglot UM, Parse RN. Effect of different pre-sowing treatments on shoot growth of custard apple (*Annona squamosa* L.). J Pharmacogn Phytochem. 2018;7(5):1945-7.
16. Pandit VK, Shantha N, Sinha JP. Improving papaya (*Carica papaya* L.) seed germination and seedling growth by pre-sowing treatments. Indian J Agric Sci. 2001;71:704-6.
17. Anjanawe SR, Kanpure RN, Kachouli BK, Mandlo DS. Effect of plant growth regulators and growth media on seed germination and growth vigour of papaya (*Carica papaya* L.). Ann Plant Soil Res. 2013;15(1):31-4.
18. Singh AK, Karki K. Effect of grading and GA_3 on germination and seedling growth attributes in ber. Prog Hortic. 2003;35(2):158-60.
19. Gurung N, Swamy GSK, Sarkar SK, Ubale NB. Effect of chemicals and growth regulators on germination, vigour and growth of passion fruit (*Passiflora edulis* Sims). Bioscan. 2014;9(1):155-7.
20. Barche S, Kirad KS, Singh DB. Response of seed treatment on germination, growth, survivability and economics of different cultivars of papaya (*Carica papaya* L.). Acta Hortic. 2010;851:279-84.
21. Thorat UK, Dheware RM, Jadhav AR. Influence of growth regulators on yield and economics of custard apple (*Annona squamosa* L.) cv. Balanagar. Int J Econ Plants. 2018;5(3):149-50.
22. Rawat D, Negi M, Mani G, Krishna. Effect of different levels of gibberellic acid (GA_3) on seed germination and seedling growth of sweet orange (*Citrus sinensis* L.) cv. Malta. Biol Forum. 2023;15(10):337-42.