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RESEARCH ARTICLE

Evaluation of seed storability and pre-sowing treatments to enhance germination and seedling performance in cinnamon (*Cinnamomum verum* J. Presl)

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Abstract

Cinnamon (*Cinnamomum verum* J. Presl) is one of the valuable spice crops in India used for food and flavouring industries belonging to the family *Lauraceae*. It is commonly propagated by seeds; however, seeds are recalcitrant and lose their viability quickly. This study evaluated the seed storability effect of several pre-sowing treatments on germination and seedling growth parameters of cinnamon. Ten treatments, including cold water soaking, hot water treatment, gibberellic acid (GA_3) at two concentrations (200 ppm and 400 ppm), mycorrhiza, wood ash, cow urine, cow dung slurry, mud ball preparation and an untreated control, were assessed. Among the various treatments imposed, the application of wood ash resulted in the highest germination percentage (52.00 %) of stored seeds. Pre-sowing seed treatment with GA_3 at 400 ppm recorded the highest rate of germination (2.86), took the least number of days for initiation of germination (14.33), 50 % germination (17.50) and final germination (35.00), highest shoot length (14.38 cm), root length (6.59 cm), seedling vigour index (929.60), fresh weight of shoot (441.00 mg), fresh weight of root (135.00 mg), dry weight of shoot (157.00 mg), dry weight of root (28.00 mg) and root to shoot ratio (0.18). The findings demonstrate pre-sowing seed treatment with wood ash improved germination percentage in stored seeds and GA_3 (400 ppm) markedly enhanced germination and seedling establishment in cinnamon. These seed priming procedures could help create a mass multiplication approach for farmers with limited resources.

Keywords: *Cinnamomum verum*; gibberellic acid; pre-sowing seed treatments; seed germination; seedling vigour; wood ash

Introduction

Cinnamon (*Cinnamomum verum* J. Presl), also called Ceylon cinnamon or true cinnamon, is one of the important tree spices of India, belonging to the family *Lauraceae* with a diploid chromosome number of 24. It is indigenous to Sri Lanka and the Western Ghats of South India. The British brought cinnamon to India during the 18th century and it is now mostly grown in the Indian states of Tamil Nadu, Kerala and Karnataka (1). The estimated world production of cinnamon in 2020-21 is 2.22 mt. Indonesia is the largest producer in the world, accounting for 0.91 mt. Other important countries contributing to total world production are China (72531 t), Vietnam (31429 t) and Sri Lanka (22910 t) (2). About 100 to 341 species of the genus Cinnamomum exist and they are extensively dispersed throughout Asia, Australia, the Pacific islands and Fiji (3). In India, the total production in 2021-22 was 6000 t and Meghalaya is the largest producer of cinnamon (70.26 %), followed by West Bengal (24.75 %) (1). The tree is mostly valuable for its dried inner bark, which is used as a spice and contains essential oils (1.88-3.2 %) (2). It is widely used in confectionery, food flavouring, alcoholic beverages, medicines and as a component in the production of candy, gum, incense and perfume. It is used to treat gastrointestinal disorders, flatulence and gastric debility and it is fragrant, astringent, anti-inflammatory, antibacterial, antidiabetic, stomachic, stimulant and carminative. Additionally, there is a market for young, immature fruits for the extraction of essential oils, which has industrial importance (1, 3).

Cinnamon is mainly propagated through seeds, sometimes by air layering and rarely through cuttings. The cinnamon plant blooms in January and its fruits ripen from June to August (4, 5). Seeds are extracted from ripe fruits collected from selected mother trees with desirable characteristics and sown immediately and freshly harvested seeds showed higher germination percentages. Cinnamon seeds are recalcitrant. It means that seeds cannot be kept for a longer period at normal, high, or low temperatures (6). Another difficulty is that cinnamon seeds have a limited viability, which can result in delayed and staggered germination rates. The seedling progeny might exhibit a great deal of variation as a result of seed propagation, which includes variations in the height, size and shape of the leaves, the colour of the new flush and other characteristics (4). Despite all these hurdles, seed propagation is widely practised in cinnamon due to its superior peeling efficiency (7). Besides, the seedlings produce a desirable tap root system and the trees developed from these seedlings show a straight growing habit and lesser branching, which facilitates easy peeling of the bark, in contrast to vegetatively propagated trees, which possess a much spreading habit, leading to laborious bark peeling (4).

Cinnamon seeds could have their germination and seedling growth characteristics improved by seed treatments before sowing. Pre-sowing seed treatments play a crucial role in breaking dormancy, improving germination rate and enhancing seedling vigour. Various traditional and scientific treatments, such as water soaking, growth regulators, organic inputs and microbial inoculants, are known to improve germination performance (5, 8). However, systematic evaluation of such treatments in cinnamon remains limited. Therefore, in the present investigation, an attempt has been made to study the effect of certain pre-sowing seed treatments on germination and seedling growth parameters of cinnamon by soaking in cold water, hot water, GA_3, mycorrhiza (*Glomus mosseae*), wood ash, cow urine, cow dung slurry and mud ball preparation. The objective of this study was to evaluate the effect of various pre-sowing seed treatments on germination and seedling growth of cinnamon, to identify effective strategies for improving seedling establishment and propagation efficiency.

Materials and Methods

Experimental site

The present investigation was carried out at the Department of Horticulture, University of Agricultural Sciences, Dharwad, Karnataka, from May 2023 to June 2024.

Seed material

Freshly harvested fruits were stored in a refrigerator (5 ˚C) for 4 weeks for the storage study. The stored seeds were then used to study the influence of various pre-sowing seed treatments on germination and seedling growth of true cinnamon.

Design and layout of the experiment

The experiment was laid out in a randomised block design (RBD) comprising ten treatments with three replications. A total of 300 seeds were used per treatment, resulting in an overall sample size of 3000 seeds. The treatment details of the experiment were as follows: T_1 - soaking in cold water at room temperature for 24 hr, T_2 - hot water soaking (50 °C for 5 min), T_3 - GA_3 at 200 ppm for 24 hr, T_4 - GA_3 at 400 ppm for 24 hr, T_5 - Mycorrhiza (*Glomus mosseae*) at 4g/kg sand - sowing seeds in treated sand, T_6 - coating seeds in wood ash paste, shade drying for 24 hr, T_7 – Soaking seeds in cow urine at 5 % for 24 hr, T_8 - Soaking in cow dung slurry for 24 hr, T_9 - Mud ball preparation- coating seeds in black soil and shade drying for 24 hr and T_{10} - Untreated control.

Sampling procedure

Cinnamon seeds required for the experiment were collected from 10 nine-year-old cinnamon trees of mixed population from the Department of Horticulture, University of Agricultural Sciences, Dharwad, Karnataka. Based on preliminary studies on the germination percentage of cinnamon seeds after different periods of storage, various pre-sowing seed treatments were applied to assess their effects on germination and seedling growth parameters. The treated seeds were sown in 12” grow bags filled with sterilised fine sand of neutral pH, kept under shade (50 % shade house). After sowing the seeds, the bags were covered with a portable polytunnel to create an ideal atmosphere within the tunnel for faster germination.

Observations recorded

Observations in relation to germination percentage, rate of germination, days taken for initiation, 50 % and final germination, root length, shoot length and vigour index were recorded. Final observations on root length, shoot length, number of leaves and vigour index were recorded 30 days after the final germination date; it was ensured that no seed germinated in a period of 10 days preceding the final germination date. The rate of germination was determined by counting the number of seeds germinated each day from the initiation of germination to final germination. It is expressed as an actual 'rate', i.e., number per day, as given in Equation 1-2 (9). The vigour index was calculated as per the standard methods (10, 11)

Rate of germination = Total number of seeds germinated/ number of days taken from initiation of germination to final germination (Eqn. 1)

Vigour index = [Shoot length (cm) + Root length (cm)] ´ Germination percentage (Eqn. 2)

Statistical analysis

The data was analysed statistically by using single-factor Analysis of Variance (ANOVA) in MS Excel software. Critical difference at 5 % level of significance or Tukey’s HSD (Honestly Significant Difference) test (at $p < 0.05$) was used to compare the significant difference between the treatments (12).

Results

Influence of storage period on germination

The results of the influence of storage period on germination of true cinnamon seeds are depicted in Fig. 1. The present study showed that freshly collected seeds without storage had the highest germination percentage (90.67 %) without any seed priming. However, the seed germination of cinnamon decreased significantly (45.0 %) over 4 weeks of storage (Fig. 1). Hence, the investigation was initiated to study the influence of various pre-sowing seed treatments on enhancing the seed germination in stored (8 weeks) cinnamon seeds.

Effect of pre-sowing seed treatments on germination parameters

All the seed priming techniques significantly enhanced the seed germination in true cinnamon and the results of the effect of different pre-sowing seed treatments on the germination percentage of cinnamon are presented in Fig. 2-3. Among the various treatments, wood ash-treated seeds resulted in significantly higher percentage seed germination (52 %), followed by GA_3 at 400 ppm (44.33 %). Cow urine at 5 % and water soaking also resulted in significantly higher percentage seed germination (37 % and 35 % respectively) than the control (6 %). All the organic seed priming techniques, including cow dung slurry, mycorrhiza and mudball treatments, significantly enhanced germination compared to the untreated control.

Table 1 exhibits the results of germination parameters as influenced by the various seed priming techniques. Among them, seed priming with GA_3 at 400 ppm resulted in the highest germination rate (2.86), followed by water soaking (2.64). While

Table 1. Effect of different pre-sowing seed treatments on germination parameters of cinnamon seeds

Treatments	Rate of germination	Days taken for initiation of germination	Days taken for 50 % germination	Days taken for final germination
T_1 - Cold water (room temperature)	2.64	15.33	21.00	42.00
T_2 - Hot water (50 °C for 5 min)	2.53	16.00	19.83	39.67
T_3 - GA_3 at 200 ppm	2.44	15.33	20.50	41.00
T_4 - GA_3 at 400 ppm	2.86	14.33	17.50	35.00
T_5 - Mycorrhiza at 4 g/kg sand	2.61	16.33	19.16	38.33
T_6 - Wood ash	2.22	14.67	22.50	45.00
T_7 - Cow urine at 5 %	2.42	17.67	21.16	41.33
T_8 - Cow dung slurry	2.57	17.33	19.50	39.00
T_9 - Mud ball preparation	2.50	18.00	20.00	40.00
T_{10} - Control	2.44	18.67	20.50	41.00
Mean	2.52	16.37	20.17	40.23
S. Em. ±	0.20	0.47	1.04	2.08
C. D. at 5 %	0.61	1.40	3.08	6.18
F test	*	*	*	*

* - Significant at 5 % level; mg - milligram; GA_3 - Gibberellic acid; ppm - parts per million; S.Em - Standard error of mean; C.D - Critical difference.

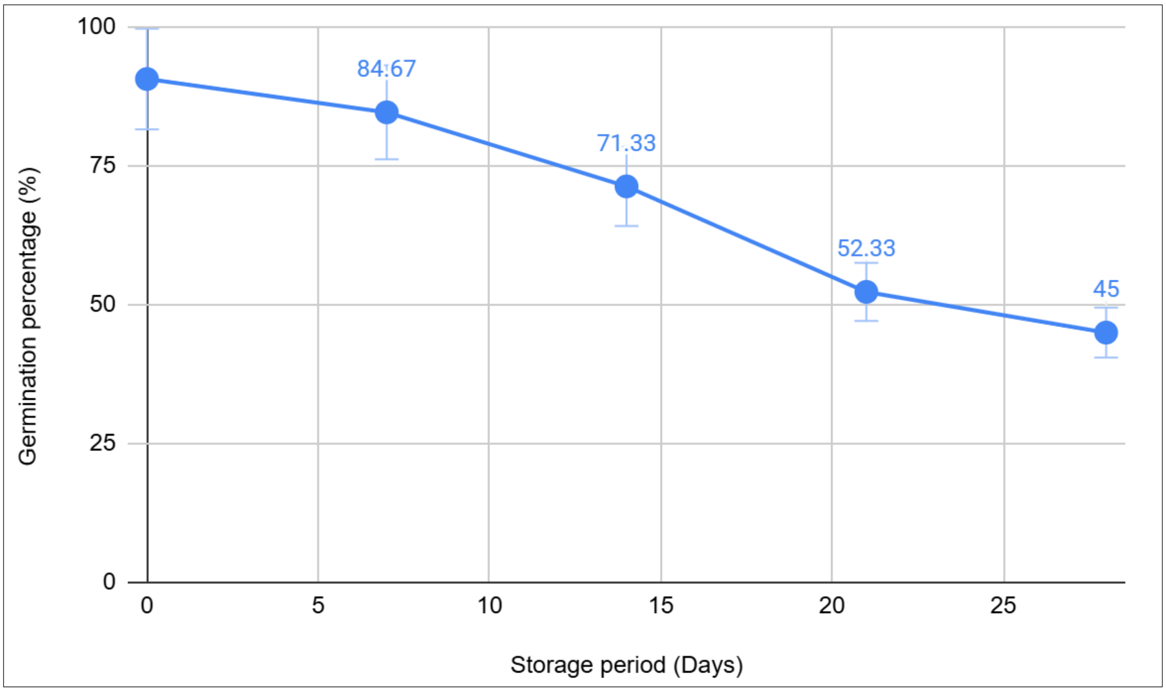

Fig. 1. Influence of storage period on germination of cinnamon seeds.

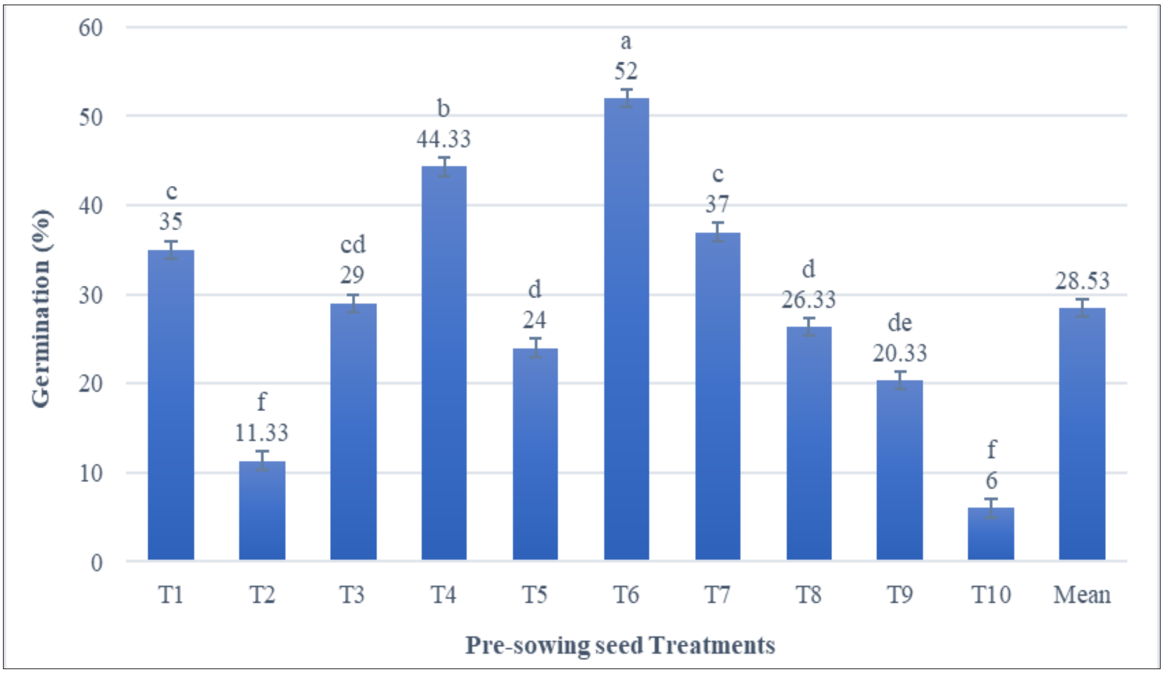

Fig. 2. Effect of pre-sowing seed treatments on the percentage of seed germination of cinnamon seeds. T_1 - Water soaking; T_2 - Hot water; T_3 - GA_3 at 200 ppm; T_4 - GA_3 at 400 ppm; T_5 - Mycorrhiza at 4 g/kg sand; T_6 - Wood ash; T_7 - Cow urine at 5 %; T_8 - Cow dung slurry; T_9 - Mud ball preparation; T_{10} - Control.

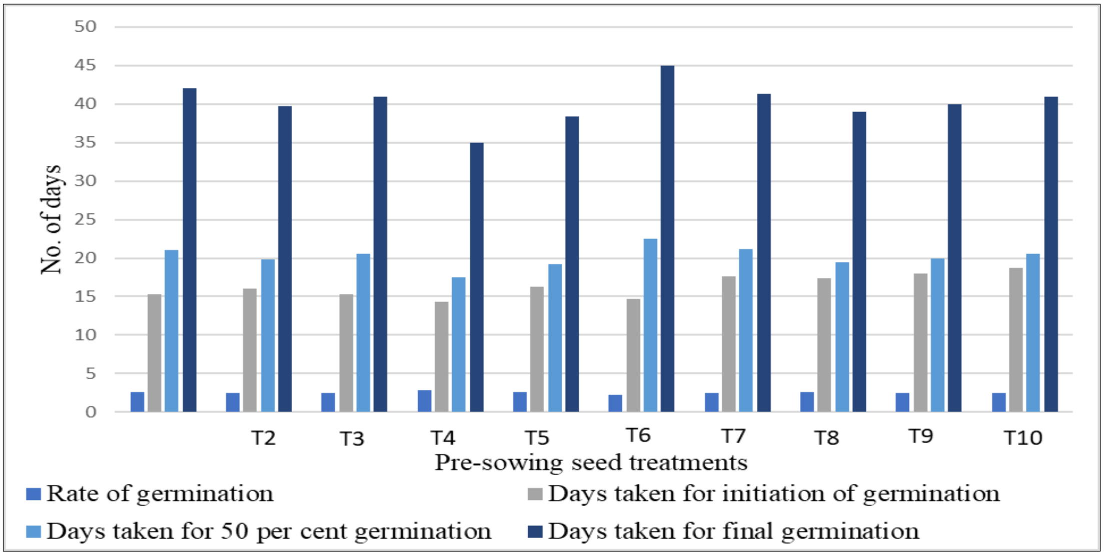

Fig. 3. Effect of pre-sowing seed treatments on germination parameters of cinnamon seeds. T_1 - Water soaking; T_2 - Hot water; T_3 - GA_3 at 200 ppm; T_4 - GA_3 at 400 ppm; T_5 - Mycorrhiza at 4 g/kg sand; T_6 - Wood ash; T_7 - Cow urine at 5 %; T_8 - Cow dung slurry; T_9 - Mud ball preparation; T_{10} - Control.

studying the germination period of cinnamon, GA_3 at 400 ppm took the least number of days for initiation of germination (14.33), 50 % germination (17.50) and final germination (35.00) (Table 1). This was superior compared to the untreated control, which required 18.67 days for initiation of germination, 20.50 days for 50 % germination and 41 days to complete germination. Although the wood ash-treated seeds exhibited the highest percentage seed germination, the rate of germination was the lowest compared to other treatments and it took a greater number of days (22.5) for 50 % germination and to complete their germination (45 days), depicting a very slow germination process in cinnamon.

Effect of pre-sowing seed treatments on seedling growth parameters

Pre-sowing seed treatments significantly influenced the seedling growth parameters, such as shoot length, root length and seedling vigour index (Table 2). Significantly higher shoot length (14.38 cm), root length (6.59 cm) and seedling vigour index (929.60) were recorded in GA_3 at 400 ppm as compared to the control. Seeds treated with cow urine at 5 % also recorded significantly higher shoot and root length than the control. Wood ash treatment was found to be the second-best treatment with respect to the seedling vigour index (911.04) due to higher germination of seeds in the treatment. Cow urine treatment also enhanced seedling vigour (766.27), while cold water soaking and GA_3 at 200 ppm performed moderately well. Seedlings of control exhibited poor growth with minimal vigour index (44.70).

The results of the influence of seed priming techniques on shoot and root biomass (fresh and dry weight of shoot and root) are displayed in Table 3. All the pre-sowing seed treatments significantly enhanced the seedling wet and dry biomass when compared to the untreated seeds. The highest fresh weight of shoot (441.00 mg), fresh weight of root (135.00 mg), dry weight of shoot (157.00 mg), dry weight of root (28.00 mg), root to shoot ratio (0.18) were recorded in GA_3 at 400 ppm, followed by cow urine at 5 % treatment. Organic seed treatments, including cow dung slurry, mycorrhiza and mud techniques, were also found to be more effective in enhancing the seedling biomass than the control. While the germination percentage was observed to be maximum in wood ash-treated seeds, all the other germination and seedling growth parameters were lower in the treatment. GA_3 at 400 ppm was found to be the most efficient pre-sowing seed treatment in true cinnamon, followed by cow urine at 5 % and water soaking.

Discussion

The investigation on the study of seed germination of true cinnamon exhibited a significant loss in germination capacity upon storage, even under refrigerated conditions. Hence, the seeds were found to be recalcitrant and lose their viability (> 50 %) considerably in 25 days

Table 2. Effect of different pre-sowing seed treatments on shoot length, root length and seedling vigour index true cinnamon seedlings

Treatments	Shoot length (cm)	Root length (cm)	Seedling vigour index
T_1 - Cold water (room temperature)	13.53	5.91	680.40
T_2 - Hot water (50 °C for 5 min)	11.62	5.35	192.27
T_3 - GA_3 at 200 ppm	13.77	6.45	586.38
T_4 - GA_3 at 400 ppm	14.38	6.59	929.60
T_5 - Mycorrhiza at 4 g/kg sand	12.55	5.03	421.92
T_6 - Wood ash	12.53	4.99	911.04
T_7 - Cow urine at 5 %	14.19	6.52	766.27
T_8 - Cow dung slurry	13.06	3.89	446.29
T_9 - Mud ball preparation	10.93	4.94	322.64
T_{10} - Control	5.61	1.84	44.70
Mean	12.22	5.15	530.15
S. Em. ±	1.30	0.55	58.18
C. D. at 5 %	3.87	1.64	172.87
F test	*	*	*

* - Significant at 5 % level; mg - milligram; GA_3 - Gibberellic acid; ppm - parts per million; S.Em - Standard error of mean; C.D - Critical difference.

Table 3. Effect of different pre-sowing seed treatments on shoot and root biomass in true cinnamon seedlings

Treatments	Fresh weight of shoot (mg)	Fresh weight of root (mg)	Dry weight of shoot (mg)	Dry weight of root (mg)	Root to shoot ratio
T_1 - Cold water (room temperature)	359.00	107.00	127.00	22.00	0.17
T_2 - Hot water (50 °C for 5 min)	261.00	95.00	102.00	16.00	0.16
T_3 - GA_3 at 200 ppm	384.00	116.00	133.00	23.00	0.17
T_4 - GA_3 at 400 ppm	441.00	135.00	157.00	28.00	0.18
T_5 - Mycorrhiza at 4 g/kg sand	333.00	91.00	119.00	18.00	0.15
T_6 - Wood ash	327.00	85.00	110.00	18.00	0.16
T_7 - Cow urine at 5 %	393.00	124.00	137.00	24.00	0.17
T_8 - Cow dung slurry	333.00	75.00	119.00	14.00	0.12
T_9 - Mud ball preparation	253.00	82.00	100.00	13.00	0.13
T_{10} - Control	101.00	29.00	43.00	5.00	0.12
Mean	318.50	93.90	114.70	18.10	0.15
S. Em. ±	30.14	7.03	9.32	1.65	0.02
C. D. at 5 %	89.54	20.88	27.70	4.89	0.06
F test	*	*	*	*	*

* - Significant at 5 % level; mg - milligram; GA_3 - Gibberellic acid; ppm - parts per million; S.Em - Standard error of mean; C.D - Critical difference.

of storage. A substantial reduction (60 %) in seed germination was observed after 1 week of storage of recalcitrant *Cinnamomum burmanii* seeds (13). It was also reported that cinnamon seeds were found to lose their viability from 94 % to 29 % over a 10-day storage period (14). When the seeds were subjected to seed priming techniques in true cinnamon, maximum germination was obtained in wood ash treatment, followed by GA_3 at 400 ppm. Wood ash contains high amounts of K, Ca, Mg, P and some micronutrients that help with better water retention and break the high dormancy of recalcitrant seeds (15, 16). GA_3 was reported to overcome all types of seed dormancies and was found to remove the germination inhibitors from the seeds and thereby help seed germination (17).

Seed priming with cow urine at 5 % and water soaking also enhanced seed germination in true cinnamon. Cow urine, reported to contain nutrients and plant growth-promoting rhizobacteria strains, which help in the production of growth hormones like auxins and gibberellins and help to break the dormancy of seeds (18, 19). Soaking the seeds in water at room temperature likely helped by softening the seed coat, removing inhibitors and reducing the time required for germination (20). A significant increase in seed germination was observed in rosemary seeds treated with cow urine and water soaking (8).

Seed treatment with GA_3 exhibited a significant improvement in germination parameters, including rate and uniformity of germination. The effect of GA_3 in increasing the rate of germination could be attributed to the seed dormancy-breaking ability of GA_3 due to protein synthesis and enhanced ethylene production, which might have invoked the synthesis of alpha amylase enzyme and leaching out of chemical inhibitors due to the action of these growth substances (21). Research has demonstrated that the highest rate of germination and the least number of days taken for 50 % germination and final germination when the seeds of *Embelia tsjeriam-cottam* were treated with GA_3 at 400 ppm (22).

Although the wood ash-treated seeds showed maximum percentage of seed germination, the other germination parameters, like the rate of germination, were minimal compared to other treatments and it took a greater number of days for 50 % germination as well as final germination. These seeds took the longest time to complete germination, with a very slow germination process in ash-treated seeds. Research indicates a similar trend in *Quercus rubra* seeds when treated with ash, resulting in 30 % higher germination than the control, but it took a prolonged period of 120 days to complete germination (23).

The increase in shoot length in GA_3 and cow urine treatments may be attributed to early germination, enhanced gibberellin-induced cell division and cell elongation. The highest seedling vigour observed with GA_3 might be due to a greater metabolic activity and respiration rate, improved metabolite mobilisation and utilisation to growth points and higher enzyme activity (21, 24). The stimulating effects of GA_3 on seedling growth parameters were reported in tamarind (25). Likewise, the presence of plant growth hormone, auxin, in cow urine may have helped to promote seedling growth (19).

While the germination percentage was observed to be maximum in wood ash-treated seeds, all the growth parameters were lower in the same. The adverse effects of wood ash at higher doses may be attributed to the presence of toxic elements exceeding the tolerance limits of seedlings (16). The reduced growth in wood ash treatment can also be partially attributed to reduced water content in seedlings caused by wood ash that might cause a loss of turgor and result in limited availability of water for cell extension and physiological processes and hence affects plant growth (26).

Root and shoot biomass of cinnamon seedlings were significantly elevated in the GA_3 treatment than in the others. Gibberellic acid might have stimulated the activity of simple sugars and their transfer to the developing embryo, where they provide energy for growth and development, resulting in a higher fresh weight of shoot and root. The dry weight of various plant sections has increased as a result of improved nutrient mobilisation brought on by using GA_3, which encourages plant growth and development (26). The highest dry weight of root and dry weight of shoot recorded with the treatment of GA_3 at 400 ppm might have resulted in the highest root-to-shoot ratio in this treatment. Overall, GA_3 at 400 ppm was found to be the most effective seed priming technique, significantly enhancing germination speed, uniformity and seedling vigour. Cow urine (5 %) and water soaking also recorded higher seed germination and seedling growth parameters, making them suitable alternatives for treating cinnamon seeds for better germination.

Conclusion

The study highlights the importance of pre-sowing seed treatments in improving germination and seedling establishment of cinnamon. Freshly harvested, ripe cinnamon fruits were used for the extraction of seeds and the seeds retain maximum viability (85-90 %) for up to 7 days after harvesting. GA_3 at 400 ppm was found to be the most effective pre-sowing seed treatment, improving germination speed, uniformity and seedling vigour.

Seed priming with cow urine at 5 % and overnight water soaking can also enhance germination and growth parameters in true cinnamon. Since the seedling progeny exhibit superior peeling efficiency, these seed priming techniques could be a boon in developing a mass multiplication method for resource-constrained farmers. Adoption of these treatments can improve nursery efficiency and ensure better plantation establishment in true cinnamon cultivation.

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Authors' contributions

GP conducted the research, result analysis and interpretation. YS designed the study, analysis and compilation of the study. RV provided the technical support to conduct the research. CMN provided technical support for the physiological response in the study. All authors read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interest to declare.

Ethical issues: None

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