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Comparison of Seed Germination and Seedling Growth Parameters in *Canarium strictum* Roxb. under Different Treatment Combinations

Neiphrelhou Medom[1], Hari Kesh[1*] and Bikram Singh[2]

[1]Dept. of Forest Biology and Tree Improvement, [2]Dept. of Silviculture and Agroforestry, College of Horticulture and Forestry, CAU (Imphal), Pasighat, (791 102), India

Corresponding Author

Hari Kesh

e-mail: harikeshkaul55v2@gmail.com

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Abstract

The experiment was conducted during March to July, 2025, in a factorial randomized block design with three replications to study the effect of different pre-sowing treatments, including KNO_3 (1% and 1.5%) and H_2O_2 (3% and 5%), and moisture content levels, including initial (12%) and reduced moisture content (10% and 8%), on seed germination and initial growth parameters of seedlings. *Canarium strictum* Roxb., commonly known as black dammar, is a highly valued and socio-economically important semi-evergreen tree species. However, the natural regeneration of this species is poor due to the hard outer pericarp for germination. The significance of moisture content and pre-sowing treatments in regulating physiological and metabolic activities associated with germination is well-established. The maximum value for germination parameters was recorded at IMC (12%), while the minimum was at RMC (8%). Among the pretreatments, the maximum value for germination parameters was recorded for KNO_3 at 1% concentration, while the minimum was observed in the control. With respect to initial seedling growth parameters, the maximum value was observed under reduced moisture content at 10% when seeds were treated with KNO_3 at 1% concentration. In conclusion, the findings highlight that IMC (12%) and RMC (10%), along with pre-sowing treatment of KNO_3 at 1% concentration, stand out as optimal ranges for ensuring the highest germination percentage, seedling vigor, and uniformity in *Cannarium strictum* seedlings. The authors argue that artificial regeneration via nursery propagation using treated seeds could significantly boost seedling establishment and offset poor natural recruitment.

Keywords: *Canarium strictum* Roxb., germination, seed, seedling growth, treatments

1. Introduction

Canarium strictum is a polygamo-dioecious tree belonging to the family Burseraceae. It is distributed across India, Myanmar, and China and is mainly used as a source of resins (Seethapathy et al., 2021). In India, it is naturally found in the states of Arunachal Pradesh, Sikkim, Assam, Meghalaya, Maharashtra, Odisha, Karnataka, Kerala, Tamil Nadu, and the Andaman Islands. It can grow up to a height of 40 m and is found in the moist deciduous to evergreen forests (Singh et al., 2018; Prasannakumar et al., 2020). The leaves of the tree are compound, alternate, leaflets 3–9 pairs with an odd one at the apex. The flowers are bisexual, yellow to dull white, and arranged in axillary panicles (Meena et al., 2012). The fruits are hard, drupe-type, shiny violet in colour, and elongated or oval in shape. *C. strictum* yields the resin known as 'black dammar'or sambrani. The resin is extracted from the bark through natural or artificial injury and serves as a crucial Non-timber Forest Product with medicinal and industrial applications. Nearly 70% of the resin production is used in the paint and varnish industry, and the remaining resources cater to incense makers (Anitha and Ticktin, 2008). Traditionally, the resin is used to treat asthma, rheumatism, fever, cough, and chronic diseases such as psoriasis and pityriasis (Khare, 2007). Local people in Meghalaya and Arunachal Pradesh consume the mature fruit of *Canarium strictum* for curing indigestion and urinary problems (Bhuyan and Laskar, 2020). The tree species is endangered and placed in the IUCN red list as vulnerable in the Southern states of India. Overexploitation, excessive tapping practices for resin collection, habitat fragmentation, pollinator and seed dispersal limitation are the important factors affecting the natural stands that result in a low flower-to-fruit ratio and diminished reproductive output (Meena et al., 2012). Due to increasing demand for the species, overexploitation, and vulnerability, the tree warrants higher concern for developing conservation strategies to save the species from local extinction (Mahmoud et al., 2016). To improve germination percentage and to save the valuable plant species from becoming extinct, various nursery techniques with appropriate pre-sowing treatments have been developed (Alamgir and Hossain, 2005). Potassium nitrate and H_2O_2 are two examples of chemical compounds that have been discovered to be useful in promoting the metabolic processes necessary for seed germination and breaking dormancy. (Bhatt et al., 2019). The earlier studies with *C. strictum* showed the highest germination percentage when seeds were treated with 4% H_2O_2 overnight, both in nursery and lab conditions. It seems that the generation of H_2O_2 activates antioxidant enzymes, particularly in the plumule, which may increase seed germination (Ghanchi et al., 2025). Likewise, potassium nitrate has also been observed to improve germination percentage in several tree species (Bhatt and Santo, 2018). Furthermore, seed storage techniques are crucial for the conservation of germplasm resources in gene banks (Schupp et al., 2010). However, information on seed storage behaviour for many higher plants is not widely available (Lan et al., 2014). Moisture content is one of the most critical factors affecting the germinability of seeds in storage, particularly if seeds are stored for long periods (Harrington, 1972). Seeds with high moisture content cannot be stored for longer periods, and over-drying can make them non-viable. The detrimental effects of high seed moisture content on the viability of tree seeds under various storage conditions have been demonstrated by many investigators (Rather et al., 2017; Jose and Jose, 2024). Therefore, this investigation was planned to study the role of moisture content and pre-sowing treatments on germination capacity and seedling growth of *Cannarium strictum.*

2. Materials and Methods

The experiment was carried out during the month of March to July, 2025 in the Research Field of the Department of Forest Biology and Tree Improvement, College of Horticulture and Forestry, Pasighat, Arunachal Pradesh. The geographical location of the research field is at a latitude of 28^0 04'N, a longitude of $95^0$19'E, and has an altitude of 153 m above MSL. The prevailing climate of an area is generally humid sub-tropical; cold weather prevails from the month of November to February. Average annual rainfall is 2500 mm and the mean maximum and minimum temperatures are 31±1.1°C and 18±1.2°C, respectively. Seeds were collected from Poba Reserve Forest, Pasighat, Arunachal Pradesh. Seeds were rinsed to remove fruit debris and then air-dried in the shade for 4–5 h. Damaged and small empty seeds were discarded, and uniform-sized seeds were selected. The seeds were subjected to drying in open trays at room conditions for one week and two weeks to achieve the reduced moisture content - RMC @ (10% (T_2) and reduced moisture content – RMC @ 8% (T_3). The initial moisture content – IMC (T_1) was 12%. A total of five pre-treatments namely, Control (M1), KNO_3 @ 1% (M_2), KNO_3 @ 1.5% (M_3), H_2O_2 @3% (M_4) and H_2O_2 @ 5% (M_5) were given to seeds at all three moisture content levels, IMC (12%), RMC (10%) and RMC (8%). The treated seeds were sown in the field conditions in the months of March and April, i.e., 24th March (IMC-12%), 1st April (RMC-10%), and 8th March (RMC-8%). The seeds were sown in a factorial randomized block design with 3 replications per treatment. The germination data was recorded for all three different moisture contents for 50 days each after sowing. The various germination parameters, such as germination percentage (GP), peak value (PV), mean daily germination (MDG), germination value (GV), and initial seedling parameters such as shoot length (cm), root length (cm), collar diameter (mm), and number of leaves, were recorded at the end of the experiment. Statistical analysis was done following the PAST 4.02 software. The significance of the difference was tested using a critical difference at a 0.05 probability (P) level.

3. Results and Discussion

3.1. Seed germination parameters

The data presented in Tables 1 to 4 revealed that all the treatments have shown significant differences for seed germination parameters like GP, PV, MDG, and GV. The GP was recorded maximum at IMC (12%) and showed a significant difference when compared at both levels of RMC (10% and 8%). All the pre-treatments differed significantly from each other, and the seeds pre-treated with KNO_3 at 1% concentration showed maximum GP, followed by H_2O_2 at 5% concentration. The minimum GP was observed under control. Concerning the interaction effect, the maximum GP was recorded in combination IMC (12%)+H_2O_2 (5%) and

Table 1: Effect of different treatment combinations on germination percentage

Treatments		M_1	M_2	M_3	M_4	M_5	Moisture content (Mean)
		Control	KNO_3 (1%)	KNO_3 (1.5%)	H_2O_2 (3%)	H_2O_2 (5%)	
IMC (12%)	T_1	50.00	83.75	77.50	76.25	91.25	75.75
RMC (10%)	T_2	52.50	90.00	55.00	71.25	67.50	67.25
RMC (8%)	T_3	12.50	53.75	21.25	30.00	27.50	29.00
Pre-treatments (Mean)		38.33	75.83	51.25	59.17	62.08	-
CD (p=0.05)		-	-	-	-	-	-

Moisture content: 2.99; Pre-treatments: 3.86; Moisture content×Pre-treatments: 6.68

Table 2: Effect of different treatment combinations on peak value

Treatments		M_1	M_2	M_3	M_4	M_5	Moisture content (Mean)
		Control	KNO_3 (1%)	KNO_3 (1.5%)	H_2O_2 (3%)	H_2O_2 (5%)	
IMC (12%)	T_1	1.37	2.99	2.74	2.51	3.34	2.59
RMC (10%)	T_2	1.44	3.62	1.83	2.45	2.49	2.37
RMC (8%)	T_3	0.44	1.79	0.80	1.01	1.00	1.01
Pre-treatments (Mean)		1.08	2.80	1.79	1.99	2.27	-
CD (p=0.05)		-	-	-	-	-	-

Moisture content: 0.19; Pre-treatments: 0.25; Moisture content×Pre-treatments: 0.43

Table 3: Effect of different treatment combinations on mean daily germination

Treatments		M_1	M_2	M_3	M_4	M_5	Moisture content (Mean)
		Control	KNO_3 (1%)	KNO_3 (1.5%)	H_2O_2 (3%)	H_2O_2 (5%)	
IMC (12%)	T_1	1.00	1.68	1.55	1.78	1.80	1.56
RMC (10%)	T_2	1.05	1.80	1.10	1.43	1.35	1.35
RMC (8%)	T_3	0.25	1.08	0.43	0.60	0.55	0.58
Pre-treatments (Mean)		0.77	1.52	1.03	1.27	1.23	-
CD (p=0.05)		-	-	-	-	-	-

Moisture content: 0.08; Pre-treatments: 0.11; Moisture content×Pre-treatments: 0.19

Table 4: Effect of different treatment combinations on germination value

Treatments		M_1	M_2	M_3	M_4	M_5	Moisture content (Mean)
		Control	KNO_3 (1%)	KNO_3 (1.5%)	H_2O_2 (3%)	H_2O_2 (5%)	
IMC (12%)	T_1	1.39	5.01	4.25	4.50	6.02	4.23
RMC (10%)	T_2	1.51	6.56	2.03	3.55	3.37	3.40
RMC (8%)	T_3	0.11	1.91	0.34	0.62	0.55	0.71
Pre-treatments (Mean)		1.00	4.49	2.21	2.89	3.31	-
CD (p=0.05)		-	-	-	-	-	-

Moisture content: 0.45; Pre-treatments: 0.58; Moisture content×Pre-treatments: 1.00

RMC (10%)+KNO_3 (1%), which are statistically at par. At RMC (8%), the GP was significantly lower (almost 1.5 to 4.0 times) in comparison to IMC (12%). However, at RMC (10%), the GP was non-significant under M_2T_2 and M_2T_4. Seeds that are not stored properly deteriorate and lose viability with time. Likewise, the PV was highest when seeds were treated with KNO_3 at 1% concentration and H_2O_2 at 5% concentration at RMC (10%) and IMC (12%), respectively. Seeds treated with KNO_3 (1% and 1.5%) and H_2O_2 (3% and 5%) resulted in better PV compared to the control among all three moisture levels. Among the moisture content levels, the PV observed maximum at IMC (12%), which is significantly higher than RMC (10%) and RMC (8%).

The interaction effect of IMC (12%)+KNO_3 (1%), IMC (12%)+H_2O_2 (3%), IMC (12%)+H_2O_2 (5%), and RMC (10%)+KNO_3 (1%) resulted in the highest value for MDG as compared to the single factor effect of moisture content or pre-treatments. Among the pre-treatments, KNO_3 (1%) caused significantly better value for MDG compared to the control and other treatments. The MDG was observed to be maximum (1.56) at IMC (12%), followed by RMC (10%), and minimum (0.58) at RMC (8%). For GV, the significantly highest value (4.23) was recorded at IMC (12%) in comparison to RMC (10%) and RMC (8%). Pre-treatment with KNO_3 at 1% concentration (4.49) showed maximum GV followed by H_2O_2 (3.31) at 5% concentration, while the minimum was observed under control (1.00). The maximum GV was found in the combined effect of RMC (10%)+KNO_3 (1%), followed by IMC (12%)+H_2O_2 (5%), M_1T_5 (6.02), and the minimum in RMC (8%)+Control. The GV was significantly lower at RMC (8%) compared to IMC (12%) and RMC (10%). The % increase in germination as compared to the control showed the efficacy of KNO_3 and H_2O_2 in pre-sowing seed treatment, as potassium nitrate inhibits the action of abscisic acid (ABA) and helps in breaking seed dormancy by improving water imbibition by the seeds (Lara et al., 2014). The results of this study are also in agreement with the findings of Jose and Jose (2024), who noted that *Canarium strictum* seed treated with 1% KNO_3 had a higher germination percentage compared to untreated seeds. Mewded et al. (2022) studied the effects of pretreatments, moisture content, storage conditions, and different storage periods over 12 months on the seed germination and storage behaviour of *Mimusops kummel*. Their findings revealed that the *M. kummel* seed with a moisture content of 3.7% can be germinated to a significant level after cold storage. Moreover, for temporary storage purposes like forest restoration and rehabilitation programs, a seed moisture content of 7.06% is substantial to attain higher germination. However, it is evident from the results that the effect of varied concentrations of both KNO_3 and H_2O_2 is different. The priming of dormant seeds stimulates a series of complex biochemical and physiological processes that ultimately enhance germination (Farooq et al., 2019). Strong oxidizing agents like H_2O_2 weaken the seed coat and allow the water uptake and gas exchange. Furthermore, hydrogen peroxide functions as a signalling molecule for the activation of germination-related genes (Farooq et al., 2019).

3.2. Seedling parameters

All the treatments, including moisture content and pre-treatments, significantly influenced the shoot length, root length, number of leaves, and collar diameter. In comparison to the control, all the treatments showed better performance for all the seedling traits. However, the effect of RMC (10%) among the three levels of moisture content and KNO_3 at 1% concentration among the different pre-treatments is more pronounced. The highest shoot length was obtained at RMC (10%), followed by RMC (8%), while the minimum was found at IMC (12%). Among the pretreatments, maximum shoot length was recorded in KNO_3 at 1% concentration, followed by H_2O_2 at 5% concentration, while the minimum was observed under control. Concerning the interaction effect, the maximum shoot length was found in under combined effect of RMC (10%)+KNO_3 (1%), followed by RMC (10%)+H_2O_2 (5%) and IMC (12%)+KNO_3 (1%). The root length was significantly highest at IMC (10%) and minimum at RMC (8%). Pre-treatments of seeds with KNO_3 at 1% followed by KNO_3 at 1.5% significantly increased the root length, while a minimum was observed in the control. The interaction effect of IMC (12%) + KNO_3 (1%), followed by RMC (10%) + H_2O_2 (5%) showed the better root length in comparison to the control (Table 5 and 6).

The maximum number of leaves was produced in the positive interaction effect of RMC (10%)+H_2O_2 (5%), followed by IMC (12%)+KNO_3 (1%). All the pre-treatments produced significantly greater numbers of leaves compared to the control at IMC (12%) as well as RMC (10% and 8%) levels. The interaction was found to be non-significant for collar diameter. The maximum collar diameter was recorded at IMC (12%) and the minimum at RMC (8%). Among the pre-treatments, seeds treated with KNO_3 at 1% concentration caused more collar diameter, followed by H_2O_2 (3%) while compared to the control. Various earlier studies have shown that potassium nitrate KNO_3 and H_2O_2 act as an effective priming agent that improves seed germination and early

Table 5: Effect of different treatment combinations on shoot length (cm)

Treatments		M_1	M_2	M_3	M_4	M_5	Moisture content (Mean)
		Control	KNO_3 (1%)	KNO_3 (1.5%)	H_2O_2 (3%)	H_2O_2 (5%)	
IMC (12%)	T_1	9.73	15.00	13.63	13.00	13.98	13.07
RMC (10%)	T_2	12.33	15.18	12.98	13.68	15.00	13.83
RMC (8%)	T_3	11.45	14.78	12.83	12.68	14.95	13.34
Pre-treatments (Mean)		11.17	14.98	13.14	13.12	14.64	-
CD (*p*=0.05)		-	-	-	-	-	-

Moisture content: 0.58; Pre-treatments: 0.74; Moisture content×Pre-treatments: 1.29

Table 6: Effect of different treatment combinations on root length (cm)

Treatments		M_1	M_2	M_3	M_4	M_5	Moisture content (Mean)
		Control	KNO_3 (1%)	KNO_3 (1.5%)	H_2O_2 (3%)	H_2O_2 (5%)	
IMC (12%)	T_1	5.83	9.15	8.73	7.43	8.08	7.84
RMC (10%)	T_2	6.48	8.73	8.58	8.38	8.75	8.18
RMC (8%)	T_3	6.20	8.63	7.80	7.83	7.45	7.58
Pre-treatments (Mean)		6.17	8.83	8.37	7.88	8.09	-
CD (*p*=0.05)		-	-	-	-	-	-

Moisture content: 0.33; Pre-treatments: 0.42; Moisture content×Pre-treatments: 0.73

seedling growth. The findings of Jose and Jose (2024) found that seeds treated with 1% KNO_3 solution under reduced moisture conditions displayed better seedling length, collar girth, and root count as compared to other pretreatments. A significant improvement has been observed for early emergence, plumule length, radicle length, plant height, and dry seedling weight of soybean cultivars pre-treated with KNO_3 (Ahmadvad et al., 2012). Hydrogen peroxide (H_2O_2) acts as a key signalling molecule mediating various physiological and metabolic processes. Recent studies have shown that H_2O_2 at low concentrations improves plant growth by enhancing antioxidant enzyme activity, membrane stability, and metabolism of lipid, fatty acid, and carbohydrate (Sun et al., 2016; Gohari et al., 2020). The effect of seed pretreatment with H_2O_2 in *Bombax ceiba* was studied for seed germination and physiological characteristics of seedlings (Zheng et al., 2018). The findings indicated that seeds treated with 80 mM of H_2O_2 showed increased photosynthetic efficiency of seedlings, which might be related to the H_2O_2-induced activity of superoxide dismutase. However, seeds treated with a higher concentration of H_2O_2 (120 mM) accelerated chlorophyll degradation and photoinhibition in seedlings. Therefore, seed pretreatments at low concentration with 80 mM of H_2O_2 can be used to improve seedling survival of *B. ceiba* under high temperature stress. In another study, H_2O_2 treatments significantly improved seedling growth and reduced the incidence of major pathogens of onion, such as Alternaria and Aspergillus spp. in onion cv. Palam Lohit highlighted the importance of H_2O_2 as an eco-friendly solution for onion productivity and health (Padiyal et al., 2025) (Table 7 and 8).

Table 7: Effect of different treatment combinations on the number of leaves

Treatments		M_1	M_2	M_3	M_4	M_5	Moisture content (Mean)
		Control	KNO_3 (1%)	KNO_3 (1.5%)	H_2O_2 (3%)	H_2O_2 (5%)	
IMC (12%)	T_1	6.00	8.25	6.75	7.75	6.00	6.95
RMC (10%)	T_2	6.00	7.50	7.25	7.00	8.50	7.25
RMC (8%)	T_3	6.00	6.75	6.50	6.75	6.50	6.50
Pre-treatments (Mean)		6.00	7.50	6.83	7.17	7.00	-
CD (p=0.05)		-	-	-	-	-	-

Moisture content: 0.40; Pre-treatments: 0.52; Moisture content×Pre-treatments: 0.90

Table 8: Effect of different treatment combinations on collar diameter (mm)

Treatments		M_1	M_2	M_3	M_4	M_5	Moisture content (Mean)
		Control	KNO_3 (1%)	KNO_3 (1.5%)	H_2O_2 (3%)	H_2O_2 (5%)	
IMC (12%)	T_1	0.178	0.223	0.203	0.215	0.208	0.205
RMC (10%)	T_2	0.188	0.245	0.225	0.240	0.195	0.219
RMC (8%)	T_3	0.185	0.220	0.215	0.228	0.208	0.211
Pre-treatments (Mean)		0.183	0.229	0.214	0.228	0.203	-
CD (p=0.05)		-	-	-	-	-	-

Moisture content: 0.011; Pre-treatments: 0.014; Moisture content×Pre-treatments: NS

4. Conclusion

The moisture content viz., IMC (12%) and RMC (10%) stand out as optimal ranges for ensuring the highest germination percentage, seedling vigor, and uniformity in *Cannarium strictum* seedlings. By aligning nursery practices with these findings, foresters and conservationists can improve the success of planting programs and contribute to the effective restoration of this valuable species in its natural habitat.

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