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Breaking Seed Dormancy in Pili (*Canarium ovatum*): Efficacy of Hot Water, Cold Water, and Scarification Treatments

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Abstract

Pili (*Canarium ovatum*) is an indigenous tree species in the Philippines valued for its edible nuts, oil, and economic importance. However, propagation of Pili is often limited by seed dormancy, which delays germination and reduces seedling production efficiency. Limited information is available regarding effective pre-germination treatments that can improve the germination performance of Pili seeds. Hence, this study aimed to evaluate the effects of different pre-germination treatments on the germination performance of Pili seeds. Specifically, the study assessed percent survival, percentage germination, germinative energy, and germinative capacity under four treatments: control (untreated), hot water soaking, cold water soaking, and scarification. A total of 320 seeds were arranged in a Randomized Complete Block Design (RCBD) with four treatments replicated four times. Hot water soaking involved immersing seeds in 100°C water for 15 seconds, cold water soaking involved soaking seeds in 10–20°C water for 12 hours, while scarification was performed through manual nicking using secateurs.

Results showed that hot water soaking produced the highest seed survival, germination percentage, germinative energy, and germinative capacity among all treatments tested. Analysis of variance (ANOVA) revealed highly significant differences among treatments for percent survival ($F = 804.60$, $p < 0.0000$), percentage germination ($F = 3092.74$, $p < 0.0000$), and germinative capacity ($F = 9720.18$, $p < 0.0000$). The findings indicate that hot water soaking is the most effective pre-germination treatment for breaking seed dormancy and improving the germination performance of Pili seeds.

Keywords: percentage germination, percentage germinative energy, percentage germinative capacity, percent survival, and pre-germination treatments

INTRODUCTION

The Philippines is recognized as a center of diversity for several fruit-bearing tree species that produce edible nuts. One of the most economically important among these is Pili (*Canarium ovatum*), a native species primarily distributed in the Bicol Region, particularly in the provinces of Sorsogon, Albay, and Camarines Sur (Mendioro, 2008). Pili belongs to the Burseraceae family and is one of several species under the genus *Canarium*, which also includes *C. indicum*, *C. album*, and *C. luzonicum*. Despite its economic and nutritional importance, Pili trees are commonly found growing in the wild rather than in organized plantations, resulting in limited and unpredictable nut production. In addition, the fruits have high fat content, making them highly perishable and requiring immediate processing or preservation after harvest (Millena and Sagum, 2018).

Pili is valued not only for its edible nuts but also for its potential contributions to food security, medicine, and livelihood generation. The species begins flowering at around four years of age, while fruiting commonly occurs five to six years after planting. Clonally

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propagated trees may bear fruit earlier, approximately three to four years after planting. Full production is generally achieved at twelve to fifteen years, with some trees yielding as much as 140 kilograms of nuts annually. However, habitat loss and uncontrolled harvesting threaten the sustainability and biodiversity of the species. Therefore, improving propagation and nursery production practices is essential for the conservation and wider cultivation of Pili. Even at room temperature, Pili seeds quickly lose their viability, thus the nuts should be sowed right away because they are recalcitrant. Only 19% of nuts sown 12 weeks after harvest germinate, compared to 98% of nuts sown immediately after harvest (Coronel, 1996).

One of the major challenges in Pili propagation is seed dormancy, which delays germination and seedling establishment. Seed dormancy is a physiological and physical condition that prevents viable seeds from germinating even under favorable environmental conditions. In many plant species, dormancy serves as an adaptive survival mechanism that allows seeds to withstand unfavorable environmental conditions and prevents simultaneous germination. However, prolonged dormancy can reduce the efficiency of nursery production and large-scale propagation efforts. According to the Bureau of Agricultural Research, Pili seeds require an average of 57 to 70 days to germinate after sowing. Every year, a substantial number of Pili seeds are lost after naturally fallen fruits fail to germinate, largely due to seed coat–induced dormancy. This low germination status threatens the species' survival and reduces the seed stock available for natural forest regeneration, as many fruits are consumed rather than stored. As emphasized by Anozie and Oboho (2019), testing various pre-germination treatments is therefore necessary to overcome dormancy barriers. According to Nurdin et al. (2022), the thick, hard seed coat of *Canarium* seeds inhibits water imbibition, thereby prolonging dormancy. Thus, the primary objective of pre-germination treatments is to rupture or create openings in the seed coat, facilitating water uptake and enhancing germination success.

Various pre-germination treatments are commonly used to overcome seed dormancy and improve germination performance. Hot water soaking softens the seed coat and increases water absorption, scarification mechanically breaks or weakens the seed coat to facilitate embryo emergence, while cold water soaking hydrates seeds and activates physiological processes necessary for germination. Previous studies have shown that these treatments can enhance germination in several forest and fruit tree species. However, limited scientific information is available regarding the most effective pre-germination treatment for Pili (*Canarium ovatum*) seeds under nursery conditions. This knowledge gap limits the development of efficient propagation techniques necessary for large-scale seedling production and conservation programs.

Hence, this study aimed to evaluate the effects of different pre-germination treatments, namely hot water soaking, cold water soaking, and scarification, on the percent survival, percentage germination, germinative energy, and germinative capacity of Pili seeds. Specifically, the study hypothesized that pre-germination treatments would significantly improve the germination performance of Pili seeds compared with untreated seeds, with hot water soaking expected to produce the highest germination response.

METHODOLOGY

Study site

This study was conducted in Barangay III, San Luis, Aurora, Philippines. Barangay III is situated at approximately 15.7223, 121.5170 (15°43' N, 121°31' E) in the island of Luzon. Elevation at these coordinates was estimated at 27.0 meters or 88.6 feet above mean sea level.

Collection and Preparation of Pili seeds

Three hundred twenty (320) mature Pili seeds were collected by climbing the Pili mother tree in Reserva, Baler, Aurora. After collection, the fruits were thoroughly washed with tap water to remove any impurities. The seeds were then stored in a sack for two days to allow the exocarp to be easily peeled off (Herter and Burris, 1989). To identify viable seeds, a flotation test was performed. Afterward, the seeds were air-dried for two days to reduce moisture content, helping to prevent seed decay (Guzzon et al., 2024). In addition, the age of the seeds was recorded at the time of collection to ensure viability. Seeds were stored under ambient conditions prior to experimentation. Initial moisture content was measured using the oven-dry method, and only physiologically mature seeds were identified by hardened shells and uniform brown coloration were included in the study.

Preparation of Propagating Media

The garden soil was collected from an open lot in Brgy. 3, San Luis, Aurora, while the rice hull was sourced from a rice mill in Brgy. Pingit, Baler, Aurora. Two (2) sacks of garden soil, each weighing 50 kilograms, and one (1) sack of rice hull, also weighing 50 kilograms, were combined. The soil mixture was sterilized by cooking for at least three (3) hours to eliminate soil-borne microbes (Tacloy et al., 2022). A gardening shovel was then used to transfer the sterilized mixture into the seedbed.

Table 1. Pre-germination treatments used in the study.

Treatments	Description
Treatment 1	Control/Untreated seeds
Treatment 2	Hot water soaking for 15 seconds in 100°C
Treatment 3	Cold water soaking for 12 hours in 10 to 20°C
Treatment 4	Scarification/manually nicking using secateurs

Preparation of Treatments

In this study, seeds were subjected to four (4) treatments including a control and were replicated four (4) times with ten (10) assessment units, with a total of 320 seeds. Seeds under Treatment 1 were not treated since it served as the control. Meanwhile, seeds under Treatment 2 were soaked in hot water for 15 seconds in a medium-size stainless pot at a temperature of 100 degrees Celsius (Missanjo et al., 2014). After soaking for the prescribed amount of time, the seeds were taken out right away and submerged in tap water to halt the heating process. For Treatment 3, the seeds were soaked in cold water for 12 hours in an icebox container at a temperature of 10 to 20°C (Obideen et al., 2024). To ensure consistent temperatures, a thermometer was used and checked every six hours. Ice cubes were added as needed to maintain the required temperature over a 12-hour period (Odoi et al., 2021). For Treatment 4, the seeds were manually nicked using secateurs, following the method described by Missanjo et al. (2014). The pointy apex end of the seed is the precise position of the incision, ensuring that the cutting tool stays a safe distance from the embryo. In order to ensure that the incision has only penetrated the shell layer, the depth of the cut is precisely controlled by stopping the force application at the precise instant that the hardshell resistance lowers. This is done by searching for the visible color contrast of the lighter, underlying internal tissue. Afterwards, the seeds were planted immediately in a seedbed with the same length of 1.2 meters. The following treatments used in the study is presented in Table 1.

Experimental Design and Lay-out

The experiment was laid out using Randomized Complete Block Design (RCBD). The study used four treatments including the control which is replicated 4 times for a total of 320 seeds with 10 experimental units. The corresponding data are presented in Figure 1.

Data Collection

The seedbeds were maintained at an ambient temperature, with relative humidity ranging from 65–75%. Seedlings were exposed to natural sunlight for approximately 10 hours daily. Watering was performed twice daily (early morning and late afternoon) using tap water, ensuring uniform soil moisture across treatments. These conditions were standardized to minimize variability and enhance reproducibility of results. Throughout the 53-day germination period, environmental parameters were monitored to ensure consistency across treatments.

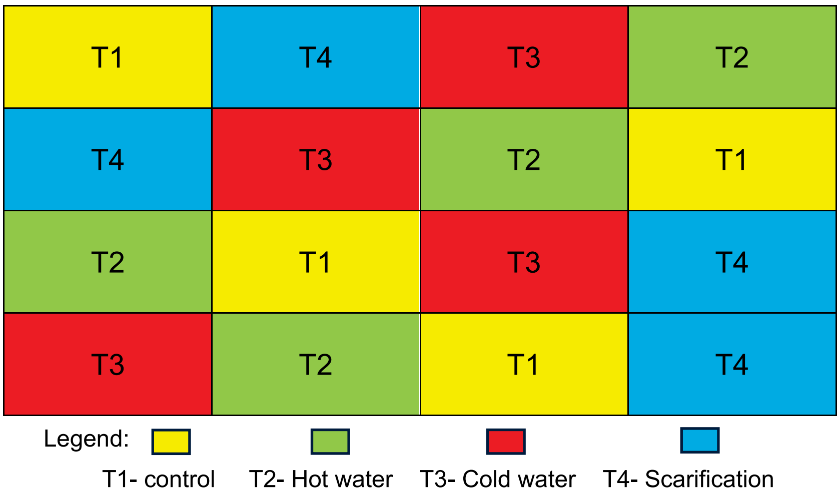

Figure 1. Experimental layout used in the study.

1. Percent Survival (PS)

To determine the percent survival, the total number of seedlings that survived was divided by the total number of seeds planted, then multiplied by 100 (Bhardwaj, 2014).

$$\% \, Survival = \frac{\begin{array}{c} Total \; number \\ of \; seedlings \; survived \end{array}}{\begin{array}{c} Total \; number \\ of \; seeds \; planted \end{array}} \, x\, 100$$

2. Percentage Germination (PG)

To determine the percentage germination, the total number of seeds germinated was divided by the total number of seeds planted, multiplied by 100 (Pabalan and Aquino, 2020).

$$\% Germination = \frac{\begin{array}{c} Total \; number \\ of \; seeds \; germinated \end{array}}{\begin{array}{c} Total \; number \\ of \; seeds \; planted \end{array}} \, x\, 100$$

3. Percentage Germinative Energy (PGE)

To determine the percentage germinative energy, the total number of germinated seeds up to the peak period was divided by the total number of seeds planted then multiplied by 100 (Pabalan and Aquino, 2020). The peak period refers to the day with highest number of seeds germinated.

$$\begin{array}{c} \% Germinative \\ Energy \end{array} = \frac{\begin{array}{c} Number \; of \; seed \; sown \; up \\ to \; the \; peak \; period \end{array}}{Total \; seeds \; planted} \, x\, 100$$

4. Percentage Germinative Capacity (PGC)

To determine the percentage germinative capacity, the sum of the number of seeds germinated and the number of ungerminated sound seeds was divided by the total number of seeds planted, then multiplied by 100 (Olujobi et al., 2022). Ungerminated sound seeds are viable seeds that, despite their capability to germinate, fail to sprout during a specific germination test (Vicient, 2017).

$$\begin{array}{c} \% Germinative \\ Capacity \end{array} = \frac{\begin{array}{c} Total \; number \; of \\ seeds \; germinated \end{array} + \begin{array}{c} number \; of \\ ungerminated \\ sound \; seeds \end{array}}{Total \; seeds \; of \; planted} \, x\, 100$$

Data Analysis and Interpretation

A one-way analysis of variance (ANOVA) was performed using the Statistical Tool for Agricultural Research (STAR v1.0) to evaluate the effects of different treatments on seed germination. Mean separation among germination related parameters including percent survival, percent germination, germinative energy, and germinative capacity was conducted using Tukey's Honestly Significant Difference (HSD) test at the 5% significance level.

RESULT AND DISCUSSION

Variation in Seed Survival Response of Canarium ovatum

Treatment 2 *(hot water soaking)* resulted in the highest mean percent survival at 60%, indicating a superior outcome compared to the other treatments. Treatment 3 *(cold water soaking)* followed with a mean survival rate of 32.5%, while the control group Treatment 1 *(control)* exhibited a slightly lower mean of 30%. In contrast, Treatment 4 *(scarification)* recorded the lowest survival rate at 20%. These results clearly indicate that hot water soaking significantly enhances seed survival compared to other pre-germination methods. The findings support the study of Paquit et al. (2024), who reported that hot water pre-treatment at 80°C notably increased the cumulative germination percentage (CGP) of *Falcataria falcata* seeds, achieving 60–70% germination within just 4–5 days—far exceeding the performance of untreated seeds. Similarly, Mganga and Mziho (2025) observed that 24-hours hot water soaking effectively weakened the hard seed coat of *Adansonia digitate*, improving both germination and seedling vigor. Further evidence from Dai et al. (2023) demonstrated that soaking *Ormosia hosiei* seeds in hot water at 90°C for 5 minutes significantly boosted germination rates up to 70%. Likewise, Fabiao et al. (2014) found that *Retama sphaerocarpa* seeds achieved a 28.7% germination rate after hot water soaking at 80°C for 30 seconds, outperforming untreated seeds which only reached 11.3%. These findings suggest that hot water soaking not only facilitates the breakdown of physical dormancy in seeds by softening or cracking hard seed coats but also helps leach out chemical inhibitors that may impede germination (Anwar and Malik, 2007). This dual mechanism likely accounts for the higher seedling survival observed in the current study. The results imply that hot water soaking is a highly effective pre-germination treatment for enhancing Pili seed survival, presenting a practical and low-cost technique for large-scale propagation. This method could greatly benefit nursery operations and contribute to the more efficient establishment of Pili plantations. On the other hand, the poor performance of scarification can be attributed primarily to increased susceptibility to predation, underscoring the need for improved protective strategies should this method be applied in future propagation trials.

Seed Germination Attributes of Canarium ovatum

Among the four pre-germination treatments, Treatment 2 (*hot water soaking*) recorded the highest germination rate at 75%, followed by Treatment 1 (*control*) at 40%, Treatment 3 (*cold water soaking*) at 35%, and the lowest in Treatment 4 (*scarification*) at 20%. These findings reinforce the effectiveness of hot water soaking in breaking Pili seed dormancy. The improved germination rate under hot water soaking is likely due to structural modifications in the seed coat caused by the exposure to heat, which facilitates greater water uptake and enzymatic activity essential for germination initiation. The low performance of scarification may be attributed to damage to the seed coat or increased vulnerability to microbial infection or predation.

Similarly, Khalil and Suleman (2022) found that hot water soaking dramatically increased the germination percentage of *Ceratonia siliqua* to 96.67%, as opposed to only 48% in untreated seeds. Further supporting evidence from Seid et al. (2023) demonstrated that hot water soaking at 75°C for 10 minutes, followed by a 12-hour cooling period, led to the highest daily germination rates in drought-adapted species such as *Balanites aegyptiaca* and *B. rotundiflora*. In addition, Mewded et al. (2019) reported a significant increase in the germination percentage (80%) of *Terminalia laxiflora* seeds when exposed to hot water at 78°C for 10 minutes.

However, not all studies reported uniformly positive outcomes for hot water soaking. In contrast to the current findings, Abere (2022) observed that hot water treatment negatively affected the germination of *Adansonia digitata* seeds, resulting in a reduced germination rate of 70%. In that study, cold water soaking proved more effective, achieving a notably higher germination rate of 96.67%. This variability in response highlights the species-specific nature of seed dormancy mechanisms and emphasizes the importance of tailoring pre-germination treatments to the physiological characteristics of the target species. Nevertheless, the consistent superiority of hot water soaking observed in the present study strongly suggests that it is an effective method for enhancing Pili seed germination, offering practical implications for improving propagation success in plantation or nursery settings.

At day 25 prior to sowing, Treatment 4 (*scarification*) showed the earliest germination, producing two early germinants, suggesting that the method initially facilitated faster water absorption. However, despite its quick onset, the progression of germination in this treatment slowed down significantly. This decline is attributed to ant predation, which was reportedly triggered by the appetizing aroma released from the opened seed coats of scarified seeds (Millena and Sagum, 2018). By the end of the observation period, the total number of germinated seeds was highest in Treatment 2 *(hot water soaking)* with 48 germinants, followed by Treatment 3 (*cold water soaking*) with 26 germinants, Treatment 1 (*control*) with 24 germinants, and Treatment 4 (scarification) with the lowest count of 16 germinants. Interestingly, between days 25 to 41, Treatment 2 (*hot water soaking*) and Treatment 4 (*scarification*) exhibited prolonged germination periods, suggesting delayed germination in some seeds, possibly due to variation in individual seed coat resistance or environmental micro conditions.

Treatment 2 (*hot water soaking*) achieved the highest mean germinative energy at 41.25%, indicating its superior capacity to induce rapid and uniform germination. This was followed by Treatment 1 (*control*) with 32.50%, Treatment 3 (*cold water soaking*) at 30%, and lastly, Treatment 4 (*scarification*) with the lowest mean of 18.75%, reinforcing its limited effectiveness in enhancing early germination in Pili seeds. These results are consistent with the findings of Obiazi (2015), who observed that *Leucaena leucocephala* seeds immersed in hot water for just one minute achieved 100% early germination, significantly outperforming longer immersions and untreated controls. The study concluded that hot water soaking is effective in breaking physical dormancy by weakening the seed coat while avoiding damage to the embryo. However, it also emphasized the importance of optimizing treatment duration and temperature, as excessive exposure may reduce germination due to heat stress (Tahing et al., 2024).

In contrast, Ogbu and Otah (2017) reported a 49.6% germinative energy in *Dialium guineense* seeds subjected to cold soaking, suggesting that this method may be effective in specific species. Interestingly, Amokoah et al. (2017) documented that *Pouteria campachiana* seeds exhibited 62.2% germination even without any treatment, indicating high inherent viability, which contrasts with the relatively low germinative energy observed in untreated Pili seeds in this study. In summary, hot water soaking not only promotes a higher percentage of germination but also facilitates faster and more synchronized seedling emergence, making it the most effective method among the treatments tested. Conversely, while scarification triggers early germination, it also increases exposure to predation and results in lower overall germinative energy, thus rendering it less suitable for Pili propagation under current conditions.

Figure 2 illustrates the cumulative germination trends of Pili seeds over a 41-day observation period under four different pre-germination treatments. It compares the total number of seeds germinated per treatment across time and highlights the rate and duration of germination events. The earliest germination was recorded in Treatment 4 (*scarification*), occurring 25 days after sowing, indicating that scarification initially facilitated rapid water uptake and early embryo activation. However, both Treatment 2 (*hot water soaking*) and Treatment 4 (*scarification*)

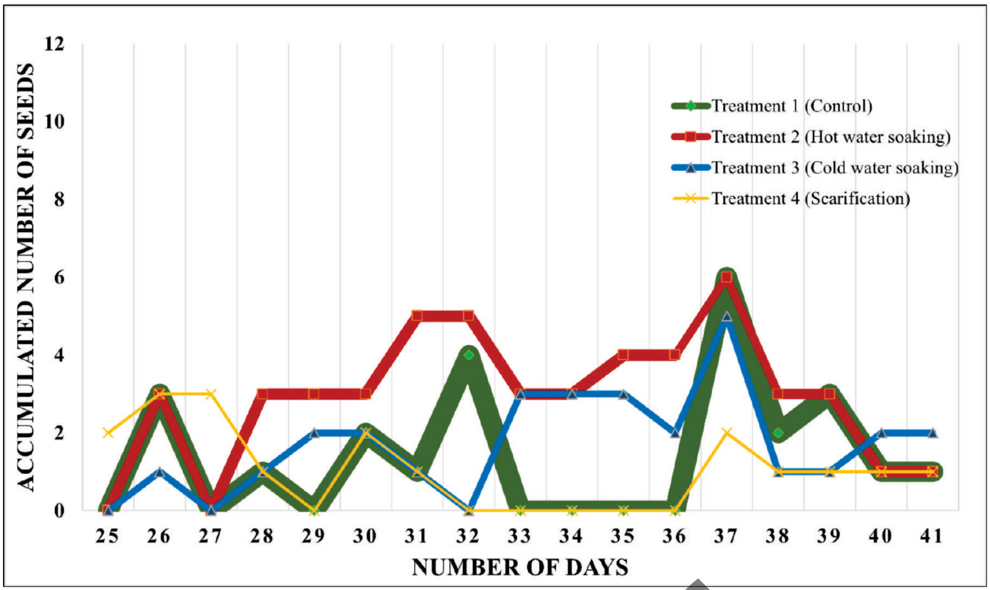

Figure 2. Percentage germinative energy of different treatments from day 25 to day 41

exhibited the longest germination duration, extending up to 41 days, as shown in the raw germination data. Treatment 1 (*control*), represented in green, exhibited a gradual and steady increase in germination, reaching a peak of approximately 6 seeds by day 37. This indicates a moderate but delayed response, likely due to the intact dormancy mechanisms. Treatment 2 (*hot water soaking*), depicted in red, demonstrated a rapid early germination trend, with a sharp increase observed between days 27 and 37, also peaking at around 6 seeds. This suggests that the treatment effectively softened the seed coat, promoting synchronized germination. Treatment 3 (*cold water soaking*), shown in blue, followed a pattern like the control group, with a slow and steady accumulation of germinated seeds, peaking at around 4 seeds by day 37, and gradually declining thereafter. Treatment 4 (*scarification*), highlighted in yellow, displayed an inconsistent germination pattern, with a sudden rise in germination on day 27 (3 germinants) followed by a decline and minimal additional germination until day 41. The erratic trend may be attributed to seed coat damage or environmental exposure, resulting in susceptibility to pest infestation and unfavorable conditions.

Therefore, the graph reveals that Treatment 2 (*hot water soaking*) not only achieved a high germination percentage but also promoted relatively uniform and sustained germination, making it the most promising method for Pili seed propagation. In contrast, although Treatment 4 (*scarification*) induced early germination, its irregular and declining trend indicates limited viability for large-scale application without improved posttreatment protection.

Moreover, Treatment 2 (*hot water soaking*) exhibited the highest mean germinative capacity at 83%, significantly outperforming the other treatments. Both Treatment 1 (*control*) and Treatment 3 (*cold water soaking*) followed with 46% and 38%, respectively. Meanwhile, Treatment 4 (*scarification*) resulted in the lowest germinative capacity at 25%. Upon dissection, a substantial proportion of scarified seeds were found to be rotten, suggesting that physical damage and subsequent microbial decay hindered their development. These findings highlighted the efficacy of hot water soaking in breaking dormancy and maximizing seed viability in Pili. Supporting this result, Spadoni et al. (2014) demonstrated that hot water treatment at 80°C for 5 minutes was the most effective pre-germination method for *Bentinckia condapanna*, among 13 treatments tested. Similarly, Paquit et al. (2024) reported that *Flemingia falcata* seeds subjected to hot water pretreatment at 80°C achieved 60–70% germination, far surpassing untreated seeds. In both studies, the treatment effectively softened the seed coat, promoting water uptake and facilitating embryo growth.

However, the result of this study is in contrast with several findings. For instance, Uttam Thangjam and Sahoo (2017) observed that cold water soaking yielded the highest germination percentage (72%) in *Parkia timoriana*, outperforming boiling water treatments (58.33%). Similarly, Fredrick et al. (2017) reported that manual nicking achieved the highest cumulative germination percentage (69.67%) in *Faidherbia albida*, whereas hot water soaking yielded the lowest rate (23.17%). Additionally, Mahajan et al. (2023) found that mechanical scarification significantly enhanced germination in *Gloriosa superba* (80%), followed by cold soaking for 24 hours.

In the present study, the performance of Treatment 4 (*scarification*) may be attributed to the

Table 2. Influence of different pre-germination treatments on percent survival, percentage germination, percentage germinative energy, and percentage germinative capacity of *Canarium ovatum.*

Treatments	PS	PG	PGE	PGC
T_1: Untreated	30.59^{c}	40^{b}	30.64^{c}	46^{b}
T_2: Hot water soaking	60.00^{a}	75^{a}	41.00^{a}	83^{a}
T_3: Cold water soaking	32.00^{b}	35^{c}	32.00^{b}	38^{c}
T_4: Scarification	20.00^{d}	20^{d}	18.00^{d}	25^{d}
Mean	35.50	42	30.25	48
S.Em. (±)	0.3791	1.34	0.7370	0.3570
C.D. at 5 %	7.43	11.75	6.49	6.99
C.V. (%)	15.10	19.87	15.41	10.52

Values with similar alphabets within a column are not significantly different. *S.Em: Standard Error of mean, C.D.: Critical Difference, C.V.: Coefficient of Variation

susceptibility of the exposed seed interior to microbial infection and ant predation, which were reportedly triggered by the fragrant and appetizing scent of damaged Pili seeds (Fernandes et al., 2018). This exposure led to water saturation, tissue decay, and ultimately, seed failure. In conclusion, hot water soaking proved to be the most effective pre-germination treatment in enhancing the overall germinative capacity of Pili seeds. Conversely, scarification resulted in substantial seed loss, underlining the need for cautious application and possible protective measures if such a method is to be utilized.

CONCLUSION

Based on the findings, among the four-pre-germination treatments, Treatment 2 (hot water soaking) resulted in higher percent survival (60%), higher germination rate (75%), higher germination energy (41%) and higher mean germinative capacity (83%). In contrast, Treatment 4 (scarification) proved ineffective, as it did not enhance survival, germination rate, germination energy, or germinative capacity. Therefore, hot water soaking treatment (at 100°C for 15 seconds) is recommended as the most effective and reliable pre-germination technique for Pili seeds. Further research and investigation of other pre-germination is needed to find other suitable pre-germination treatment for Pili.

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