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RESEARCH ARTICLE
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Effect of Scarification Treatments on Germination and Early Seedling Growth of (*Bauhinia variegata* L.)

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ABSTRACT

This study was conducted in the wooded shade of the Faculty of Agriculture/Department of Forestry Sciences in the second week of March 2025 with the aim of determining the best method for treating the dormancy of Seed caused by seed coat impermeability represents a major constraint in the propagation of Bauhinia variegata L. This study aimed to evaluate the effectiveness of different dormancy-breaking treatments on germination and early seedling growth. The experiment was conducted in March 2025 at the Faculty of Agriculture, Department of Forestry Sciences. Seeds were subjected to three scarification treatments (hot water, sulfuric acid, and mechanical scarification) in addition to an untreated control under a completely randomized design.

Statistical analysis revealed significant differences among treatments in germination percentage, mean germination time, and seedling vigor traits. Sulfuric acid scarification (15 min) produced the highest germination rate and the shortest germination time, as well as superior seedling growth indicators, including stem length, root length, and dry biomass. Mechanical scarification ranked second in effectiveness and represents a practical alternative for nursery conditions where chemical treatments may be limited. Hot water treatment showed moderate improvement compared with the control.

These findings indicate that dormancy-breaking treatments are essential for improving B. variegate L. seed propagation, with sulfuric acid scarification being the most efficient method under the conditions of this study.

***Keywords*:** seed dormancy, germination, scarification, sulfuric acid, Bauhinia variegate.

INTRODUCTION

Bauhinia sp trees, including *Bauhinia variegata*, are among the most important tropical and subtropical forest trees used in urban and public park afforestation due to their high aesthetic and environmental value, rapid growth, and ability to adapt to a wide range of environmental conditions **[1].**The taxonomic and environmental entry published in the CABI database refers to the agricultural and environmental importance of this species and its widespread use in urban afforestation programs **[2]**.

The growing scientific interest in this species is not limited to its uses in urban afforestation, but extends to its physiological, chemical, and adaptive characteristics, as confirmed by recent reviews of its diverse biological characteristics **[3,4,5,6].**

Despite the practical importance of *B. variegate* L. , its propagation by seed faces challenges related to low and uneven germination rates, which are often associated with seed dormancy due to the hardness of the seed coat **[7, 8].** This phenomenon is common in many species of the genus Bauhinia sp., where the seed coat is characterized by thick, woody layers that limit water absorption, delaying the onset of the metabolic processes necessary for germination. Applied studies on Bauhinia species have shown that breaking dormancy requires effective pretreatments to improve water permeability and stimulate germination**[9,10]**.

A recent study on the effect of environmental factors on the germination and growth of *B. variegate* L. , seedlings and related species showed that temperature, planting depth, and seed size significantly affect the germination rate and speed, indicating the sensitivity of this species to the physical conditions surrounding the seed **[11,12,13].** The importance of these results is highlighted by the fact that they indicate that successful germination depends not only on environmental factors related to planting, but also on the physical condition of the seed itself and its readiness to absorb water and begin embryonic growth **[14,15].**

As recent physiological studies on *B. variegate* L. , have shown, the developmental responses of this species are significantly influenced by biotic and environmental factors, reflecting the role of metabolic processes in determining seedling vigor and initial growth rate**[16].**

This confirms that improving germination rates is not limited to increasing the number of germinated seeds, but extends to improving the quality of the resulting seedlings . In light of the above, recent studies confirm the urgent need to develop precise propagation protocols based on a comprehensive physiological understanding of the behavior of *B. variegata* seeds **[17,18].**

The integration of the results of environmental, physiological, and applied studies allows for the construction of a scientific framework that explains the response of seeds to different dormancy-breaking treatments and contributes to increasing the efficiency of seedling production in nurseries and sustainable afforestation programs**[19].** Therefore, this study focuses on evaluating the effect of dormancy-breaking treatments on the germination and growth of *B. variegata* seeds based on recent scientific background that has highlighted the importance of physical and environmental factors in improving the germination performance of this species**[20]**. Based on the above, there is a need for a systematic comparative study of the effect of different dormancy-breaking treatments (hot water, sulfuric acid, and mechanical scarification) on the germination and growth of Bauhinia seedlings, with the aim of improving seedling production and increasing the efficiency of afforestation programs**[21]**. This study seeks to fill this knowledge gap by evaluating the physiological and germination response of Bauhinia seeds under different treatments, leading to practical recommendations that can be applied in nurseries and sustainable propagation programs**[22,23,24].**

Materials and methods

1- Source of samples

Seeds were collected in late May and late June from mature pods in the verbalization stage before they opened from *B. variegata* trees from different locations in Kirkuk province, as they are adapted to the province's environment. The seeds were transported to the laboratory in paper bags and dried at a shade temperature (20–25°C) for 3–7 days before temporary storage**[12,21].**

2- Examination of seed viability and initial characteristics

A preliminary examination of moisture content, seed mass, and morphological description of the seed coat was conducted according to descriptive criteria (random samples: 100 seeds). Also, examine and estimate the germination viability of the samples before planting, and record the seed dimensions (length, width) and coat thickness according to the seeds (n = 30) in micrometers for later use in interpreting differences in response to treatments**[12,20].**

3- Experimental design and treatments

A completely randomized design (CRD) with four treatments and replicates (4 replicates per treatment) was used, with each replicate containing 25 seeds—a total of 400 seeds—based on previous studies on the propagation and germination of the genus Bauhinia**[11].**

The treatments were as follows:

T0: Control (no treatment)

T1: Hot-water scarification. This is commonly used in studies of Pohonia and hard-shelled forest tree seeds, where hot water at 90°C is poured over the seeds, which are then left to cool and soak in the resulting water at room temperature for 20–24 hours before planting **[21,5]**.

T2: Mechanical scarification using fine sandpaper (180–240 grit) on one side of the seed until the tissue color appears without exposing the embryo, followed by brief soaking (1–2 hours) in water before planting to facilitate water absorption (similar techniques have been reported in mechanical studies on similar seeds**[4,20].**

T3: Chemical treatment (acid scarification) with concentrated sulfuric acid H_2SO_4 (98%). The seeds are exposed to concentrated acid for 10–15 minutes and then washed thoroughly under running water for several minutes until the acid is removed. For safe and effective use, it is recommended to start with 15 minutes, depending on the apparent thickness of the coat, which has been shown to be effective in experiments on Bauhinia species**[22,2,7].**

4- Growing medium and germination conditions

Seeds were sown in sterile plastic pots or containing a sterile medium of vermiculite/peat moss (1:1, volumetric) as used in previous studies on the germination of *B. variegata* L. seeds to ensure adequate drainage and balanced moisture retention**[11]**.

The pots were kept in a growth chamber at a temperature of (28 ± 3) °C with light hours ranging from 10/12 hours and controlled relative humidity (50–70)%, in accordance with ISTA recommendations for germination tests for forest species **[22,21].**

5- Measurement traits and data recording

Final Germination Percentage (GP, %): number of germinated seeds/total seeds × 100 after 30 days or until results stabilize.

Mean germination time (MGT): calculated using the standard equation.
Germination Index (GI) and Seedling Vigor Index (SVI) were calculated based on study **[11].**
After 32-40 days of germination, seedling characteristics were measured: stem length (cm), root length (cm), fresh weight and dry weight (g) after drying at 70°C until weight stabilization. These measurements are used to assess seedling quality, as in studies of the growth of newly grown Bauhinia seedlings**[23].**

Results and Discussion

The results of this study showed that *B. variegate* L. seeds undergo clear physical dormancy related to seed coat characteristics, where the application of dormancy-breaking treatments led to significant increases in germination rates and clear improvements in early growth indicators**[14,21,22]**. The very high value of the F coefficient for germination rate ($F = 637.71$) supports the conclusion that the main determinant of germination in this species is seed coat impermeability, rather than random variation between replicates**[14].** as indicated by the results in Table**[22,8]**.

Table 1: Indicators of seedling vigor

Treatment	Stem length (cm)	Root length (cm)	Dry weight (g)
T0	6.2	5.8	0.45
T1	9.1	8.4	0.78
T2	10.8	9.9	1.05
T3	12.4	11.6	1.25

This interpretation is consistent with that of Yadav et al **[11]**. who explained that the germination response of Bauhinia species is strongly influenced by the characteristics of the seed coat, and that any physical or environmental modification that increases its permeability leads to a marked improvement in the germination rate and speed**[2,7].**
The clear superiority of the sulfuric acid treatment can be explained anatomically by the fact that the acid weakens the palisade layer that forms the seed coat, allowing for increased water permeability and rapid and uniform imbibition**[12]**. As in Figure (1)

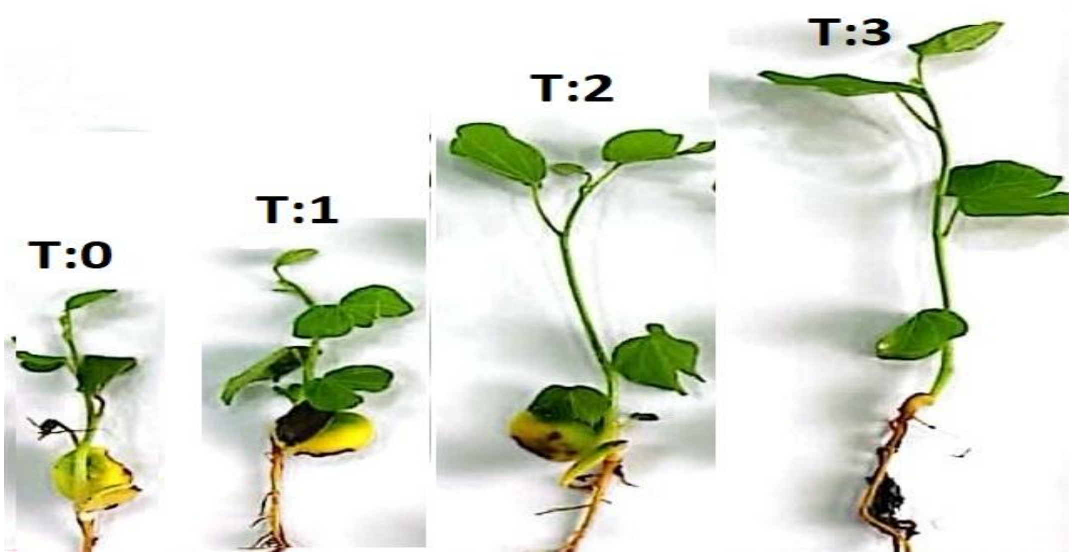

Figure 1. Seedling growth of *B. variegata* under scarification treatments.

A study by Jeromini et al. (2021) showed that the morphological structure of Bauhinia seeds includes dense layers of palisade cells that form a mechanical barrier to water entry, which explains the strong response to chemical treatment**[12,9].**

The results regarding the reduction in average germination time ($p = 0.0078$) support the hypothesis that removing the physical barrier contributes to accelerating internal physiological processes**[19,24].** as shown in Table 2.

Table 2: Germination rates according to treatments

Treatment	Description	Germination (%) Mean ± SD	Tukey Group (α = 0.05)
T3	Sulfuric acid scarification	90.0 ± 0.82	A
T2	Mechanical scarification	77.0 ± 2.58	B
T1	Hot water treatment	62.0 ± 1.83	C
T0	Control (untreated)	35.0 ± 1.83	D

Once water absorption is complete, mitochondrial activity is reactivated, respiration increases, and enzymes that break down storage materials (such as amylase and protease) begin to work, accelerating root emergence **[5,13].** Physiological studies on the behavior of ***Bauhinia malabarica*** seeds have confirmed that improving the permeability of the coat is directly related to accelerating the emergence of seedlings and increasing their uniformity, according to**[7,23].**

Mechanical treatment has shown high effectiveness, but less than acid treatment, which can be explained by the fact that localized scratching may not be uniform among all seeds, leading to relative variability in water absorption speed **[17].** However, its high efficiency confirms that breaking the physical barrier, even if localized, is sufficient to stimulate germination in a large proportion of seeds, making it a practical option in nurseries that lack acid treatment equipment **[10,13].**

With regard to hot water treatment, the relative improvement compared to the control suggests that thermal expansion may have caused micro cracks in the coat, but the failure of other treatments to achieve germination efficiency indicates that the thickness of the coat in this species requires more profound treatment to induce effective structural changes in the seed coat **[14,21]**.

This suggests that seed response may vary depending on their anatomical characteristics, which is consistent with data in the CABI database on the environmental and agronomic characteristics of *B. variegata*. It is important to note that the significant improvement in seedling length (F = 325.96) reflects the close relationship between dormancy breaking efficiency and subsequent growth quality**[9]**. Seeds that started germinating early had a longer growth period within the time frame of the experiment, which led to an increase in length and biomass, as shown in Table (3) .

Table (3) Effects on Germination and Seedling Performance

Treatment	Germination (%) Mean ± SD	MGT (days) Mean ± SD	Seedling Length (cm) Mean ± SD	Overall Rank
T3 – H_2SO_4	90.0 ± 0.82 (a)	29.5 ± 1.29 (c)	9.78 ± 0.17 (a)	1
T2 – Mechanical	77.0 ± 2.58 (b)	31.5 ± 1.29 (bc)	8.38 ± 0.22 (b)	2
T1 – Hot Water	62.0 ± 1.83 (c)	33.3 ± 2.63 (b)	6.70 ± 0.30 (c)	3
T0 – Control	35.0 ± 1.83 (d)	37.3 ± 3.86 (a)	3.50 ± 0.41 (d)	4

Furthermore, uniformity at the onset of germination reduces competition between seedlings and promotes a more efficient distribution of resources, as demonstrated by a study by **[22,23].** On the growth response of *Bauhinia variegata* L. to different agricultural treatments. Based on this, scientific sources confirm that physical dormancy in the genus Bauhinia represents an environmental adaptation mechanism, but it poses a practical challenge in propagation programs**[8]**.

The results of this study indicate that chemical treatment with sulfuric acid is more effective in breaking dormancy, while mechanical treatment is a suitable alternative, with the need to take into account environmental and occupational safety aspects **[10,13,22].** As in Figure (2)

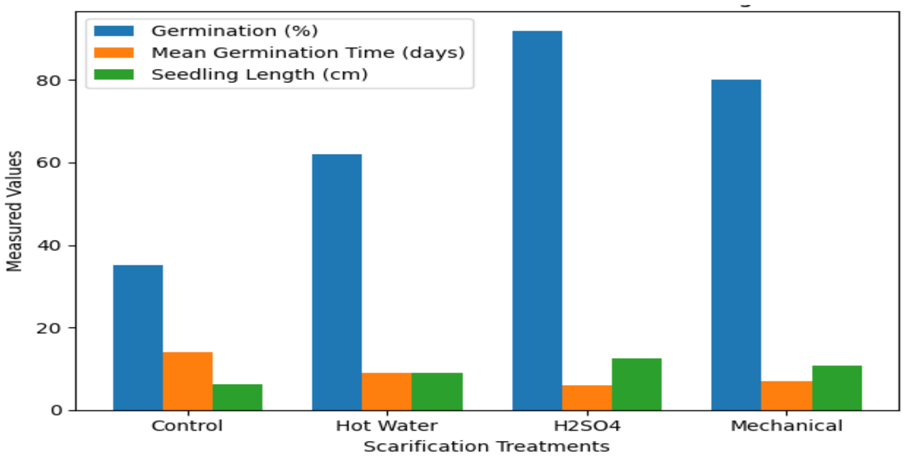

Figure 2. Germination and seedling response of *B. variegata* to scarification.

Overall, these results confirm that careful control of seed coat characteristics is key to improving seedling production in urban afforestation and environmental rehabilitation programs, and that the development of standardized protocols for breaking dormancy can increase seedling production efficiency by improving germination rates and reducing losses in nurseries**[18,20,21].** As in Figure (3)

Figure 3. Post-germination growth performance of *B. variegata* under nursery conditions.

Conclusion

The results of this study validate the fact that eed dormancy in *B. variegata* L. is primarily physical and governed by seed coat impermeability. Significant treatment effects confirm that dormancy-breaking interventions are essential to improve germination performance and early seedling growth. Sulfuric acid scarification (15 minutes) was the most effective treatment, markedly increasing germination percentage, reducing mean germination time, and enhancing seedling vigor. Mechanical scarification also improved germination substantially and offers a practical alternative for nursery applications, whereas hot water treatment showed limited effectiveness.

Effective disruption of the seed coat accelerates water uptake and metabolic activation, leading to improved seedling uniformity and quality. Optimized scarification protocols are therefore critical for reliable propagation and large-scale afforestation programs.

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تأثير معاملات كسر السكون في إنبات ونمو بادرات *Bauhinia variegata* L.

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الخلاصة

اجريت هذه الدراسة في الظلة الخشبية التابع لكلية الزراعة / قسم علوم الغابات في الاسبوع الثاني من شهر مارس للعام 2025 بهدف تحديد افضل طريقة لمعالجة سكون بذور اشجار خف الجمل (البوهينيا ***Bauhinia variegate L***) التي تعاني من طور سكون فيزيائي ناتج عن صلابة وعدم نفاذية غلاف البذرة، مما يؤدي إلى انخفاض نسبة الإنبات وتأخره في حال عدم إجراء معاملات تمهيدية لكسر السكون. وقد أثبتت نتائج التحليل الإحصائي وجود فروق معنوية واضحة بين معاملات كسر السكون المدروسة في جميع مؤشرات الإنبات والنمو.

أظهرت المعاملة بحامض الكبريتيك المركز لمدة 15 دقيقة أعلى نسبة إنبات وأقل متوسط زمن للإنبات، إضافةً إلى تفوقها في مؤشرات قوة البادرة (طول الساق، طول الجذر، الوزن الجاف)، مما يدل على كفاءتها العالية في تحسين نفاذية الغلاف البذري وتسريع العمليات الفسيولوجية المرتبطة ببدء الإنبات. وجاءت معاملة الخدش الميكانيكي في المرتبة الثانية من حيث الفاعلية، مع تحقيق تحسن ملحوظ مقارنة بالشاهد، مما يجعلها خيارًا عمليًا وآمنًا في البيئات التي تتطلب تقليل المخاطر الكيميائية. أما معاملة الماء الحار فقد حسّنت نسبة الإنبات مقارنة بالشاهد، لكنها كانت أقل كفاءة من المعاملتين الأخريين.

بناءً على ذلك، تعد معاملات كسر السكون خطوة مهمة في رفع كفاءة إكثار البوهينيا بالبذور، وأن المعاملة الكيميائية بحامض الكبريتيك تمثل الخيار الأكثر فاعلية في الظروف المدروسة، مع إمكانية اعتماد الخدش الميكانيكي كبديل مناسب لإنتاج الشتلات على نطاق واسع.

الكلمات المفتاحية: كسر السكون، الإنبات، الخدش، حامض الكبريتيك، Bauhinia sp.