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Seed Scarification Improves Viability and Vigour of *Mucuna bracteata* Seedlings

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ABSTRACT

Generative propagation of *Mucuna bracteata* is hindered by its thick seed coat, which causes seed dormancy. This study aimed at evaluating viability and vigor of *M. bracteata* due to pre-treatments. A completely randomized design was used to test four pre-treatments: no treatment (Kon), soaking in warm water (50°C) for 2 hours (AHA), soaking in plain water for 24 hours (ABI), and scarification on cotyledon side (DLU). Variables measured were germination percentage, maximum growth potential (MGP), germination rate, vigor index (VI), uniformity of germination (UG), and growth speed (GS). Germination percentage and MGP data were analyzed using descriptive statistics, while germination rate, VI, UG, and GS data were analyzed using analysis of variance. The results showed that pre-treatment of *M. bracteata* seeds increased germination percentage, reaching 98.66% on day 3, and MGP reached 98.0%. Likewise, there was a highly significant increase ($p<0.001$) in germination rate (7–11 days), VI (15.99–91.99%), UG (18.66–97.33%), and GS (14.33–25.83%/day). The highest scores for all variables were found in DLU treatment. It is concluded that soaking seeds in warm water, plain water, or scarifying the seed coat improves viability and vigor of *M. bracteata* seeds, with DLU being the best technique.

Keywords: dormancy, *Mucuna bracteata*, seed viability, seedling vigor

INTRODUCTION

Mucuna bracteata is an important vining legume widely utilized in agriculture and livestock production systems. In agriculture, *M. bracteata* is used as a cover crop to prevent soil erosion, reduce evaporation, maintain soil moisture, suppress weed growth, improve soil fertility through its nitrogen-fixing ability and high organic biomass production, as well as enhance nutrient cycling efficiency (Sitanggang *et al.* 2020; Syarovy *et al.* 2021). In livestock farming, *M. bracteata* serves as a potential source of forage due to its high productivity and quality. Wahyuni (2019) reported that the dry biomass yield of *M. bracteata* in dryland humid climates ranged between 12.7 and 13.09 tons/ha/year. The leaf protein content ranges from 25.8% to 34.5%, with crude protein values averaging 11.14% to 18.37%, depending on harvest age (Wahyuni 2019; Darmin *et al.* 2024). The use of *M. bracteata as* feed for cattle (Hanum 2023) and goats (Sirait *et al.* 2009) has also shown positive responses in animal production.

M. bracteata can be propagated both generatively and vegetatively. However, the main constraint in generative propagation is its relatively thick seed coat, which restricts water absorption, thereby inducing seed dormancy (De Lima 2012). The thickness and impermeability of the seed coat influence the timing and success of germination (Ariyanti *et al.* 2017). Therefore, treatments that enhance water absorption through the seed coat are expected to accelerate the germination process of *M. bracteata*. Scarification is one such method, as it increases seed permeability to water and gases, thereby facilitating embryo growth and improving germination percentage (Panggabean 2021). Scarification techniques are generally classified into mechanical and chemical methods (Hastuti *et al.* 2023). Several studies (Astari *et al.* 2014; Imbiri *et al.* 2022; Fefirenta *et al.* 2023) reported that the germination rate of untreated *M. bracteata* seeds was very low, ranging between 0.5% and 38.7%, compared with scarified seeds, which reached up to 98.4% (Hastuti *et al.* 2023). Nevertheless, these previous studies present certain limitations, as scarification techniques were either evaluated individually or compared only partially, and the germination media commonly used were cotton, paper, or sterilized substrates. In light of these limitations, the present study was designed to evaluate the viability and vigor of *M. bracteata* seeds subjected to different scarification techniques and germinated directly in natural media without prior sterilization or treatment of the substrate.

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METHODS

Experimental Design

This experiment was conducted over a 21-day period (5–26 September 2025) in the germination house at the Field Laboratory of the Faculty of Animal Husbandry, Marine and Fisheries Sciences, Nusa Cendana University. The experimental design employed was a Completely Randomized Design consisting of four treatments and five replications, with 15 seeds/replicate, resulting in a total of 75 seeds/treatment. The four treatments were as follows: no scarification (KON), soaking in warm water at 50℃ for 2 hours (AHA), soaking in tap water at room temperature for 24 hours (ABI), and mechanical scarification by incising the seed coat (DLU) with a cutter at the point farthest from the embryo growth axis.

Research Procedure

M. bracteata seeds were self-produced from the researcher’s experimental garden. Seeds were harvested from the same mother plant and selected for uniformity in shape and size. Loamy soil was collected from the same location and used as growth media, placed in polybags of 20 × 25 cm. The soil was not subjected to any pretreatment. Once filled, the polybags were arranged into groups of 15 according to the number of replications. Treated seeds were randomly assigned and sown into the soil medium at a depth of approximately one finger joint (one seed per polybag) and subsequently covered with soil. Following sowing, the polybag groups (replications) were randomly arranged under shaded conditions. Watering was performed daily in the morning with 1 liter of clean water per polybag. Observations were carried out every morning at 08:00 for 21 consecutive days.

Observed Variables and Measurement Procedures

The number of germinated seeds was recorded daily and served as the basis for calculating other germination variables. Germination percentage (GP) and maximum growth potential (MGP) were calculated according to the formulas proposed by Tefa (2017). Germination rate was calculated using the equation described by Winarni *et al.* (2017). Vigor index was determined by calculating the percentage of normal seedlings in the first count, conducted on day 5 after sowing, following ISTA (2010) guidelines. Seedling uniformity was measured as the percentage of strong normal seedlings on the fifth day after sowing, following the formula of Saputra *et al.* (2020). Growth speed was calculated based on the number of normal seedlings emerging per 24-hour interval, using the formula proposed by Sutopo (2012).

Data Analysis

Data on germination percentage and maximum growth potential were analyzed using descriptive statistics, while data on germination rate, vigor index, seedling uniformity, and growth speed were subjected to analysis of variance to test treatment effects at a significance level of α = 0.05. Significant differences among treatments were further examined using Duncan’s Multiple Range Test. Statistical analyses were performed using SPSS version 27.

RESULTS AND DISCUSSION

Germination Percentage and Maximum Growth Potential

The germination percentage (GP) of *M. bracteata* seeds in this study is presented in Figure 1. The data indicate that scarified seeds germinated more rapidly than untreated seeds. On average, 92.0% of seeds subjected to mechanical scarification by cutting the seed coat (DLU) had germinated by day four, whereas seeds from the other treatments, including non-scarified seeds, had not yet germinated (0%). Germination in KON, AHA, and ABI treatments was first observed on day five, ranging between 12.0% and 32.0%, while the DLU treatment had already reached 97.3%.

In non-scarified (KON) and soaking treatments (AHA and ABI), germination exceeded 70% only after day 15. In contrast, seeds in the DLU treatment reached peak germination as early as day six (Figure 1). By the end of the 21-day observation period, the highest germination percentage was recorded in the DLU treatment (98.7%), compared with only 77.3%–80.0% in the KON, AHA, and ABI treatments.

Seed scarification accelerated germination and improved germination percentage, as it enhanced seed imbibition, thereby facilitating a more effective mobilization of food reserves during germination. Water plays a key role in this process by softening the seed coat, diluting the protoplasm, and enabling the transport of nutrients and oxygen. Oxidation reactions occurring during germination require oxygen for energy production, and the presence of water (H_2O) functions as an oxygen donor, thereby initiating the germination process (Mulyani *et al.* 2018).

The low germination percentage observed in non-scarified seeds (KON) was attributed to the thick seed coat, which hindered water absorption. This finding is consistent with Bramasto *et al.* (2015), who reported that seed coat thickness and impermeability adversely affect germination by restricting imbibition. The swelling of the seed coat following soaking in warm water (AHA) or tap water (ABI) was assumed to promote imbibition of both water and oxygen into the seed. Water absorption, driven by matric potential, contributes to restoring membrane and organelle structure (Fua *et al.* 2025), thereby triggering physiological and biochemical processes of growth, including metabolic activity, cell division, and cell enlargement (Godínez-Álvarez *et al.* 2012).

Nevertheless, the present findings demonstrate that mechanical scarification by cutting the seed coat (DLU) allowed direct penetration of water and oxygen into the seed, resulting in faster initiation of physiological and biochemical processes (Lestari *et al.* 2020). As a result, the germination percentage of scarified seeds reached 92.0% by day 4, compared with only 16–22% for water-soaking treatments (AHA and ABI) and 0% for non-scarified seeds (KON). Similarly, Arceo-Gómez *et al.* (2022), who investigated pre-germinative treatments in Enterolobium cyclocarpum and Piscidia piscipula (Fabaceae), reported that hot-water soaking produced a germination rate of 76.0%, whereas mechanical scarification achieved higher germination at 92.0%.

Maximum growth potential (MGP) reflects the ability of seeds to germinate and grow to their full capacity. The percentage of MGP is closely related to germination percentage, as it represents the proportion of seeds that successfully break dormancy and show signs of viability, either as normal or abnormal seedlings. Data presented in Figure 2 indicate that the highest MGP was achieved in mechanically scarified seeds (DLU), at 98.66%, compared with only 77.33% in seeds subjected to hot-water soaking (AHA).

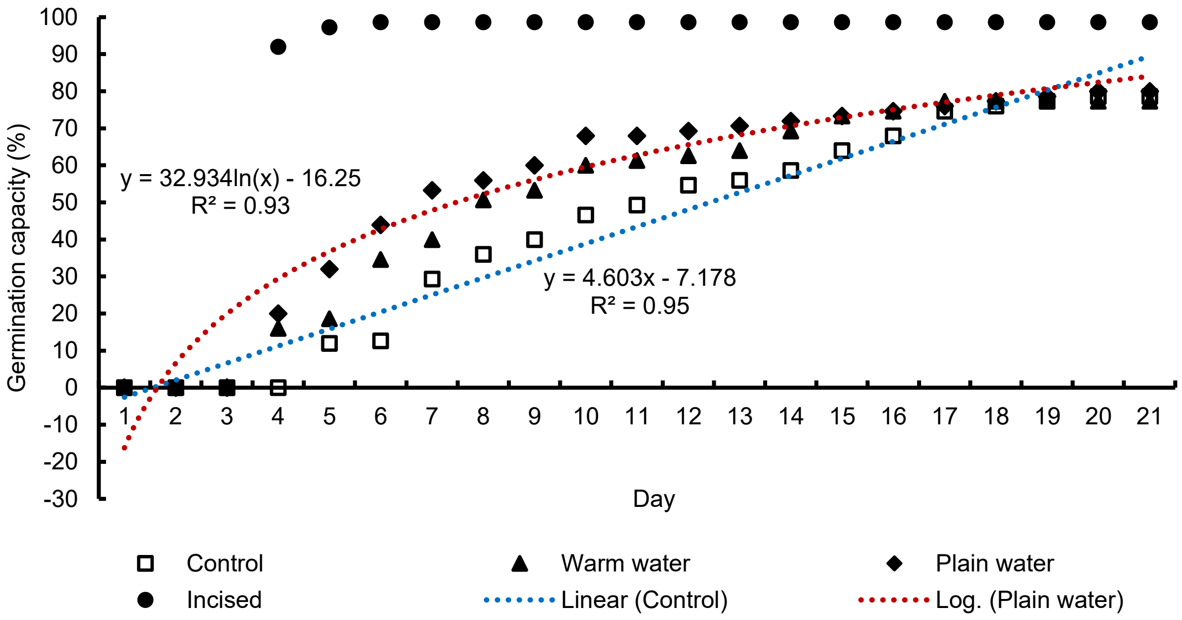

Figure 1 Effect of seed scarification techniques on the germination of *Mucuna bracteata* seeds.

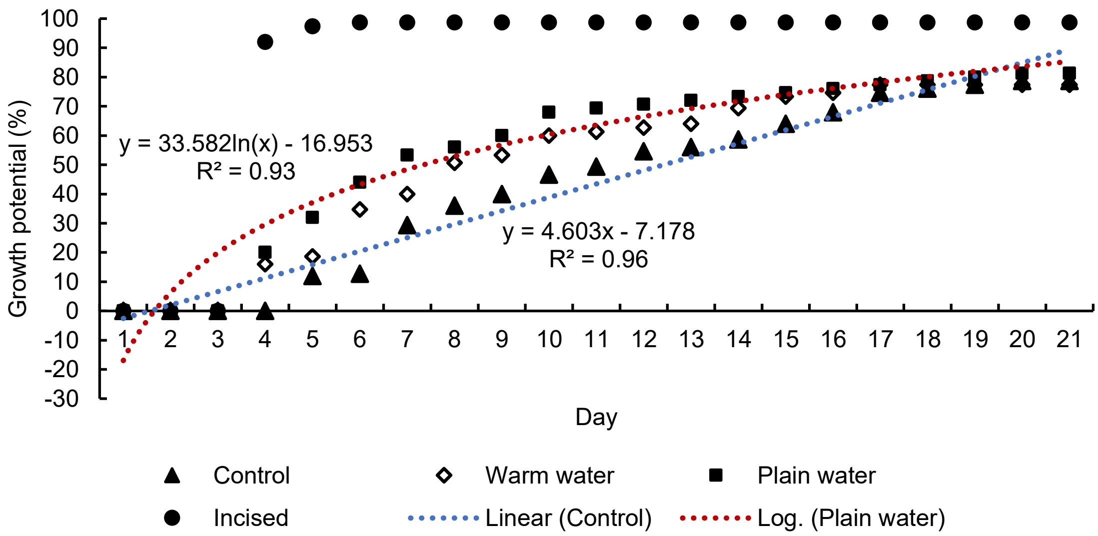

Figure 2 Effect of seed scarification on the maximum growth potential of *Mucuna bracteata* seeds.

Analysis of the germination trend depicted in Figure 1 confirmed that the degree of seed coat disruption correlated strongly with seed germination. Three distinct trends were observed in the figure. The first was a surge-and-plateau trend shown by the DLU group. Incision of the seed coat allowed free access of water and oxygen into the seed, thereby stimulating metabolic processes and resulting in a more synchronized germination pattern. The second trend was a quadratic pattern observed in seeds soaked in warm water (AHA) and plain water (ABI). There was a lag time of five days, followed by a moderate rate of germination (4.6% per day) until it reached a peak on day 10, after which it began to decline. This trend suggested that the seed coat had swollen and softened due to water absorption, facilitating a moderate rate of water and oxygen imbibition. The third trend was a linear pattern shown by the control group, clearly demonstrating that allowing *M. bracteata* seeds to germinate naturally not only delayed germination but also resulted in a slower rate and a lower final germination percentage (64%).

The high MGP value observed in scarified seeds (98.6%) was attributed to the successful removal of the physical barrier posed by the thick seed coat, which otherwise restricts imbibition. Physiologically, all seeds in this study were expected to possess homogeneous growth potential, as they were harvested simultaneously from the same mother plant and carefully sorted prior to use. However, mechanical scarification enhanced the infiltration of water and oxygen into the seeds, thereby efficiently activating the physiological and metabolic processes of germination (Hamdiah *et al.* 2022). Nelson (2015) demonstrated that radio-frequency dielectric heating treatment at 39 MHz, with 5.8% moisture content and an initial temperature of 24℃, applied at an electric field intensity of 2.4 kV/cm for 4.8 minutes to alfalfa seed, rendered the seed coat, hence improved growth potential by 68%.

In contrast, the relatively low MGP observed in non-scarified seeds (78.7%), warmwater soaked seeds (77.3%), and room-temperature soaked seeds (81.3%) was most likely due to restricted infiltration of water and oxygen through the seed coat, which acted as a limiting factor for germination and growth. This rationale aligns with the conclusions drawn by Šerá and Hnilička (2023), who emphasized the significant influence of dormancy, water, and oxygen on germination and seedling development. The lower MGP observed in the warm-water soaking treatment (AHA) compared with other treatments may also be attributed to temperature effects. Supporting evidence was reported by Moro *et al.* (2020), who found that heat treatment in woody plant seeds resulted in an average MGP of only 77.6%. Analysis of the MGP trend depicted in Figure 2 showed a similar pattern to the seed germination rate and percentage presented in Figure 1. Therefore, the interpretation was consistent with the arguments discussed in the previous section.

Seed Vigor

Seed vigor encompasses a set of characteristics that describe the ability of seeds to produce normal, rapid, and uniform seedlings under both optimal and suboptimal growing conditions (Singh *et al.* 2024). In this experiment, three vigor parameters were evaluated: vigor index, growth rate, and seedling uniformity.

The vigor index (VI) represents the percentage of normal seedlings observed at the first count. When the first evaluation was conducted on day 5, germination in the control group (KON) had not yet commenced (0%). Therefore, the VI calculation was performed on day 5, when all treatments had shown visible germination. Data presented in Table 1 indicate that the highest VI was recorded in the mechanically scarified group (DLU), at 97.33%. Statistical analysis confirmed that this value was significantly higher than the three other treatments. Soaking in tap water (ABI) also produced a VI significantly different from the control (KON) and warm-water soaking (AHA), although its value was only 31.99%. No significant difference was detected between KON and AHA treatments based on Duncan's test.

As with MGP, the trend observed in VI was strongly influenced by water and oxygen availability. This supports the assertion of Choirunnisa *et al.* (2021) that deficiencies in water, oxygen, and nutrients negatively affect physiological processes such as chlorophyll content, nitrate reductase activity, and photosynthetic rate, ultimately reducing assimilate production for root growth and other plant organ development.

Statistical analysis revealed that seed scarification had a highly significant effect (p < 0.01) on the vigor index (VI) of *M. bracteata* seeds (Table 1). This finding indicates that scarification accelerated germination, increased germination percentage, and consequently improved VI values. Seeds subjected to scarification exhibited superior early growth because the softened

Table 1 Vigor value of *Muccuna bracteata* seedling as results of seed scarification techniques

Variables	Treatment				SEM	*p-value*
	KON	AHA	ABI	DLU		
Vigor index (%) day-4	0.00^{a}	15.99^{b}	16.66^{b}	91.99^{c}	3.96	0.001
Vigor index (%) day-5	11.99^{a}	18.66^{ab}	31.99^{b}	97.33^{c}	4.69	0.001
Seedlings uniformity (%)	11.99^{a}	18.66^{ab}	28.33^{b}	97.33^{c}	4.59	0.001
Growth rate (%/*etmal*)	12.11^{a}	14.33^{ab}	15.26^{b}	25.83^{c}	1.06	0.001

Notes: The same Superscript in the same row indicate a highly significant effects (p<0,01). KON = No scarificatio; AHA = soake in warm water at 50℃ for 2 hours; ABI = soaked in plain water for 24 jam; DLU = seeds were incised at growth tip.

or incised seed coat facilitated water and oxygen penetration. This, in turn, promoted enzymatic hydrolysis of food reserves and activated metabolic processes required for germination. Smiderle and Souza (2021) stated that scarification plays a critical role in inducing significant hormonal changes that regulate physiological dormancy, thereby activating seed metabolism and enabling embryo development, which ultimately leads to the production of stronger seedlings.

A VI value exceeding 60% is generally considered to represent high vigor. Based on this criterion, the DLU treatment (mechanical scarification) produced seeds classified as high-vigor, capable of rapid and uniform growth. Scarification not only accelerated germination to four days but also resulted in a high germination percentage (98.66%) and a rapid germination rate (seven days), thereby producing more vigorous seedlings. Similarly, Guariz *et al.* (2023) demonstrated that mechanical scarification produced stronger seedlings with faster germination and emergence.

The VI obtained from the DLU treatment was significantly higher than that of the other three treatments (KON, AHA, ABI), reinforcing the evidence that the thick seed coat of *M. bracteata* acts as a major barrier to germination. Soaking seeds in warm water (AHA) or tap water (ABI) also resulted in significantly higher VI values (15.99–16.66%) than the control (0%). Water soaking caused the seed coat to swell, thereby facilitating partial infiltration of water and oxygen, although not as effectively or rapidly as in scarified seeds. Water contributes to softening of the seed coat, oxygen entry, protoplasm dilution for cellular function, and nutrient transport, all of which enhance germination percentage, speed of germination, and ultimately seed vigor uniformity (De Lima 2012).

Low-vigor seeds negatively affect both viability and explant responsiveness for efficient shoot regeneration (Mangena 2021), which in turn reduces germination speed, increases susceptibility to disease, and results in poor productivity (Anwar *et al.* 2024).

Seedling Uniformity (SUN) and Growth Rate (SGR)

High seedling uniformity (SUN) is indicative of strong seed vigor, as it reflects the ability of seed lots to germinate rapidly, emerge uniformly, and produce normal seedlings under varying field conditions (Lesilolo *et al.* 2013). In this study, SUN of M. *bracteata* ranged from 11.99% (KON) to 97.33% (DLU) (Table 1). Statistical analysis confirmed that the SUN of the DLU treatment differed highly significantly (p<0.01) from the other three treatments, whereas no significant difference was detected between AHA and ABI. Furthermore, the SUN of AHA treatment was not significantly different from the control (KON). Similarly, Hidayat and Marjani (2018) reported that scarified kenaf seeds (*Hibiscus cannabinus* L.) exhibited a SUN of 89%, compared with only 0.5–10% for water-soaked seeds. Both scarification and softening of the seed coat reduce physical barriers to imbibition, thereby facilitating water uptake and mobilization of food reserves for energy production, which triggers germination. Consequently, higher germination speed translates into greater seedling uniformity (Widyawati *et al.* 2009). According to Ningsih *et al.* (2018), SUN values above 70% are considered very good, whereas values below 40% indicate low vigor.

Seedling growth rate (SGR) reflects cell division and elongation processes that result in irreversible increases in plant size over a given time period. Various pre-germination treatments, including soaking in water, scarification, soaking in warm water, and acid scarification (H_2SO_4), have been reported to improve seed quality (Mulyani *et al.* 2018; Master *et al.* 2025). In the present study, SGR of *M. bracteata* seeds ranged from 11.9%/day in the control (KON) to 25.83%/day in the DLU treatment (Table 1). These values are considered good and notably higher than those reported for *Jatropha curcas* (0.15–17.0%/day) by Rahmasyahraini *et al.* (2009).

Statistical analysis revealed that seed scarification significantly affected SGR (p<0.01). Similar trends have been reported by previous studies (Elfianis *et al.* 2019; Kartika *et al.* 2015), showing that scarified seeds consistently exhibit higher growth rates compared to untreated seeds. Silva *et al.* (2020) explained that mechanical scarification enhances imbibition by creating openings in the seed coat, thereby facilitating water entry—a critical first step in the germination process. Seeds with higher growth rates, indicative of greater vigor, are better able to withstand sub-optimal field conditions (Perdana *et al.* 2023; Sari *et al.* 2023).

CONCLUSION

Based on the results of this study, it can be concluded that pre-treatments of *M. bracteata* seeds, either by soaking in warm water, soaking in cold water, or by seed coat incision, effectively enhanced seed viability and vigor. Among these treatments, mechanical scarification of the seed coat was found to be the most effective method.

REFERENCES

Arceo-Gómez TM, Robles-Díaz F, Manrique-Ortega MD, Martínez-Campos AR, Aragón-Gastélum JL, Aguirre-Crespo FJ, Ramírez-Albores JE, Pérez-Suárez M, Robles R, Reyes-Trujeque J. 2022. Pre-germinative treatments and morphophysiological traits in *Enterolobium cyclocarpum* and *Piscidia piscipula* (*Fabaceae*) from the Yucatan Peninsula, Mexico. *Plants*. 11: 2844. https://doi.org/10.3390/plants11212844

Anwar MdP, Akhter M, Aktar S, Kheya SA, Islam AKMM, Yeasmin S, Hasan AK, Rashid MdH. 2024. Relationship between seed priming mediated seedling vigor and yield performance of spring wheat. *Phyton-International Journal of Experimental Botany*. 93(6):1159–1177. https://doi.org/10.32604/phyton.2024.049073.

Ariyanti M, Soleh MA, Maxiselly MA. 2017. Respon pertumbuhan tanaman aren (*Arenga pinnata* Merr.) dengan pemberian pupuk organik dan pupuk anorganik berbeda dosis. *Kultivasi Universitas Padjadjaran.* 16(1)*:* 271–278. https://doi.org/10.24198/kltv.v16i1.11543

Astari RP, Rosmayati, Bayu ES. 2014. Pengaruh pematahan dormansi secara fisik dan kimia terhadap kemampuan berkecambah benih Mucuna (*Mucuna bracteata* D.C). *Jurnal Online Agroekoteknologi.* 2(2)*:* 803–812

Bramasto Y, Wijayanto N, Siregar IZ. 2015. Morfologi, anatomi dan kandungan kimia benih mindi dari berbagai asal benih. *Jurnal Penelitian Ekonomi dan Sosial Kehutanan*. 3(1): 11–23.

Choirunnisa JP, Widiyastuti Y, Sakya AT, Yunus A. 2021. Karakter morfologi akar dan fisiologi *Echinacea purpurea* pada berbagai cekaman salinitas. *Agropross.* 5: 65–74. https://doi.org/10.25047/agropross.2021.207

Darmin V, Mullik ML, Dami Dato TO, Lestari GAY. 2024. Pengaruh umur tanam terhadap produksi hijauan dan rasio daun batang *Mucuna bracteata* di lahan kering iklim kering NTT. In: *Prosiding Seminar Nasional HITPI ke-XIII*, Denpasar 4–5 November 2024.

De Lima D. 2012. Pengaruh waktu perendaman dalam air panas terhadap daya kecambah leguminosa centro (*Centrosema pubescens*) dan siratro (*Macroptilium atropurpureum*). *Agrinimal.* 2(1): 26–29.

Elfianis R, Hartina S, Permanasari I, Handoko J. 2019. Pengaruh skarifikasi dan hormon giberelin (GA3) terhadap daya kecambah dan pertumbuhan bibit palem putri (*Veitchia merillii*). *Jurnal Agroteknologi*. 10(1): 41–48. https://doi.org/10.24014/ja.v10i1.7306

Fefirenta AD, Sunardi, Prawestri AD. 2023. Perkecambahan empat jenis legume cover crop (LCC). *Prosiding Seminar Nasional Biologi (SEMABIO) Gunung Djati Conference Series*. 18: 101–112

Fua D, Wua W, Mustafab G, Yanga Y, Yanga P. 2025. Molecular mechanisms of rice seed germination. *New Crops*. 2: 100051. https://doi.org/10.1016/j.ncrops.2024.100051.

Godinez-Alvarez H, Morin C, Rivera-Aguilar V. 2012. Germination, survival and growth of three vascular plants on biological soil crusts from a Mexican tropical desert. *Plant Biology*. 14(1): 157–162. https://doi.org/10.1111/j.1438-8677.2011.00495.x.

Guariz HR, Shimizu G, Picoli MHS, de Paula JCB. 2023. Can the coloring of internal tissues of amburana-de-cheiro seeds be an indicative of vigor. *Scientia Agraria Paranaensis*. 21(3): 314–318. https://doi.org/10.18188/sap.v21i3.29537.

Hamdiah S, Karas L, Houšková K, Van Damme K, Attorre F, Vahalík P, Habrová H, Lvončík S, Eler K, Maděra P. 2022. Seed viability and potential germination rate of nine endemic boswellia taxa (*Burseraceae*) from Socotra island (Yemen). *Plants*. 11: 1418. https://doi.org/10.3390/plants11111418

Hanum C. 2023. The potential of oil palm plantation byproducts as feed for beef cattle. *IOP Conference Series*: *Earth and Environmental Science*. 1286(1): 012035. https://doi.org/10.1088/1755-1315/1286/1/012035

Hastuti PB, Parwati WDU, Purwanto H, Suparyanto T, Nirwantono R, Pardamean B. 2023. Seed dormancy breaking and germination rate improvement in mucuna (*Mucuna bracteata*) seeds using mechanical and fungicide treatments. *BIO Web of Conferences*. 94(7): 06002. https://doi.org/10.1051/bioconf/20249406002

Hidayat RST, Marjani M. 2018. Teknik pematahan dormansi dua aksesi benih kenaf (*Hibiscus cannabinus* L.) untuk meningkatkan daya berkecambah benih. *Buletin Tanaman Tembakau, Serat dan Minyak Industri*. 10(2): 72–81. https://doi.org/10.21082/btsm.v10n2.2018.72-81

Imbiri AG, Hafsah S, Syamsuddin. 2022. Pengaruh beberapa konsentrasi H2SO4 terhadap pematahan dormansi dan vigor benih mucuna (*Mucuna bracteata*). *Jurnal Ilmiah Mahasiswa Pertanian*. 7(4): 290–295. https://doi.org/10.17969/jimfp.v7i4.22533

[ISTA] International Seed Testing Association. 2010. *Seed Science and Technology: International rules for seed testing*.

Kartika K, Surahman M, Susanti M. 2015. Pematahan dormansi benih kelapa sawit (*Elaeis guineensis* Jacq.) menggunakan KNO3 dan skarifikasi. *Enviagro: Jurnal Pertanian dan Lingkungan*. 8(2): 48–55

Lesilolo MK, Riry J, Matatula EA. 2013. Pengujian viabilitas dan vigor benih beberapa jenis tanaman yang beredar di pasaran Kota Ambon. *Jurnal Agrologia.* 2(1): 1–9. https://doi.org/10.30598/a.v2i1.272

Lestari I, Karno, Sutarno. 2020. Uji viabilitas dan pertumbuhan benih kedelai (*Glycine max*) dengan perlakuan invigorasi menggunakan eSUN rak bawang merah. *Journal of Agro Complex*. 4(2): 116–124.

Mangena P. 2021. Analysis of correlation between seed vigour, germination and multiple shoot induction in soybean (*Glycine max* L. Merr.). *Heliyon*. 7(5–6): e07913. https://doi.org/10.1016/j.heliyon.2021.e07913.

Masters MAM, Abere M, Gasheye D, Asfaw MJ, Ayana DA. 2025. Germination response and seedling growth performance of *Adansonia digitata* L. tree seeds under innocuous pre-treatment techniques for efficient seedling production. *Rhizosphere*. 34: 101110. https://doi.org/10.1016/j.rhisph.2025.101110.

Moro AVI, Bravo SJ, Abdala NR, Borghetti F, Chaib AM, Galetto L. 2021. Heat shock effects on germination and seed survival of five woody species from the Chaco region. *Flora*. 275: 151751. https://doi.org/10.1016/j.flora.2020.151751.

Mulyani C, Syukri, Kurniawan R. 2018. Respon perkecambahan benih kopi (*Coffea sp*.) terhadap skarifikasi dan perendaman dalam air kelapa. *Jurnal Penelitian Agrosamudra*. 5(1): 53–62.

Nelson SO. 2015. *Dielectric Properties of Agricultural Materials and their Applications.* Massachusetts (USA): Academic Press. https://doi.org/10.1016/B978-0-12-802305-1.00005-1

Ningsih NNDR, Raka IGN, Siadi IK, Wirya GNAS. 2018. Pengujian mutu benih pada beberapa jenis tanaman hortikultura yang beredar di Bali. *Jurnal Agroekoteknologi Tropika.* 7(1): 64–72

Panggabean NH. 2021. Pematahan dormansi benih kelapa sawit (*Elaeis guineensis* jacq.) menggunakan metode skarifikasi dan giberelin. *Klorofil: Jurnal Ilmu Biologi dan Terapan.* 4(2): 62–70. https://doi.org/10.30821/kfl:jibt.v4i2.8786

Perdana MA, Moeljani IR, Soedjarwo DP. 2023. Pengaruh masa simpan dan suhu simpan terhadap viabilitas dan vigor benih *coating* kedelai. *Jurnal Agrium*. 20(1): 1–7. https://doi.org/10.29103/agrium.v20i1.10620

Rahmasyahraini A, Qadir, Hartati RRS. 2009. Studi periode pengujian daya berkecambah serta pengaruh perlakuan benih dan jenis media perkecambahan pada benih jarak pagar (*Jatropha curcas* L.). [Tesis]. Bogor (ID): IPB University

Saputra J, Amir RA, Mumin N, Sutariati GAK. 2020. Persistensi dan pematahan dormansi benih cabai rawit lokal menggunakan teknik bio-invigorasi benih. *Jurnal Agrotek Tropika.* 8(2): 391–400. https://doi.org/10.23960/jat.v8i2.3194

Sari VP, Lestari WP, Murtadho AR, Lestari RD. 2023. Analisis pengujian mutu benih secara fisiologis pada tanaman pangan. *Journal Proceeding of HUBISINTEK*. 3(1): 554–561.

Šerá B, Hnilička F. 2023. Genetic and environmental factors affecting seed germination. *Plants*. 12(24): 4106. https://doi.org/10.3390/plants12244106

Silva GIN, Araujo ABN, Ferraz ACN, Silva CX, Silva MAD. 2020. Utilização de diferentes tratamentos pré-germinativos para superação de dormência em sementes de *Adenanthera pavonina* L. *Diversitas Journal*. 5(2): 754–762. https://doi.org/10.17648/diversitas-journal-v5i2-1044

Singh AK, Singh JK, Kumar R, Sharma P, Kumar NM, Singh BK, Srinivasan S. 2024. Various presowing treatments for enhancing *Melia dubia* (Cav.) seed germination, seedling development, and vigor index. *Trees, Forests and People*. 17: 100629. https://doi.org/10.1016/j.tfp.2024.100629.

Sirait J, Simanihuruk K, Junjungan. 2009. Pemanfaatan *Mucuna bracteata* untuk pakan kambing: Produksi, nilai nutrisi, palatabilitas dan kecernaan. *Seminar Nasional Teknologi Peternakan dan Veteriner*. 425–433.

Sitanggang KD, Saragih SHY, Rizal K. 2020. Induksi pembungaan *Mucuna bracteata* menggunakan paklobutrazol dengan sistem tanam vertikal. *Jurnal Viabel Pertanian.* 14(2): 57–63. https://doi.org/10.35457/viabel.v14i2.1251.

Smiderle OJ, Souza AG. 2021. Do scarification and seed soaking periods promote maximum vigor in seedlings of *Hymenaea courbaril*. *Journal of Seed Science*. 43(4): 1–8. https://doi.org/10.1590/2317-1545v43254481

Sutopo L. 2012. *Teknologi Benih*. Malang (ID): Penerbit Rajawali Press

Syarovy M, Santoso H, Sembiring DS. 2021 Pertumbuhan tanaman kelapa sawit pada lahan dengan tanaman penutup tanah *Mucuna bracteata* yang tidak terawat dan alang-alang (*Imperata cylindrica*). *Warta PPKS.* 26(1): 46–54. https://doi.org/10.22302/iopri.war.warta.v26i1.46

Tefa A. 2017. Uji viabilitas dan vigor benih padi (*Oryza sativa* L.) selama penyimpanan pada tingkat kadar air yang berbeda. *Savana Cendana (Jurnal Pertanian Konservasi Lahan Kering).* 2(3): 48–50. https://doi.org/10.32938/sc.v2i03.210

Wahyuni M. 2019. Biomassa hijauan *Mucuna bracteata* dan pengaruhnya terhadap kadar N tanah di perkebunan kelapa sawit. *Jurnal Agro Estate*. 3(2): 54–62. https://doi.org/10.47199/jae.v3i2.64.

Widyawati N, Tohari P, Soemardi I. 2009. Permeabilitas dan perkecambahan benih aren (*Arenga pinnata* Wurmb. Merr.). *Jurnal Agronomi Indonesia.* 37(2): 152–158

Winarni E, Fitriani A, Purnomo, Panjaitan S. 2017. Daya kecambah benih rotan jernang (*Daemonorops draco* Blume) dengan berbagai perlakuan perendaman dalam air. *Jurnal Hutan Tropis.* 5(2): 120–126. https://doi.org/10.20527/jht.v5i2.4365