

Effects of Pre-Germination Treatments on Seed Germination of *Pachypodium mikea* Lüthy, an Endemic Xerophytic Species from Southwestern Madagascar

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Abstract

Pachypodium mikea Lüthy (Apocynaceae) is a xerophytic species endemic to southwestern Madagascar whose germination ecology remains poorly documented. This study aimed to characterize its seeds and evaluate the effects of different pre-germination treatments under nursery conditions. A total of 400 seeds were subjected to four treatments: boiling water (100°C), warm water (45°C), room-temperature water (24°C), and an untreated control. Germination was monitored for 45 days using germination percentage (GP), mean germination time (MGT), and germination speed index (GSI).

Seeds were elongated and fusiform, with mean dimensions of 8.04 ± 0.71 mm in length, 2.83 ± 0.35 mm in width, and 1.29 ± 0.19 mm in thickness. Pre-germination treatments significantly affected germination performance ($\chi^2 = 25.28$; $df = 3$; $p < 0.001$). The boiling water treatment yielded the highest germination percentage (63%), the shortest mean germination time (9 days), and the highest germination speed index (9.12). Post-germination observations

showed the early development of the caudex, succulent stem, and first spines. These results suggest the presence of partial seed coat dormancy that can be alleviated by thermal treatment. Boiling water immersion therefore represents a simple and effective technique for improving germination and supporting the conservation and propagation of *P. mikea*.

Keywords: *Pachypodium mikea*; seed germination; pre-germination treatment; seed morphometry; ex situ conservation; Madagascar

Introduction

Madagascar is recognized as one of the world's major biodiversity hotspots and harbors an exceptionally high level of plant endemism. Among its diverse ecosystems, the dry forests and xerophytic formations of the southwestern region support a highly specialized flora adapted to low rainfall, prolonged drought, and high temperatures (Goodman & Benstead, 2003; Koechlin et al., 1974). Despite their ecological importance, these ecosystems are increasingly threatened by anthropogenic pressures such as deforestation, slash-and-burn agriculture (*hatsake*), charcoal production, bushfires, and unsustainable exploitation of forest resources. These disturbances contribute to habitat degradation, biodiversity loss, and the decline of numerous endemic plant species.

One of the characteristic species of these arid environments is *Pachypodium mikea* Lüthy (Apocynaceae), a succulent tree strictly endemic to southwestern Madagascar. The species occurs mainly within the Mikea Forest complex and the surrounding xerophytic vegetation between Manombo, Andavadoaka, Lake Ihotry, and Morombe (Lüthy, 2005; IUCN, 2024). *Pachypodium mikea* is distinguished by its swollen succulent trunk adapted for water storage, numerous spine clusters distributed along the stem, narrow lanceolate leaves, and white flowers with a yellow throat (Lüthy, 2005). An adult individual is shown in **Figure 1**, while **Figure 2** illustrates the floral morphology of *Pachypodium mikea* compared with the closely related species *Pachypodium geayi*. **Figure 3** highlights the characteristic spiny trunk that contributes to the species' adaptation to arid environments.

Its restricted distribution range and increasing habitat fragmentation have led to its classification as Endangered (EN) on the IUCN Red List (IUCN, 2024). As a characteristic component of the xerophytic vegetation of southwestern Madagascar, *Pachypodium mikea* contributes to ecosystem structure and ecological interactions. Furthermore, its remarkable morphology and strict endemism provide considerable scientific, conservation, horticultural, and ecotourism value. Because of its drought tolerance and ability to survive under harsh environmental conditions, the species also

represents a promising candidate for ecological restoration and conservation programs within degraded dryland ecosystems.

Seed germination is a critical stage in the plant life cycle and plays a fundamental role in natural regeneration, population persistence, and nursery propagation (Baskin & Baskin, 2014). Germination success is influenced by seed characteristics and environmental conditions, and many species require specific pre-germination treatments to improve water uptake, accelerate emergence, and increase germination percentages (Hartmann et al., 2018). Consequently, the identification of effective germination protocols constitutes an essential step for seedling production, ex situ conservation, and ecological restoration initiatives.

Despite the ecological and conservation importance of *Pachypodium mikea*, information regarding its seed biology, germination requirements, and seedling development remains scarce. This lack of knowledge limits the development of reliable propagation techniques for conservation and ecological restoration programs in the xerophytic ecosystems of southwestern Madagascar.

Therefore, this study aimed to evaluate the effects of different pre-germination treatments on the germination of *Pachypodium mikea* seeds. Specifically, the study sought to: (i) describe the morphological and morphometric characteristics of the seeds; (ii) assess the influence of different pre-germination treatments on germination dynamics; (iii) identify the most effective treatment based on germination percentage, mean germination time, and germination speed index; and (iv) describe the main stages of post-germinative seedling development.

The general hypothesis of this study is that pre-germination treatments significantly influence the germination of *Pachypodium mikea* seeds.



Figure 1: Adult specimen of *Pachypodium mikea* Lüthy



Figure 2: Comparaison of the inflorescences of *Pachypodium geayi* (left) and *Pachypodium mikea* (right)



Figure 3: Trunk of *Pachypodium mikea*

Materials

Seed collection Site and Preparation

Seeds of *Pachypodium mikea* were collected on 26 December 2025 from natural populations located in the Anjaha sector of the Ranobe PK32 Protected Area, Atsimo-Andrefana Region, southwestern Madagascar, as shown in **Figure 4**. Healthy adult individuals with abundant fruit production were selected for seed collection. Fruits were harvested at physiological maturity following standard forest seed collection procedures (Willan, 1985; Schmidt, 2000; ENSCONET, 2009).

After collection, the fruits were transported to the experimental nursery and pre-dried in a well-ventilated environment to facilitate seed extraction. Seeds were manually extracted, cleaned, and visually sorted. Malformed, damaged, or deteriorated seeds were discarded, and only healthy seeds were retained for morphometric analyses and germination experiments (FAO, 1994; Schmidt, 2000). The seeds were stored in labeled containers under dry conditions protected from direct sunlight until sowing on 8 January 2026.

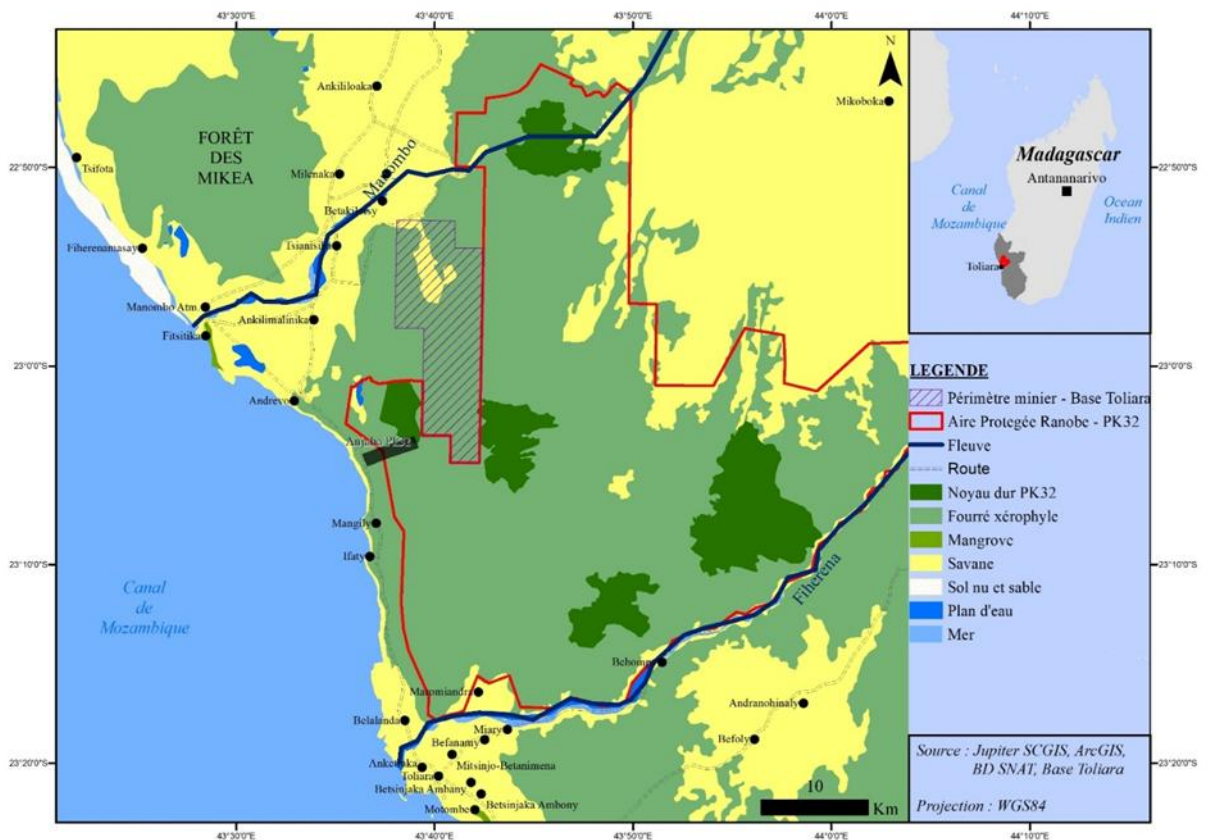


Figure 4: Geographic location of the Ranobe PK32 Protected Area and the Anjaha Site

Experimental Site

The experiments were conducted at the **Vara Mada experimental nursery**, located in Ambolimailaka, within the rural commune of Manombo, approximately **43 km north of Toliara** ($23^{\circ}02'43.52''$ S; $43^{\circ}34'14.56''$ E). All activities related to seed preparation, pre-germination treatments, sowing, and germination monitoring were carried out at this site, as shown in **Figure 5**.



Figure 5: Varma Mada Nursery

The selection of this experimental site was justified by the availability of its infrastructure, its proximity to the Anjaha PK32 seed collection area, and its direct involvement in ecological restoration programs using native species. Conducting the experiments under these conditions provides knowledge that can be directly applied to *ex situ* conservation, the production of indigenous forest seedlings, and future restoration and rehabilitation initiatives targeting degraded ecosystems in southwestern Madagascar.

Methods

Morphological and Morphometric Characterization of Seeds

A morphological characterization of *Pachypodium mikea* seeds was carried out to describe their main external features. Observations focused on seed shape, color, texture, seed coat appearance, and any distinctive structures. The seeds were observed and photographed in order to document their morphological characteristics. The general morphology of *Pachypodium mikea* seeds is shown in **Figure 6**.



Figure 6: General morphology of *Pachypodium mikea*

For the morphometric characterization, a random sample of **30 seeds** was used. Measurements were performed using a digital caliper with an accuracy of ± 0.01 mm. Three orthogonal dimensions were recorded for each seed: length (L), width (W), and thickness (T), following the methods described by Mohsenin (1986) and Schmidt (2000), as shown in **Figure 7**.



Figure 7 : Measurement of *Pachypodium mikea* seed dimensions using a digital caliper

The **geometric mean diameter (Dg)** was calculated using the following equation

$$Dg = (L \times W \times T)^{1/3}$$

where:

- **Dg** = geometric mean diameter (mm);
- **L** = seed length (mm);
- **W** = seed width (mm);
- **T** = seed thickness (mm).

The **sphericity (Φ)** was determined as:

$$\Phi = \frac{Dg}{L}$$

where:

- **Φ** = sphericity;
- **Dg** = geometric mean diameter (mm);
- **L** = seed length (mm).

The elongation index (EI) was calculated as:

$$Ia = \frac{L}{W}$$

où:

- **EI** = Elongation index;
- **L** = seed length (mm);
- **W** = seed width (mm).

Thus:

- When $EI \approx 1$, the seed has a nearly spherical shape;
- When $EI > 1$, the seed exhibits an elongated shape;
- the higher the EI value, the more elongated the seed.

This index provides information on seed shape variation and complements sphericity in the morphometric characterization of seeds.

These parameters were used to characterize the overall size and shape of *Pachypodium mikea* seeds (Mohsenin, 1986).

Pre-germination Treatments and Germination Trial

Four treatments were compared: (i) immersion in hot water at 100°C, (ii) soaking in warm water at 45°C, (iii) soaking in water at ambient temperature (24°C), and (iv) a control treatment without pre-treatment. Water temperatures were monitored using a digital thermometer prior to seed immersion. These treatments were designed to evaluate the effect of water temperature on seed germination response, as shown in **Figure 8**.



Figure 8 : Measurement of water temperature during seed pre-germination treatments

The effect of different pre-germination treatments on the germination of *Pachypodium mikea* seeds was assessed using four treatments:

- **T0 - Control:** direct sowing without pre-treatment;
- **T1 - Boiling water:** immediate immersion of seeds in boiling water (100°C), followed by a 24-hour soaking period during gradual cooling;
- **T2 - Warm water:** immersion of seeds in water at 45°C, followed by a 24-hour soaking period during gradual cooling;
- **T3 - Ambient water:** soaking of seeds in water at $24 \pm 2^\circ\text{C}$ for 24 hours before sowing.

For each treatment, 100 seeds of *Pachypodium mikea* were used. Following treatment application, seeds were immediately sown on germination beds established within the experimental nursery. This experimental design enabled the evaluation of the influence of water temperature on the germination behavior of the species (Schmidt, 2000; Baskin & Baskin, 2014), as shown in **Figure 9**.



Figure 9 : Experimental setup used for the germination trial

Germination Monitoring and Parameters Assessed

Germination was monitored for 45 days after sowing. The evolution of cumulative germination was used to evaluate germination dynamics under the different treatments.

The **final germination percentage (GP)** was calculated using the following formula:

$$GP = \frac{N_g}{N_s} \times 100$$

where:

- **GP** = final germination percentage (%);
- **Ng** = total number of germinated seeds;
- **Ns** = total number of seeds sown.

The **Mean Germination Time (MGT)** was calculated according to:

$$MGT = \frac{\sum(n_i \times t_i)}{\sum n_i}$$

where:

- **MGT** = mean germination time (days);
- **ni** = number of seeds germinated at time t_i ;
- **ti** = number of days elapsed since sowing.

Lower MGT values indicate faster germination.

The **Germination Vigor Index (GVI)** was calculated using the formula proposed by Maguire (1962):

$$GVI = \sum \frac{n_i}{t_i}$$

where:

- **GVI** = germination vigor index;
- **ni** = number of seeds germinated during observation i ;
- **ti** = number of days elapsed since sowing.

High GVI values indicate rapid and uniform germination, whereas low values reflect slower or more dispersed germination over time (Maguire, 1962).

Data Processing and Analysis

Morphometric data obtained from 30 seeds were analyzed using descriptive statistics, including the mean, standard deviation, minimum and maximum values, and coefficient of variation. These parameters were used to characterize the morphometric variability of *Pachypodium mikea* seeds (Mohsenin, 1986; Schmidt, 2000).

For the germination experiment, four pre-germination treatments were evaluated: the untreated control (T0), boiling water treatment (T1), warm water treatment at 45°C (T2), and ambient-temperature water treatment (T3). Each treatment consisted of a single experimental unit comprising **100 seeds**, resulting in a total of **400 seeds**. No independent replicates were included.

For each treatment, the total number of germinated seeds, final germination percentage (GP), mean germination time (MGT), and germination vigor index (GVI) were calculated to assess germination performance (Maguire, 1962; Baskin & Baskin, 2014).

Due to the absence of independent replicates, statistical comparisons were restricted to analyses of final germination frequencies. The proportions of germinated and non-germinated seeds among treatments were compared using a **Chi-square (χ^2) test of independence** (Zar, 2010; Sokal & Rohlf, 2012). Observed frequencies were compared with expected frequencies to determine whether an association existed between pre-germination treatments and seed germination. **Pearson residuals** and **adjusted residuals** were examined to identify treatments contributing significantly to the observed differences (Agresti, 2018).

Results

Morphological Characteristics of the Seeds

Figure 6 presents the general appearance of *Pachypodium mikea* seeds. The observed seeds exhibit an elongated and fusiform morphology, characterized by a narrow body with gradually tapering pointed ends. Their overall shape is distinctly slender, with a pronounced dominance of the longitudinal axis.

Seed coat color ranges from light beige to pale brown, occasionally displaying slightly darker grayish shades. The outer surface appears dry and dull, with fine longitudinal striations visible to the naked eye, giving the seeds a slightly fibrous appearance. The outline is generally regular, although some seeds exhibit slight curvature or subtle asymmetry.

Overall, the seeds show a high degree of uniformity in both shape and coloration within the studied seed lot.

These characteristics confer on *Pachypodium mikea* seeds a distinctive elongated and fusiform morphology. Such a morphology may be associated with the ecological constraints of the xeric environments of southwestern Madagascar.

Morphometric Characteristics of the seeds

The morphometric characterization of *Pachypodium mikea* seeds was conducted on a random sample of thirty (30) seeds collected from the Anjaha PK32 seed lot, as presented in **Table 1**.

Table 1: Morphometric characteristics of *Pachypodium mikea* (n = 30)

Parameter	Minimum	Maximum	Means $\pm$ SD	CV (%)
Length (mm)	6,19	9,18	8,04 $\pm$ 0,71	8,82
Width (mm)	2,12	3,59	2,83 $\pm$ 0,35	12,43
Thickness (mm)	0,93	1,67	1,29 $\pm$ 0,19	15,00
Geometric Mean Diameter (Dg) (mm)	2,52	3,58	3,07 $\pm$ 0,25	7,98
Sphericity (Φ)	0,33	0,44	0,38 $\pm$ 0,03	8,08
Elongation Index (L/l)	2,20	3,88	2,88 $\pm$ 0,41	14,36

Morphometric analysis revealed a mean length of 8.04 ± 0.71 mm, a mean width of 2.83 ± 0.35 mm, and a mean thickness of 1.29 ± 0.19 mm. The observed values demonstrate a clear predominance of length over the other two dimensions, with width representing on average only about one-third of the seed length, while thickness remains particularly low. This dimensional pattern confirms the narrow and elongated appearance observed during the morphological characterization.

The recorded minimum and maximum values indicate that this trend is maintained across all examined seeds. Even the shortest seeds remain substantially longer than wide, reflecting a homogeneous morphology dominated by the longitudinal axis. This feature is also evident in the photographs, where the seeds display a fusiform silhouette with gradually tapered extremities.

The geometric mean diameter of 3.07 ± 0.25 mm indicates a relatively small overall seed size. Despite their small dimensions, the seeds exhibit well-defined proportions that contribute to their distinctly elongated shape.

The mean sphericity value of 0.38 ± 0.03 represents one of the most remarkable findings. Such a low value indicates that the seeds differ greatly from a spherical shape and instead possess a strongly elongated geometry. This low sphericity directly confirms the previously described fusiform morphology and reflects the marked difference between the longitudinal and transverse dimensions.

The elongation index averaged 2.88 ± 0.41 , with values reaching 3.88 in some seeds. These results indicate that seed length is, on average, nearly three times greater than seed width. This pronounced dominance of the longitudinal axis explains the narrowly elliptical appearance observed during morphological characterization and constitutes the main distinguishing trait of *Pachypodium mikea* seeds.

Overall, all morphometric parameters strongly support the morphological observations. *Pachypodium mikea* seeds are characterized by a

fusiform to narrowly elliptical shape, reduced transverse dimensions, low thickness, and marked longitudinal elongation. Furthermore, the relatively low coefficients of variation recorded for most parameters indicate that these traits are fairly consistent within the studied seed lot.

Germination of Seeds

Germination Dynamics

Figure 10 shows the cumulative germination rate of *Pachypodium mikea* seeds subjected to different pre-germination treatments over the 45-day monitoring period.

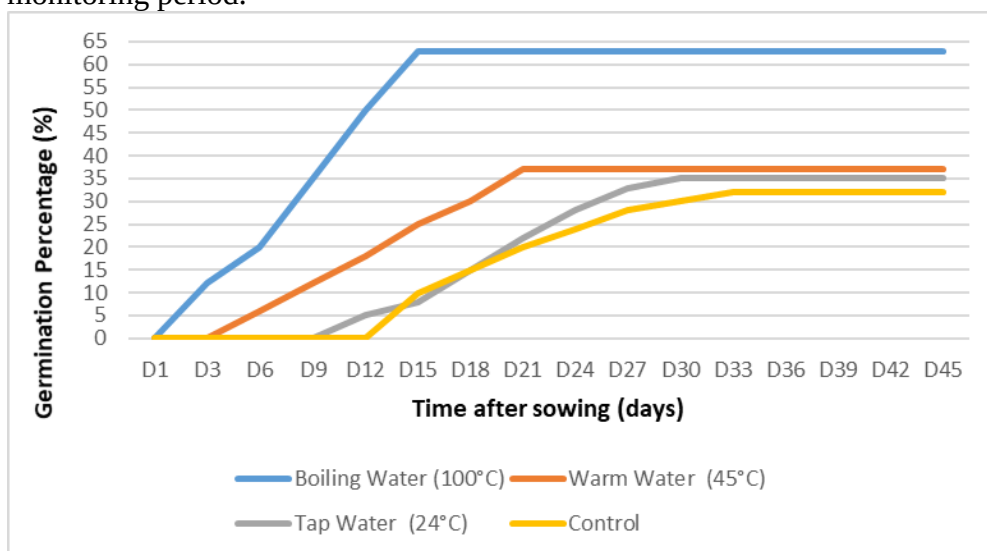


Figure 8: Germination kinetics of *Pachypodium mikea* seeds subjected to different pre-germination treatments

The first germination events were observed as early as the third day after sowing in seeds treated with boiling water (100°C). This treatment also exhibited the most rapid germination progression, reaching a final plateau of 63% by the fifteenth day. The warm-water (45°C) and ambient-water (24°C) treatments showed slower germination responses, with final germination percentages of 37% and 35%, respectively. The latest and poorest germination performance was observed in the control treatment, which reached only 32% germination.

Overall, most germination occurred during the first thirty days following sowing. Thermal treatments enhanced both the onset and magnitude of germination, with boiling water proving to be the most effective treatment.

Germination Parameters

Table 2: Germination parameters of *Pachypodium mikea* seeds subjected to different pre-germination treatments

Traitement	GP (%)	MGT (days)	GVI
Boiling water (100 °C)	63	9	9,12
Warm water (45 °C)	37	14	3,24
Ambiant water (24 °C)	35	20	1,84
Control	32	21	1,62

Germination parameters varied according to treatment. The boiling-water treatment (100°C) produced the best overall performance, with the highest germination percentage (**63%**), the lowest mean germination time (**9 days**), and the highest germination vigor index (**9.12**). In contrast, the control treatment showed the poorest performance, with a germination percentage of **32%**, a mean germination time of **21 days**, and a germination vigor index of **1.62**.

These results indicate that boiling-water treatment simultaneously improves germination percentage, seedling emergence rate, and overall germination vigor, as shown in **Table 2**.

Effet of Pre-germination Treatments on Final Germination

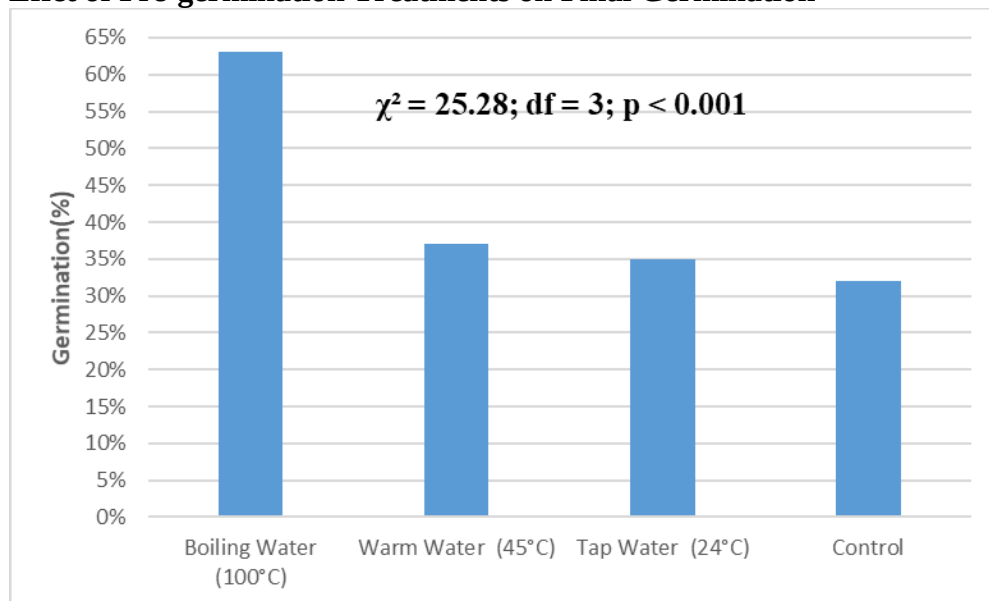


Figure 9: Final Germination Percentage under Different Pre-germination Treatments

Final germination percentages differed significantly among the pre-germination treatments ($\chi^2 = 25.28; df = 3; p < 0.001$). The boiling-water treatment (100°C) achieved the highest final germination percentage (**63%**), followed by warm water (**37%**), ambient water (**35%**), and the control (**32%**).

Analysis of adjusted residuals revealed that the boiling-water treatment contributed most strongly to the observed differences, with a significantly greater number of germinated seeds than expected under the null hypothesis of no treatment effect. Conversely, the control treatment exhibited a significantly lower germination proportion than expected.

These findings confirm the effectiveness of boiling-water treatment in promoting germination of *Pachypodium mikea* and suggest the presence of partial seed-coat dormancy that can be alleviated through the action of heat on the seed coat, as shown in **Figure 11**.

Post-germinative Development

The first seedlings of *Pachypodium mikea* displayed a fleshy and slightly swollen hypocotyl axis during the earliest stages of development, foreshadowing the formation of the characteristic caudex of the species.

Young seedlings rapidly developed simple, narrow, lanceolate leaves arranged in an apical rosette. As growth progressed, the basal swelling became increasingly pronounced, while the stem gradually acquired a succulent structure.

The appearance of the first spines near the apical meristem marked an important stage in juvenile development. Despite their young age, the seedlings already exhibited several morphological traits characteristic of the genus *Pachypodium*, including a succulent axis, foliage concentrated at the apex, and developing spines.

This developmental phase highlights the early establishment of the principal morphological features of the species, particularly caudex formation, stem succulence, and progressive spine development, as shown in **Figure 12**.



Figure 10: Young individual of *Pachypodium mikea* during post-germinative development

Discussion

Seed Morphology and Morphometry

Pachypodium mikea seeds exhibited an elongated and fusiform morphology, characterized by low sphericity (0.38 ± 0.03) and a relatively high elongation index (2.88 ± 0.41). These characteristics indicate a strong dominance of the longitudinal axis and confirm the morphological observations made during seed description. The low coefficients of variation recorded for most parameters further suggest a relatively homogeneous seed lot.

To our knowledge, no previous study has provided a detailed morphometric description of *Pachypodium mikea* seeds. Therefore, the present results represent an original contribution to the biological knowledge of this endemic species from southwestern Madagascar. The reported values may serve as a reference for future studies focusing on the ecology, germination, conservation, and propagation of the species.

Effect of Pre-germination Treatments on Germination

The results demonstrated that the boiling-water treatment (100°C) significantly improved the germination of *Pachypodium mikea* seeds. This treatment produced the highest final germination percentage (**63%**), the lowest mean germination time (**9 days**), and the highest germination vigor index (**9.12**). The Chi-square test confirmed a significant effect of pre-germination treatments on seed germination ($\chi^2 = 25.28$; $\text{df} = 3$; $p < 0.001$).

The effectiveness of the boiling-water treatment suggests the presence of **partial physical or seed-coat dormancy** in *Pachypodium mikea* seeds. According to Bewley et al. (2013), physical dormancy is generally associated with low seed-coat permeability, which restricts water uptake required for the initiation of germination. Heat exposure may therefore have altered the seed-coat structure, promoting imbibition and activating the physiological processes necessary for embryo growth resumption.

The warm-water (45°C) and ambient-water (24°C) treatments also allowed germination to occur, but with substantially lower performance than the boiling-water treatment. These findings suggest that lower temperatures were probably insufficient to produce significant modifications of the seed coat. According to Baskin and Baskin (2014), the intensity of thermal treatment is often a critical factor in breaking physical dormancy in species adapted to harsh environmental conditions.

These findings are particularly important for the conservation of *Pachypodium mikea*, an endemic species of southwestern Madagascar. Propagation within the genus *Pachypodium* relies primarily on seed production, while vegetative propagation through cuttings is generally limited. Consequently, seed germination represents an essential pathway for producing

individuals intended for ex situ conservation programs and the restoration of natural populations.

The analysis of adjusted residuals showed that the boiling-water treatment contributed most strongly to the observed differences among treatments. This finding confirms that thermal treatment constitutes a simple and effective method for improving germination percentage, accelerating seedling emergence, and enhancing overall germination performance in *Pachypodium mikea*.

Post-germinative Development.

Observations made during post-germinative development revealed the early appearance of a basal swelling, indicating the progressive formation of the characteristic caudex, together with the development of a succulent stem and the first spines. These features emerged during the earliest growth stages and correspond to the principal morphological traits described for species of the genus *Pachypodium* (Rapanarivo & Leeuwenberg, 1999; Lüthy, 2005).

The early formation of the caudex observed in young seedlings suggests the rapid establishment of specialized storage structures characteristic of the species. In *Pachypodium*, the development of succulent tissues constitutes a key adaptation to the drought conditions prevailing in the arid and semi-arid regions of Madagascar and southern Africa (Rapanarivo & Leeuwenberg, 1999; Koechlin et al., 1974). This adaptation enables individuals to store water and better withstand prolonged periods of water deficit.

The gradual appearance of spines during juvenile development is also consistent with available morphological descriptions of *Pachypodium mikea* and other species of the genus (Lüthy, 2005; Rapanarivo & Leeuwenberg, 1999). These structures represent one of the defining characteristics of the genus and contribute to the protection of succulent tissues.

Overall, the results indicate that the principal morphological traits of *Pachypodium mikea* are established at very early developmental stages. These observations enhance current knowledge of the species' biology and provide useful information for propagation, **ex situ conservation**, and ecological restoration programs.

Study Limitations

The present study generated novel information on the seed morphology, germination, and post-germinative development of *Pachypodium mikea*. Nevertheless, several limitations should be considered when interpreting the results.

The germination experiment was conducted using a single seed lot collected from one location, and treatments were not replicated independently.

Consequently, the findings should be regarded as a preliminary contribution to the understanding of the germination biology of the species. Future studies incorporating multiple seed lots, different collection periods, and experimental replicates would help confirm and strengthen the robustness of the observed results.

In addition, only thermal treatments were evaluated in this study. The effectiveness of other dormancy-breaking methods, such as mechanical scarification, chemical scarification, and the use of plant growth regulators, also deserves investigation in order to further optimize germination protocols for *Pachypodium mikea*.

Conclusion

This study provided the first detailed description of the seed morphology, germination behavior, and post-germinative development of *Pachypodium mikea*, an endemic species of southwestern Madagascar. The seeds are characterized by an elongated and fusiform shape, low sphericity, and a high elongation index, providing valuable baseline information for future ecological, conservation, and propagation studies. Observations of post-germinative development also revealed the early establishment of key morphological traits, including caudex formation, stem succulence, and spine development.

The results demonstrated that pre-germination treatments significantly influence the germination of *Pachypodium mikea* seeds, thereby supporting the initial hypothesis of this study. Among the treatments evaluated, immersion in boiling water (100°C) proved to be the most effective, resulting in the highest germination percentage (63%), the shortest mean germination time (9 days), and the highest germination vigor index. These findings indicate that boiling-water treatment represents a simple and practical technique for nursery propagation, ex situ conservation, and ecological restoration programs. Future studies should include replicated experiments, multiple seed lots, and additional dormancy-breaking methods to further optimize propagation protocols and strengthen conservation strategies for *Pachypodium mikea*.

Conflict of Interest: The authors reported no conflict of interest.

Data Availability: All data are included in the content of the paper.

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