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# Evaluation of the germination of *Capparis spinosa* L. and *Anacyclus pyrethrum* var. *pyrethrum* in the context of rural nurseries

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**Abstract**: This research assessed germination of *Capparis spinosa* L. and *Anacyclus pyrethrum* var. *pyrethrum* within a rural nursery located in Morocco's High Atlas uplands (*Aït M'Hamed*, Azilal region). Seeds were harvested locally and soaked in water prior to planting inside a greenhouse under semi-controlled conditions (10°C at night, 25°C during the day, irrigation when required, peat substrate). In *C. spinosa*, soaking in hot water (50°C) facilitated the breaking of dormancy and significantly shortened latency by four days with a higher germination percentage (62.9% vs 51.4% in control). By contrast, in *A. pyrethrum* much longer soaking at room temperature was more beneficial (germination beginning on the third day and a high final rate 90.0% compared with 67.9%). These findings showed that low cost, easily accessible, and ecological water treatments are effective in enhancing dormancy release and seed germination vigor of these both species especially for two emblematic species of the PAM from Morocco. Application of these treatments in village cooperatives could encouraged the domestication and cultivation of *C. spinosa* and *A. pyrethrum*, reduce pressure on wild collections, help to conserve biodiversity and increase income generation at local level. More studies of other treatments and seedling growth are required to validate these practices.

## 1. Introduction

Morocco's geographical location, combined with the diversity of its reliefs and altitudinal gradients, results in a wide range of Mediterranean bioclimates, explaining the exceptional floristic richness of its ecosystems and establishing the country as a true biodiversity hotspot [1,2,3]. There are 3,913 species and 1,298 subspecies in its vascular flora, which are organized into 155 groups and 981 genera. Of them, 640 species (16%) and 280 subspecies (32%) are endemic [4]. With 600–800 species, 25% of which are indigenous, aromatic and medicinal plants (AMP) have a significant position among them [5]. In addition to being vital sources of income for rural

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communities, these resources are strategically important for the agri-food, cosmetics, and pharmaceutical industries and serve as a lever for sustainable development [6, 7].

Conversely, overexploitation of these resources, which are typically unsustainable in nature, poses a severe danger to biodiversity and impairs ecological integrity [8, 9]. Consequently, domestication and cultivation of PAMs offer viable long-term solutions that help to reconcile conservation with economic development [10,11] even more so when combining traditional knowledge with modern methods [12].In this perspective, the province of Azilal in the central Middle Atlas is an interesting case: The region is known for being rich in aromatic and medicinal plants, contributing to its rise as a rural area with many local cooperatives—often run by women or young farmers-influencing PAM sector structure through resource valorization and income improvement.

The most famous plant in that legacy is *Capparis spinosa* (caper bush) and *Anacyclus pyrethrum* var. *pyrethrum* species (African pyrethrum), which are of both ecological and economic significance.

*Capparis spinosa* L. (caper) is a perennial deciduous shrub distributed in the Mediterranean area, Asia and Oceania [13, 14]. It is a xerophytic species with resistance to drought, salt and poor soils, the plant plays an important role in soil conservation [15,16].

Its taxonomic richness, with 22 recognized variations, demonstrates its high adaptability [17]. Since ancient times, capers and caperberries have been consumed as sauces [16,18], while its seeds and other organs are a rich source of phenolic and bioactive substances with nutritional and pharmacological importance [19, 20, 21].

Recent research verifies its multi-target benefits on cancer, diabetes, and inflammatory illnesses [22], supporting its nickname "millennium plant" [15]. Beyond its therapeutic value, C. spinosa represents a crucial crop in the face of climate change [23], but it is still threatened by overexploitation and genetic erosion, necessitating its domestication [14].

This domestication, however, is limited by low seed germination and difficult rooting of cuttings, which limit plant output and cultivation [24,16]. The nearly nil germination is a key impediment to its propagation [25], which is connected to a combination of dormancy: a hard integument and endogenous inhibitors that prevent imbibition and the development of the radicle [24]. The exogenous application of gibberellins ($GA_3$) can partially lift this internal blockage [26].

Despite these limits, seeding is still the most popular method for cultivating capers [23], emphasizing the need for improved dormancy breaking protocols. Several treatments have been explored, including hydrothermal soaking, mechanical or chemical scarification ($H_2SO_4$), stratification (cold or temperature variation), immersion in $KNO_3$ solutions, and $GA_3$. Scarification combined with $GA_3$ results in higher rates compared to those without treatment [27]. The authors reported up to 75% germination after a 15-minute bath in sulfuric acid, followed by rinsing and growing on $GA_3$-enriched medium. However, while these procedures are effective, they are costly, risky, and unsuitable for rural nurseries with limited resources, necessitating the development of inexpensive, safe, and reproducible alternatives tailored to local resources.

African pyrethrum (*Anacyclus pyrethrum* var. *pyrethrum*) is a perennial species native to Morocco and Algeria [28, 29, 30], traditionally used for its medicinal properties due to bioactive compounds concentrated in its roots [33, 34]. Known locally as "*Ighuendez*" and "*Tiguendizt*" [31–32], the species has demonstrated anti-inflammatory, neuroprotective, and gastro-protective effects in recent studies.

Intensive root harvesting has led to a severe decline in natural populations, resulting in its classification as a vulnerable species by the IUCN. Domestication is therefore essential but remains constrained by strong seed dormancy. Germination depends on environmental conditions and seed physiology [41, 42], and previous studies have shown that simple pretreatments, such as cold stratification or imbibition at moderate temperatures, can significantly improve germination, whereas hot water inhibits it [30, 43]. Developing locally adapted pretreatments is thus critical for sustainable cultivation and conservation of *A. pyrethrum*.

In this context, the present study evaluates the effectiveness of simple water pretreatments on *C. spinosa* and *A. pyrethrum* seeds, in order to propose practical protocols adapted to rural nurseries and to contribute to their domestication and sustainable conservation.

## 2. Materials and Methods

### 2.1. The study area

Seeds were collected from the commune of *Aït M'Hamed* situated in southern Azilal province (Béni Mellal-Khénifra region, central High Atlas). This site is located at an average altitude of 1,550 m (31°50′45″ N; 6°31′10″ W) and presents a Mediterranean mountain climate from semi-arid to sub-humid with occasional but relatively high rainfall during autumn and spring. Local communities are dependent in a great extent on natural and agricultural or forest resources, which often fall under customary law management. The *Aït M'Hamed* pilot nursery, established in 2017 on two hectares, serves as a platform for conservation and information transfer, connecting scientific research to rural cooperative needs.

### 2.2. Methodology

After harvesting, the seeds were cleaned according to a species-specific protocol. For *Capparis spinosa*, the fruits were manually opened, the seeds extracted, and then dried at room temperature. For *Anacyclus pyrethrum*, the dry flower heads were manually beaten to release the seeds, which were then sieved to remove plant debris and visually selected to retain only intact and well-formed seeds. The seeds thus prepared were stored in paper bags, placed in dry and ventilated conditions, until cultivation.

Sowing was carried out on February 8, 2025, in an experimental greenhouse offering semi-controlled conditions. The temperature was maintained at an average of

10 °C at night and 25 °C during the day, with humidity regulated by daily watering. The peat substrate used was kept moist but not excessively moist to prevent root anoxia.

Two treatments were tested. For *Capparis spinosa*, one batch underwent a brief soak in hot water at 50°C for three minutes, while the other served as a control without treatment. For *Anacyclus pyrethrum*, one batch underwent a prolonged soak in water at room temperature for twelve hours, while the other served as the control. Each experimental modality included 4 replicates of 35 seeds (*C. spinosa*) and 70 seeds (*A. pyrethrum*), for a total of 140 and 280 seeds, respectively. The seeds were planted immediately after the application of the pretreatments. The experimental design was established according to a completely randomized design (CRD), with independent repetitions for each modality (control and treated). Germination was monitored every morning at a fixed time (9 a.m.) for 21 days. Seeds, sown in a moist peat substrate, were considered germinated as soon as the cotyledons emerged on the surface of the substrate,

Five parameters were used to evaluate germination performance: i) the germination rate (GR, %) representing the proportion of germinated seeds compared to the total number of seeds sown; ii) the germination energy (GE, %) which is the percentage of seeds germinated at a date reflecting initial vigor; iii) the mean germination time (MGT, days) corresponding to the weighted average of the time required for germination, calculated from the number of seeds germinated each day ($\Sigma ni \times ti / \Sigma ni$); iv) the germination speed index (GSI), measuring of the speed of the process, obtained by dividing the number of seeds germinated by the number of days ($\Sigma ni / ti$); and v) the latency time (LT, days) corresponding to the time elapsed between sowing and the appearance of the first germination.

Comparison of germination proportions was performed using Pearson's $\chi^2$ test ($\alpha = 0.05$). Differences in mean germination time between modalities were assessed using a Welch t-test (inequalities of variances). Results are presented with exact p values, odds ratios (OR) and their 95% confidence intervals (95% CI).

## 3. Results

*Capparis spinosa* L. seeds showed epigeal germination. The hot water treatment (50 °C, 3 min) was more effective than the control, inducing earlier germination (D11 vs. D15) and a final rate of 62.86% (88/140) vs. 51.43% (72/140). This dynamic is illustrated in Figure 1, which presents the germination kinetics for each experimental modality.

At D17, germination energy already reached 37.9% in the treated batch (53/140) compared to only 9.3% in the control (13/140). Germination indices confirm the kinetic advantage of the pretreatment: TMG = 15.96 days (mean ± SD over 4 replicates: 15.9 ± 0.3) versus 18.62 days (18.6 ± 0.2), a gain of 2.66 days; IVG = 8.36 (treated) versus 6.44 (control). These results indicate faster and more homogeneous germination after soaking. The observed differences are statistically significant: final proportions (88/140 vs 72/140): $\chi^2(1) = 4.03$, $p = 0.045$, OR = 1.66 (95% CI [1.01; 2.75]); germinative energy at D17 (53/140 vs 13/140): $\chi^2(1) = 29.22$, $p = 6.9\times10^{-8}$, OR = 6.85 (95% CI [3.47; 13.54]). Comparison of GMTs by replicate (Welch test) confirms this effect: $t = -12.57$, ddl ≈ 5.9, $p = 4.2\times10^{-5}$; ΔTMG = −2.66 days (95% CI [−3.28; −2.04]).

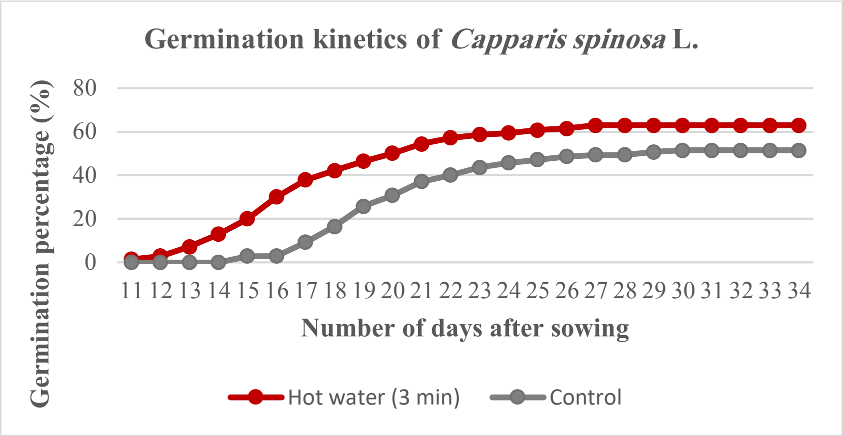


Figure 1 :Kinetics of germination of seeds of *Capparis spinosa*: soaking in hot water for 3 minutes, and untreated control

Table 1 : Seed germination parameters of *Capparis spinosa according*

| **Compared parameter** | **Control group** | **Treated (50°C, 3 min)** | **Test** | **Value** | **ddl** | **p** | **Effect of treatment** |
|---|---|---|---|---|---|---|---|
| Final germination rate | 72/140 (51.4%) | 88/140 (62.9%) | $\chi^2$ | 4.03 | 1 | 0.045 | OR = 1.66 [1.01–2.75] |
| Germinative energy J17 | 13/140 (9.3%) | 53/140 (37.9%) | $\chi^2$ | 29.22 | 1 | $6.9\times10^{-8}$ | OR = 6.85 [3.47–13.54] |
| Average germination time (GGT) | 18.62 d (±0.2) | 15.96 d (±0.3) | Welch t | −12.57 | ≈5.9 | $4.2\times10^{-5}$ | Δ = −2.66 j [−3.28; −2.04] |

African pyrethrum (*Anacyclus pyrethrum* var. *pyrethrum*) seeds showed epigeal germination. Seeds immersed in water at room temperature for 12 hours germinated more quickly and uniformly than untreated seeds. Germination began on day 3 in the treated batch, vs day 5 in the control. The majority of germination took place during days 3-7 for treated seeds and days 5-9 for control seeds, with no fresh germination after day 9.
The final germination rate in soaking seeds was significantly greater (90%) than in the control (67.86%). On day 7, germination energy reached 90% in the treated batch, compared to 60.7% in the control. Overall, 12 hours of water imbibition greatly increased both the speed and percentage of germination.

Germination indices confirm the kinetic advantage of the pretreatment. The mean germination time (MGT) is 4.17 days (mean ± standard deviation over 4 replicates: 4.16 ± 0.11) compared to 6.19 days (6.19 ± 0.05) for the control, a gain of 2.03 days.

The germination speed index (GSI) is 64.71 for the treated batch compared to 31.48 for the control. The differences are highly significant. For the final proportions (252/280 versus 190/280): $\chi^2(1) = 41.27$, $p = 1.32\times10^{-10}$, odds ratio (OR) = 4.26 (95% CI [2.68; 6.78]). For the germinal energy at D7 (252/280 versus 170/280): $\chi^2(1) = 64.66$, $p = 8.91\times10^{-16}$, OR = 5.82 (95% CI [3.68; 9.21]). Comparison of TMGs by replicate (Welch t-test) confirms the effect: $t = -34.70$, ddl ≈ 4.15, $p = 2.85\times10^{-6}$; ΔTMG = −2.03 days (95% CI [−2.19; −1.87]).

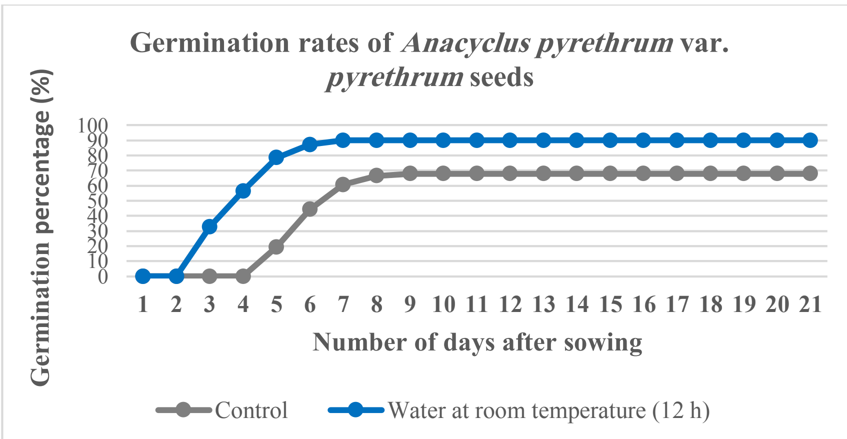


Figure 2 : Germination kinetics of seeds of *Anacyclus pyrethrum var. pyrethrum*

Table 2 : Seed germination parameters *of Anacyclus pyrethrum var. pyrethrum*

| **Compared parameter** | **Control group** | **Treated (12 h, room temperature)** | **Test** | **Value** | **ddl** | **p** | **Effect of treatment** |
|---|---|---|---|---|---|---|---|
| Final germination rate | 190/280 (67.9 %) | 252/280 (90%) | $\chi^2$ | 41.27 | 1 | $1.32\times10^{-10}$ | OR = 4.26 [2.68–6.78] |
| Germinative energy J7 | 170/280 (60.7 %) | 252/280 (90%) | $\chi^2$ | 64.66 | 1 | $8.91\times10^{-16}$ | OR = 5.82 [3.68–9.21] |
| Average germination time (GGT) | 6.19 d (±0.05 ) | 4.16 d (±0.11) | Welch t | −34.70 | ≈4.15 | $2.85\times10^{-6}$ | Δ = −2.03 j [−2.19; −1.87] |

## 4. Discussion

The results show that soaking *Capparis spinosa* L. seeds in hot water at 50 °C for three minutes promotes germination significantly compared to the untreated control. The appearance of the first seedlings on the 11th day, along with an increase in the final germination rate (62.86% vs. 51.43% for the control), indicates that this pretreatment helped to reduce the mechanical resistance of the seed coat and accelerate imbibition without causing embryonic damage. These findings support the work of [44], who demonstrated the effectiveness of hot water soaking in partially removing caper seed coat dormancy [44].

Caper seed dormancy is widely thought to be mixed, combining a physical barrier due to the impermeability of the seed coat with a physiological component caused by internal inhibitors [27]. The authors demonstrated that combining chemical scarification ($H_2SO_4$, 15 min) and gibberellins ($GA_3$, 2000 ppm) resulted in 75% germination rates under controlled settings [27]. However, such technologies remain unsuitable for rural settings due to their high cost, the complexity of the protocols, and the hazards connected with handling caustic chemicals. In contrast, [24] indicated that imbibition via the hilum was sufficient to commence the germination process and that the administration of $GA_3$ alone, without chemical scarification, might result in germination rates close to 99% [24]. These results confirm that the impermeability of the integument is not the only limiting factor and that physiological dormancy plays a major role.

In this regard, the results of this study using simple thermal soaking support the concept that light, non-polluting, and easily accessible interventions can be a viable alternative to chemical techniques. This is also consistent with recent research findings emphasizing the need of creating approaches tailored to rural nurseries, where financial and technical resources are frequently constrained [10].

Environmental factors play an important influence as well. According to [45], high daytime temperatures (up to 43 °C) significantly reduce C. spinosa germination rate (≈ 12.9%), while moderate thermal conditions (20-30 °C) encourage greater dormancy breaking. Our results, obtained in a greenhouse at 10-25 °C, contribute to this dynamic by supporting the need of reasonable temperature regime control in improving germination. Soaking *Anacyclus pyrethrum* var. *pyrethrum* seeds for 12 hours at room temperature significantly improved germination performance. This therapy allowed for quicker emergence, as early as the third day vs the fifth day for the control, and resulted in a final germination rate of 90%, which was much greater than the 67.9% attained without treatment. These findings support the effectiveness of hydro-priming as a simple and repeatable strategy for inducing germination.

The underlying physiological mechanism is mostly based on water imbibition, which is the initial step in the germination process. This gradual rehydration causes softening of the seed coat, reactivation of hydrolytic enzymes, and fast mobilization of seed reserves [43]. Furthermore, oxygen availability during this period is critical, allowing mitochondrial respiration to resume and ATP to be produced, which is required for the radicle and cotyledons' first growth [46]. The observed efficiency of simple water soaking illustrates that biochemical and energetic processes can be activated without the use of chemicals.

Our results align with those of [30], who found that various pretreatments can enhance germination of this species. Cold stratification at 4°C resulted in 88% germination, followed by $KNO_3$ treatment (80%) and sulfuric acid scarification (60%). However, treatment with boiling water entirely stopped germination. In this context, the methodology examined here is particularly interesting because it delivers similar results to cold stratification without the need of chemicals or refrigeration infrastructure. Another deciding aspect is the provenance of the seeds. The wild lots obtained in the Timahdite region by [30] had a relatively poor initial germination potential (20-32%). However, seeds from the *Aït M'Hamed* nursery exhibited a high spontaneous germination rate (~68% for the control). This difference can be explained by factors related to the provenance.

On a practical level, soaking at room temperature for 12 hours is an ideal strategy for rural nurseries since it is low-cost, simple to implement, and does not require any complicated infrastructure. Furthermore, it eliminates the dangers associated with handling chemicals ($H_2SO_4$, $KNO_3$) and can be easily integrated into sustainable manufacturing procedures. This simplicity makes it the preferred strategy for supporting the domestication of *A. pyrethrum* in the High Atlas regions, where overexploitation of native populations has resulted in the species' dramatic decrease and designation as "vulnerable" on the IUCN Red List.

All of these observations suggest that, while the seeds of *Capparis spinosa* and *Anacyclus pyrethrum* var. *pyrethrum* are subject to complex dormancy, this constraint can be partially overcome by using simple techniques such as prolonged water soaking or gentle thermal scarification. The success of room temperature imbibition in *A. pyrethrum* and hot water soaking in *C. spinosa* demonstrates the potential of these low-cost techniques, which are easily adaptable to rural settings. Unlike other complex procedures, such as the application of growth regulators ($GA_3$) or severe chemical treatments ($H_2SO_4$, $KNO_3$), these alternatives rely on ecologically friendly processes, limiting both dangers and damage.

These findings are part of a larger pattern of applied research aiming at bringing scientific discoveries closer to rural nursery practices. They confirm the necessity of simple, reproducible germination techniques tailored to local resources in order to strengthen domestication of these species and lessen the burden of wild harvesting, which is the primary driver of natural population decline. In the socio-ecological setting of the High Atlas, where floristic biodiversity is abundant but vulnerable, the implementation of such protocols serves as a tangible lever to promote the sustainability of aromatic and medicinal plant (AMP) sectors. However, the scope of this study is limited by the small quantity of seeds available, which prevented testing a larger range of treatments.

Finally, large-scale diffusion of adapted germination procedures, accompanied by research on more representative batches, is a critical step in reconciling biodiversity protection, economic development, and sustainable development in Morocco's mountain areas.

## 5. Conclusion

The findings of this study suggest that modest water pretreatments are a promising way to improve dormancy break and germination success in two important PAM species. Brief heat soaking (50°C, 3 min) of *Capparis spinosa* hastened germination and considerably boosted final germination rate when compared to the control. Extended ambient soaking (12 hours) was highly effective for *A. pyrethrum* var. *pyrethrum*, giving you fast, concentrated and even germination of more than 90%. Safety, cost and ease of application in rural nursery make both treatments attractive for people and they could be an alternative to chemical or hormonal methods.

However, this study should be regarded as a preliminary one. The limited number of seeds available also prevented us from testing a broader range of treatments or contrasting sources, however it restricted the breadth of our results. Further studies are required to evaluate inter-population variability and seed origin impacts, optimize pretreatment settings to enhance efficacy with minimal loss of viability, and investigate seedling vigour, growth and survival post transplant.

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