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RESEARCH PAPER

Mechanical scarification: The key to optimal germination parameters in nine flowering species of the United Arab Emirates

Nour El Houda Debouza[1], Sunil Mundra[1], Iltaf Shah[1], Taoufik Ksiksi[1]

1 *Department of Biology, College of Science, United Arab Emirates University, Al Ain 15551, United Arab Emirates*

Corresponding author: Taoufik Ksiksi (tksiksi@uaeu.ac.ae)

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Abstract

Seed germination is the most essential stage of the plant life. Prior to germination, seed dormancy provides protection to the seed against germinating under unfavorable conditions. The seeds of many plants in arid regions are particularly characterized by having a hard seed coat. Seed dormancy is essential to the survival of plants, however in some incidents such as reforestation on desert areas, it is important for ecologists to investigate methods of breaking the dormancy of seeds in order to maximize the production of plants. In this study, we tested four methods of seed pre-treatment (Mechanical scarification (MChip), chemical scarification with sulfuric acid at two exposure durations (SAcid15, SAcid30), and soaking in water for 24 h (Soak)) on 9 flowering plants (*Senna italica*, *Sorghum sudanense*, *Tephrosia nubica*, *Senna angustifolia*, *Acacia tortilis*, *Senna occidentalis*, *Abutilon pannosum*, *Prosopis cineraria*, *Crotalaria persica*) of the UAE. Six germination parameters (Final germination percentage (G) %, Mean germination time (MGT) day, Mean germination rate (MGR) day, Coefficient of velocity of germination (CVG) %, Mean Daily Germination Percentage (MDG) %, and Germination index (GI) day) were calculated to assess the germination. Final Germination Percentage (G) significantly improved ($P < 0.005$) in seven species (100% in *S.italica*, 98% in *S.sudanense*, 97% in *T.nubica*, 99% in *S.angustifolia*, 98% in *A. tortilis*, 99% in *P. cineraria*, and 93% in *C. persica*) with Mchip and SAcid30 (1.124% in *S. italic*, 28% in *S. sudanense*, 3% in *T. nubica*,82% in *S. angustifolia*, 96% in *A. tortilis*, 99% in *P. cineraria*, and 25% in *C. persica*), three species (1.562% in *S. italica*, 28% in *S. sudanense*, 3% in *T. nubica*, 62% in *S. angustifolia*, and 62% in *P. cineraria*) with (SAcid15), and only two species (3% in *T. nubica* and 5% in *A. tortilis*) with Soak. *S. occidentalis* was the only species that did not show significant changes in germination parameters after each treatment. Mechanical scarification is the safest and most affective pretreatment method according to our findings.

Keywords

Seed germination, germination parameters, mechanical scarification, chemical scarification, UAE, native plants

Introduction

The first stage of plant growth is germination, and it is one of the most sensitive phases for the formation of all plants (Kheloufi et al. 2019). For trees and desert species in particular, the hardness of the seed coat then inflicts on the seed a physical dormancy. It is a protective mechanism that initiates the germination solely under favorable environments to ensure the subsistence of the successfully germinated plant (Venier et al. 2011). As a result, hard-coated seeds require particular pretreatment methods prior to sowing to achieve quick and high germination rate (Burrows et al. 2009). Numerous researches have been conducted to develop functional treatments to ensure that the seeds germinate quickly by break dormancy artificially (Iroko et al. 2021). The strength of dormancy may differ depending on the genotype and the environment in which the seeds are formed (Kheloufi et al. 2017). Treatments such as chemical stratification (typically with acid) (Hassan et al. 2024), mechanical scarification (using sand paper or clippers), water soaking (hot or cold) are commonly used because they can improve the seed germination rate in a reasonably short period of time (Kheloufi et al. 2017; Iroko et al. 2021). The principle behind these methods is derived from natural processes that occur in nature, such as dispersal through wind and being scratched against sands and rocks, animal vectors such as birds and camels which eat the seeds and dispose them through excretory system (Cain et al. 2000; Levey et al. 2005; Venable et al. 2008). The effectiveness of these methods is to control the impermeability of the seed coat and increase seed germination has been reported for different species (Burrows et al. 2009; Al-ansari and Ksiksi 2016; Kheloufi et al. 2017; Kheloufi et al. 2019). However, the effectiveness of these treatment varies with plant species, acid concentration and duration of treatment, in the case of chemical stratification (Kheloufi et al. 2017). For example, in the case of Ghaf trees (*Prosopis cineraria*) the germination percentage was improved for up to 75% with the use of sulfuric acid pretreatments (Hassan et al. 2024). Soaking in distilled water was reported to improve germination percentage in perennial grass like *Leymus chinensis* by up to 89% (He et al. 2016). Moreover, mechanical scarification improved germination percentage of some grain species like *Avena fatua* by 25% (Rocha et al. 2022).

In this research, a collection of 9 flowering species (*Senna italica*, *Sorghum sudanense*, *Tephrosia nubica*, *Senna angustifolia*, *Acacia tortilis*, *Senna occidentalis*, *Abutilon pannosum*, *Prosopis cineraria*, *Crotalaria persica*) from different plant families in the UAE were selected to test four pretreatment methods on six germination parameters: Final germination percentage (G) , Mean germination time (MGT) , Mean germination rate (MGR) , Coefficient of velocity of germination (CVG), Mean Daily Germination Percentage (MDG), and Germination index (GI). The overall goal is to establish the most effective pretreatment method for each of the species, providing a solid method for breaking the dormancy of the seeds and achieving the highest levels of germination parameters, and ultimately higher germination and seedling growth and survival rate.

Materials and methods

Plant species

Senna italica, also known as *Italian senna*, is a leguminous plant that is native to the Mediterranean region and is widely distributed throughout North Africa, the Middle East, and parts of Asia (Omer 2022). The plant has several characteristics that make it valuable, including its pinnate leaves, yellow flowers, and ability to grow up to 5 meters in height. *S. italica* is primarily used for its laxative and purgative properties, as it contains anthraquinone glycosides that stimulate the colon and promote bowel movements (Olorukooba et al. 2022). Additionally, the plant is used in traditional medicine to treat skin diseases, fever, and inflammation (Omer et al. 2022). *S. Italica* has several other uses, including as a natural dye and as a source of edible seeds (Olorukooba et al. 2022). Its medicinal properties and other uses continue to make it a valuable plant species today.

Sorghum sudanense, also known as *Sudan grass* or *Sorghum sudan* grass, is an annual grass species that is commonly grown for forage. It is rich and fiber and contains high protein levels which makes it a favorable source of nutrition for livestock (Ananda et al. 2023). It is a hybrid between *Sorghum bicolor* and *Sorghum arundinaceum* and is known for its high yield and fast growth. *S. sudanense* has the ability to grow in a wide range of soils and it relatively drought tolerant, making it a standard option for farmers particularly in dry and arid regions (Josephrajkumar et al. 2022). Moreover, it is used in soil conservation studies and as a cover crop due to its capability to recover soil fertility and structure (Balehegn et al. 2022).

Tephrosia nubica is a leguminous shrub species grows up to 2 meters tall and has a wide range of uses in agriculture, environmental conservation, and traditional medicine. The plant is known by its dark green leaves and purple flowers that bloom after periods of rainfall (Jongbloed 2003). *T. nubica* is used in traditional medicine to treat illnesses like fever, stomach disorders, and malaria (Al-Yousef et al. 2020). The plant is also used in the agriculture field as a cover crop and green manure, as it is able to fix nitrogen in the soil, therefore enhancing soil fertility (Coulot and Coulot 2023).

Senna angustifolia is a perennial shrub that grows up to 1 meter tall and is native to India, Pakistan, United Arab Emirates, and Sudan (Jongbloed 2003). The plant is characterized by its narrow, stretched leaves and yellow flowers that bloom after rainfall. *S. angustifolia* is widely cultivated for its medicinal characteristics, mainly as a natural laxative. Additionally, *S. angustifolia* has been used in traditional medicine to treat a wide range of diseases, including arthritis, ever, and skin diseases (Vali et al. 2020).

Acacia tortilis, or Umbrella Thorn Acacia, is a tree species that is native to The Middle East and Africa (Or and Ward 2003). It is known by its unique umbrella-like shape and sharp, long thorns that protect it from herbivores. *A. tortilis* has traditional medicine and modern agriculture uses. The tree is also significant in agroforestry and land management systems, as it is able to fix nitrogen in the soil, improve soil fertility, and provide shelter for livestock (Al-Shaharani and Shetta 2011). Moreover, the tree has multiple environmental benefits including, preventing soil erosion, providing habitat for wildlife, and helping to minimize desertification (Omer et al. 2022).

Senna occidentalis, also known as Negro coffee or coffee senna, is a shrub species that is native to tropical regions of Africa, Asia, and the Americas (Nde et al. 2022). It grows up to 2 meters tall and is known by its green, feathery leaves and yellow flowers that bloom in the summer (Jongbloed 2003). The plant has been shown to have insecticidal abilities, making it a unique natural pest control studies and applications (Lusweti et al. 2023).

Abutilon pannosum, or velvetleaf abutilon, is a perennial shrub species that is native to Asia and South America. It is recognized by its soft, velvety leaves and bright yellow flowers that bloom during the year (Jongbloed 2003).In traditional medicine, the plant has been used to treat digestive and respiratory issues, and leaves are steeped to make tea that is alleged to have antioxidant and anti-inflammatory properties (Arbat 2012). In horticulture, *A. pannosum* is grown as a decorative plant due to its pretty leaves and flowers. It is also used in landscaping, as it is drought-resistant and able to grow in a multiple soil type (Roba and Oba 2009).

Prosopis cineraria, also known locally in the UAE as the "Ghaf" tree, is a species of small, thorny tree native to arid regions of the Indian subcontinent and the Middle East (Garg and Mittal 2013). It is known for its deep roots and feathery green leaves, both characteristics that are important for the survival under harsh desert conditions (Jongbloed 2003). The tree has essential uses in traditional medicine. Various parts of the tree like leaves, bark, and pods have been used to treat a variety of conditions, including asthma, digestive disorders, and skin diseases (Janbaz et al. 2012). In agriculture, the tree is used for soil stabilization and land restoration (Gupta et al. 1998). *P. cineraria* is also an important source of honey, as bees are enticed to its aromatic flowers (Afifi and Al-rub 2023).

Crotalaria persica, also known as *Persian crotalaria*, is a shrub that is native to Asia and some parts of the Middle East. It is known by its green, spear-shaped leaves and yellow flowers that flourish in the summer (Jongbloed 2003). In traditional medicine, the plant has been used to treat illnesses like skin condition, fever, and respiratory infections. Its seeds are used as a de-wormer, to remove parasitic worms from the body (Bhatt et al. 2016). In modern agriculture, *C. persica* is used as green manure due to its ability to improve soil fertility by nitrogen fixation. The plant has also been shown to have insecticidal abilities, making it a natural pest control method (Mathimaran et al. 2007).

Overall, all 9 species (Fig. 1) are valuable grass, shrub and tree species with a wide range of benefits for environment conservation, human health, and agriculture.

Collection sites

All species were collected from different locations in Al-Ain City (Fig. 2) (United Arab Emirates University main campus (24.2006°N, 55.6760°E), Al-Ain Zoo (24.1739°N, 55.7359°E), Local Plants Park Asharij (24.0718°N, 55.4523°E), and Mazyad district (24.1818°N, 55.6760°E). The seeds were collected from the trees and kept in their pods. The pods were then transferred in black plastic bags and stored at lab room temperature until the time of experiments.

Pretreatment methods

Each preliminary treatment was carried out as a distinct experiment, involving a total of 20 seeds for each of the specific four pre-treatments. These seeds were cleaned with a 15-minute soak in 5% bleach solution, then placed in 9 cm petri dishes with one layer of filter paper at the bottom. Each pre-treatment was repeated five times (total of 100 seeds per species per treatment). During the 14-day germination trial, the seeds were monitored for germination and sprayed with distilled water as necessary. All the petri dishes were maintained in an incubator set at a temperature of 24°C with continuous darkness. Germination progress was recorded every afternoon at 3 pm, and the germinated

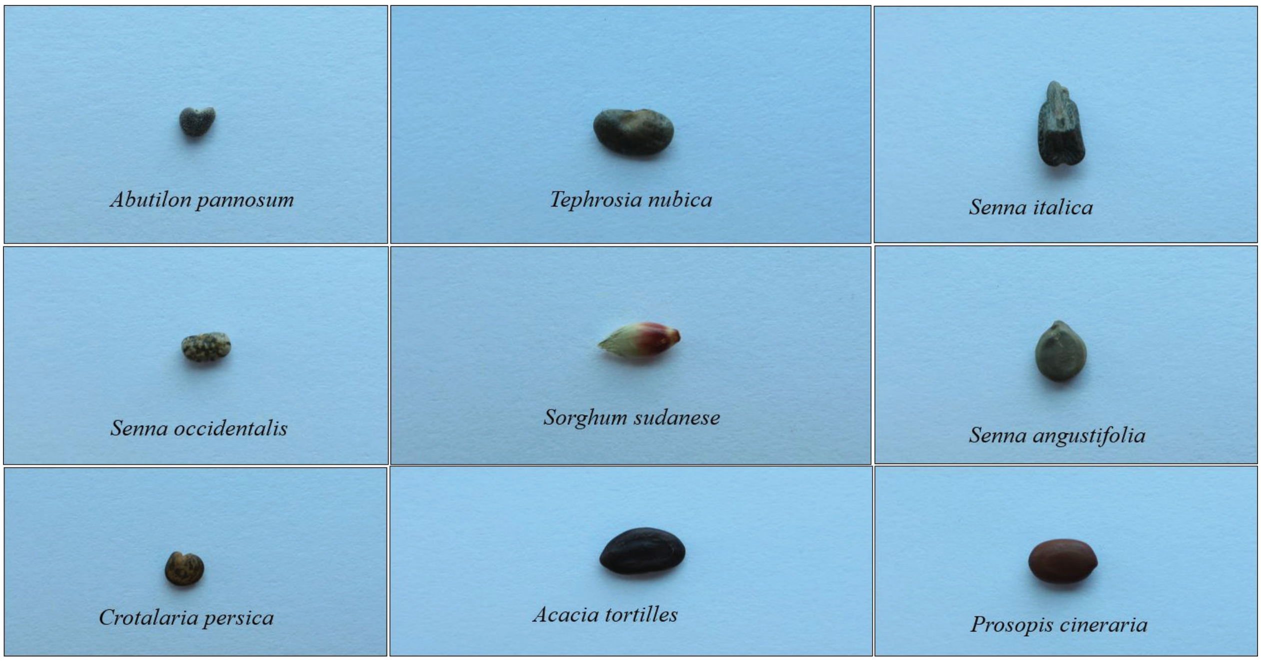

Figure 1. Plant seeds used in the study.

Figure 2. United Arab Emirates map. The squares represent the 4 collection cites of the seeds inside Al-Ain City. Maps were generated by RStudio softwere Version: 2023.09.1+494.

seeds were discarded from the petri dishes after counting. On the 9th day, any remaining seeds were cleansed again with the 5% bleach solution, and the filter papers were replaced to prevent bacterial and fungal growth.

The pretreatments that were examined included manually chipping with nail clippers across the seed (Mchip), soaking in tap water for 24 hours (Soak), and exposure to sulfuric acid (96% H_2SO_4) for two durations of 15 and 30 minutes (SAcid15, SAcid30). All these groups were compared against a controlled treatment (Control), which included the disinfecting step of the seeds only.

Germination parameters calculations and equations

Six germination parameters were assessed according to the formulas listed by Al-Ansari and Ksiksi (2016)(Table 1).

Table 1. Six germination parameters assessed according to the formulas listed by Al-Ansari and Ksiksi (2016).

Parameter	Equation
Final Germination Percentage (G)	$\frac{\textit{total seeds germinated at end of trial}}{\textit{number of initial seeds used}} \times 100$
Mean Germination Time (MGT)	$\frac{\sum Fx}{\sum F}$; where F is the number of seeds germinated on day x
Mean Germination Rate (MGR)	$\frac{CV}{100} = \frac{1}{T}$; where T is mean germination time and CV: coefficient of velocity.
Coefficient of Velocity of Germination (CVG)	N1+N2….Ni/100 × N1T1+….NiTi ; where N is the number of seeds germinated every day and T is the number of days from seeding corresponding to N
Daily Germination Percentage (MDG)	= percentage of full seed at the end of test divided by the number of days to the end of the test
Germination Index (GI)	(20×N1) +(19×N2)+….+(1×N20); where N1,N2….N20 is the number of germinated seeds in the first, second and subsequent days until 20th day and the multipliers (e.g. 20,19…etc.) are weights given to the days of the germination.

Statistical analysis

One-way ANOVA was used to compare the means of each treatment per species. For all comparisons, Dunnett's method was used for P-value adjustments. All statistical analysis and graphs were generated using different packages available in RStudio software (Version: 2023.09.1+494.)

Results

The mean values of six germination parameters for nine flowering species are illustrated in Figs 3–8. These values were influenced by four treatments: Mechanical Chipping (Mchip), 24-hour Soaking in tap water (Soak), Sulfuric Acid exposure for 15 minutes (SAcid15), and 30 minutes (SAcid30). One-way ANOVA and Post Hoc tests were applied to compare the means of the Control against the four treatments, and significant differences ($P < 0.001$) were marked on the graphs with letters.

Germination percentage (G)

Fig. 3 shows that Final Germination Percentage (G) significantly improved ($P < 0.001$) in seven species (100% in *S. italica*, 98% in *S. sudanense*, 97% in *T. nubica*, 99% in *S. angustifolia*, 98% in *A. tortilis*, 99% in *P. cineraria*, and 93% in *C. persica*) with Mchip and SAcid30 (1.124% in *S. italic*, 28% in *S. sudanense*, 3% in *T. nubica*,82% in *S. angustifolia*, 96% in *A. tortilis*, 99% in *P. cineraria*, and 25% in *C. persica*), three species (1.562% in *S. italic*, 28% in *S. Sudanense*, 3% in *T. nubica*, 62% in *S. angustifolia*, and 62% in *P. cineraria*) with (SAcid15), and only two species (3% in *T. nubica* and 5% in *A. tortilis*) with Soak.

Mean germination rate (MGR)

For Mean Germination Rate (MGR), as illustrated in Fig. 4, significant improvement was detected in seven species (0.892 days in *S. italica*, 0.68 days in *S. sudanense*, 0.586 in *S.angustifolia*, 0.844 days in *A. tortilis*, 0.568 days in *A. pannosum*, 0.972 days in *P. cineraria*, and 0.78 days in *C. persica*) with SAcid30, four species with SAcid15 (0.654 days in *S. italica*, 0.428 days in *S. angustifolia*, 0.456 days in *A. tortilis*, and 0.502 days in *A. pannosum*), and one species (0.674 days in *S. angustifolia*) with Mchip. Soaking did not yield a significant enhancement in this parameter for any of the species.

Mean germination time (MGT)

Fig. 5 exhibits that Mean Germination Time (MGT) significantly improved in seven species (0.892 days in *S. italica*,0.8 days in *T. nubica*, 1.778 days in *S. angustifolia*, 1.212 days in *A. tortilis*, 1.806 in *A. pannosum*, 1.03 days

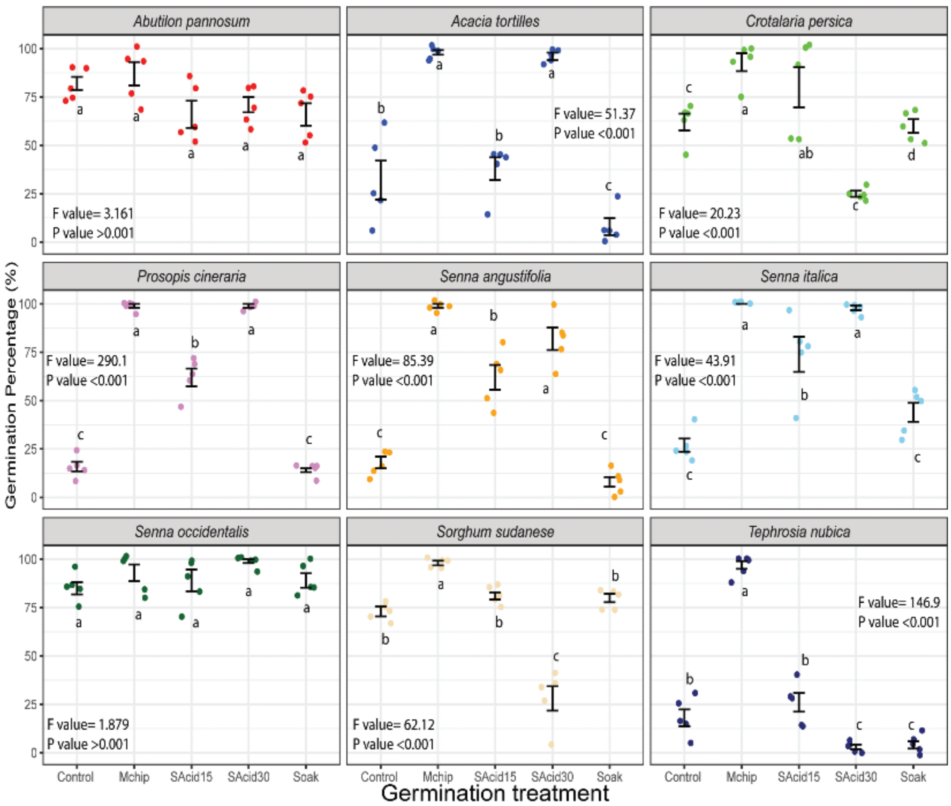

Figure 3. Final Germination Percentage (G) mean values for the nine flowering species, as affected by 5 treatments (Control, Mechanical chipping (Mchip), 24 h soaking (Soak), Sulfuric Acid exposure for 15 minutes (SAcid15), and 30 minutes (SAcid30). The scatter plots represent the Mean values for each replica.

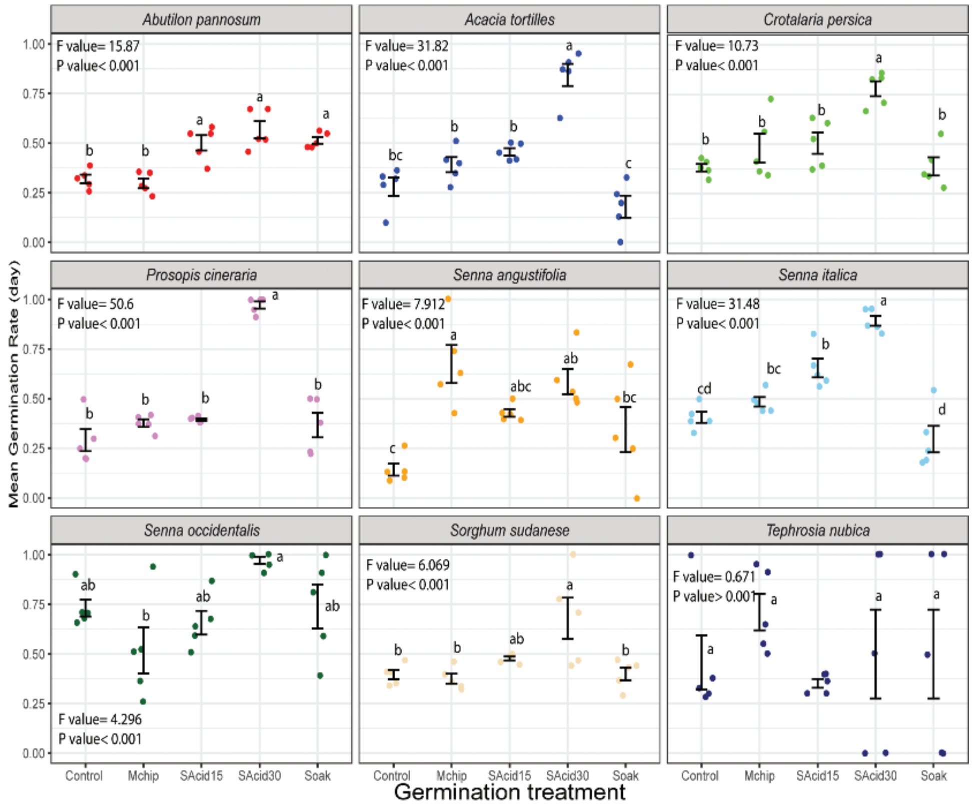

Figure 4. Mean Germination Rate (MGR) mean values for the nine flowering species, as affected by 5 treatments (Control, Mechanical chipping (Mchip), 24 h soaking (Soak), Sulfuric Acid exposure for 15 minutes (SAcid15), and 30 minutes (SAcid30). The scatter plots represent the Mean values for each replica.

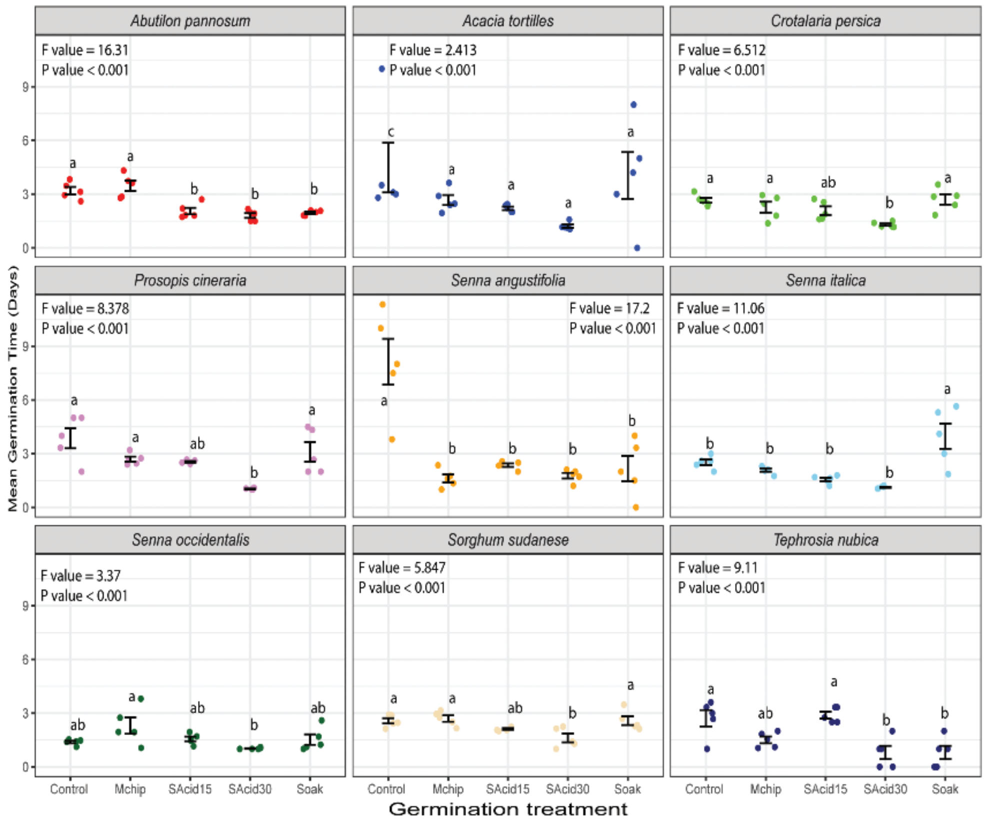

Figure 5. Mean Germination Time (MGT) mean values for the nine flowering species, as affected by 5 treatments (Control, Mechanical chipping (Mchip), 24 h soaking (Soak), Sulfuric Acid exposure for 15 minutes (SAcid15), and 30 minutes (SAcid30). The scatter plots represent the Mean values for each replica.

in *P. cineraria*, and 1.294 in *C. persica*) with SAcid30, four species (3.98 days in *S. italica*, 0.8 days in *T. nubica*, 2.166 days in *S. angustifolia*, and 1.954 days in *A. pannosum*) with Soak, four species (1.954 days in *A. pannosum*, 0.8 days in *T. nubica*, 3.98 days in *S. italica*, and 2.166 days in *S. angustifolia*) with SAcid15, and one species (1.61 days in *S. angustifolia* with Mchip.

Coefficient of velocity of germination (CVG)

Coefficient of Velocity of Germination (CVG), displayed in Fig. 6, showed significant improvement in six species (58.54% in *S. angustifolia*, 84.344% in *A. tortilis*, 56.62% in *A. pannosum*, 97.23% in *P. cineraria*, and 78.094% in *C. persica*) with SAcid30, four species (65.336% in *S. italica*, 42.738% in *S. angustifolia*, 45.6.4 in *A. tortilis*, 56.62% in *A. pannosum*, 97.23% in *P. cineraria*, and 78.094% in *C. persica*) with Acid15, and two species (65.336% in *S. italica*, 67.252% in *S. angustifolia*, with Mchip and only one species (51.368% in *A. pannosum*) with Soak.

Mean daily germination percentage (MDG)

In Fig. 7, Mean Daily Germination Percentage (MDG) significantly improved in six species (12.324% in *S. italica*, 9.046% in *S. Sudanense*,15.256% in *S. angustifolia*, 16.042% *T.nubica* ,34.061% in *A. tortilis*, 8.234% in *P. cineraria*, and 5.884% in *C. persica*) with Mchip and six species (18.4%% in *S. italica*, 3% *S. Sudanense*, 0.5% in *T. nubica*, 4.426% in *S. angustifolia*, 17.334% *A. tortilis*, 19.5% in *P. cineraria*, and 4.3% in *C. persica*) with SAcid30, three species (11.05% in *S. italica*, 7.268% *S. angustifolia*, and 5.168% at *P. cineraria*) with SAcid15, and only species (0.7% in *T. nubica*) with Soak.

Germination index (GI)

Lastly, Germination Index (GI), shown in Fig. 8, significantly improved in six species (7.14 days in *S. italica*, 6.928 days in *T. nubica*, 7.07 days *S. angustifolia*, 7 days in *A. tortilis*, 7.07 days in *P. cineraria*, and 4.426 days in *C. persica*) with Mchip, five species (7 days in *S. italica*, 5.856 days in *S. angustifolia*, 6.858 days in *A. tortilis* , 5.07 days in *A. pannosum*, and 7.07 days in *P. cineraria*) with Acid30, four species (5.286 days in *S. italica*, 4.426 days in *S. angustifolia*, 5.07 days in *A. pannosum*, 7.07 days in *P. cineraria*, and 5.714 days in *C. persica*) with Acid15, and only one species (4.714 days in *A. pannosum*) with Soak.

Overall, each species established an improvement in at least one germination parameter with the use of all pretreatment methods. Notably, *S. occidentalis* was the only species that did not show significant changes in germination parameters after each treatment.

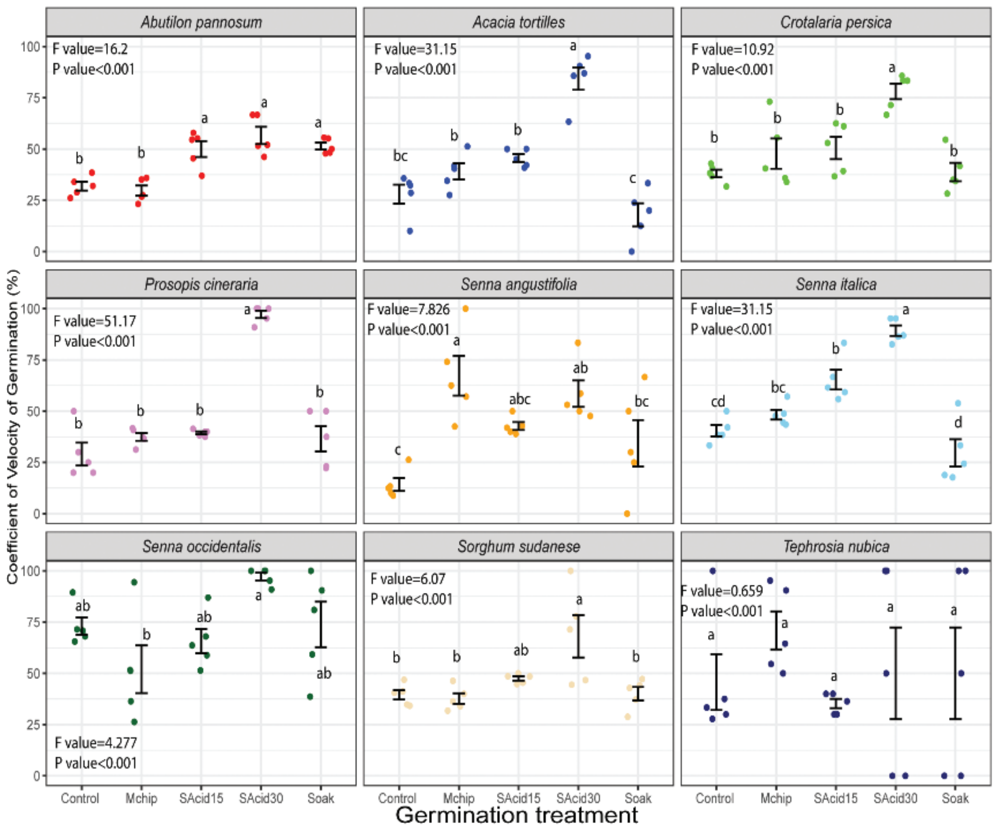

Figure 6. Coefficient of Velocity of Germination (CVG) mean values for the nine flowering species, as affected by 5 treatments (Control, Mechanical chipping (Mchip), 24 h soaking (Soak), Sulfuric Acid exposure for 15 minutes (SAcid15), and 30 minutes (SAcid30). The scatter plots represent the Mean values for each replica.

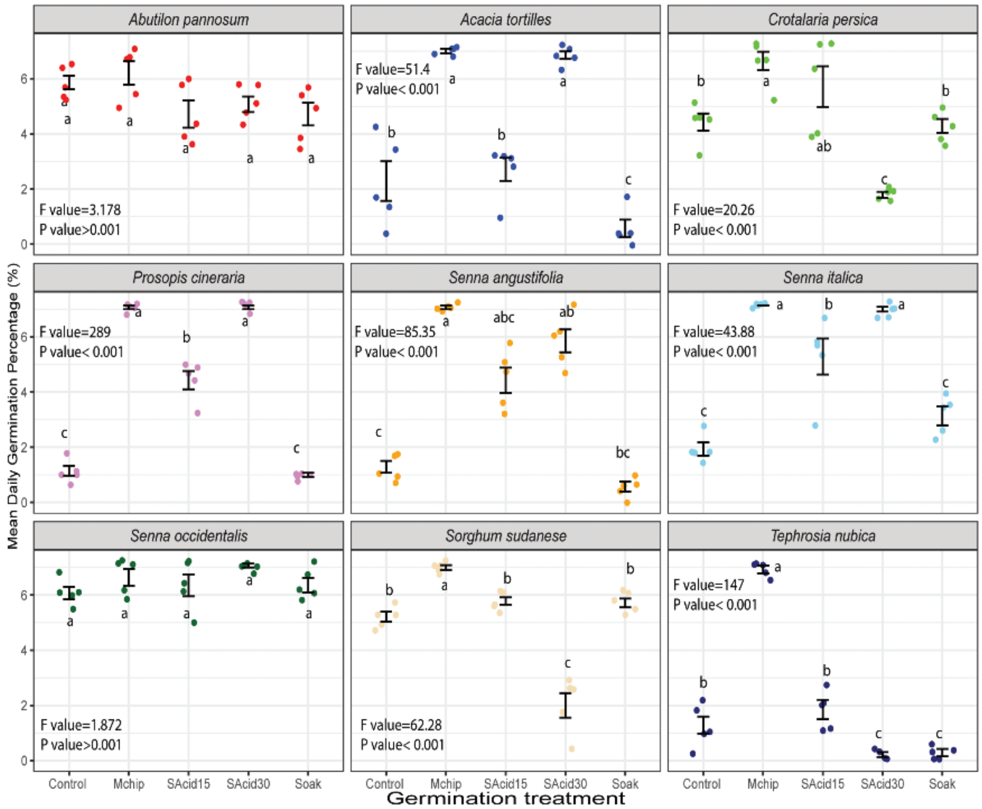

Figure 7. Mean Daily Germination Percentage (MDG) mean values for the nine flowering species, as affected by 5 treatments (Control, Mechanical chipping (Mchip), 24 h soaking (Soak), Sulfuric Acid exposure for 15 minutes (SAcid15), and 30 minutes (SAcid30). The scatter plots represent the Mean values for each replica.

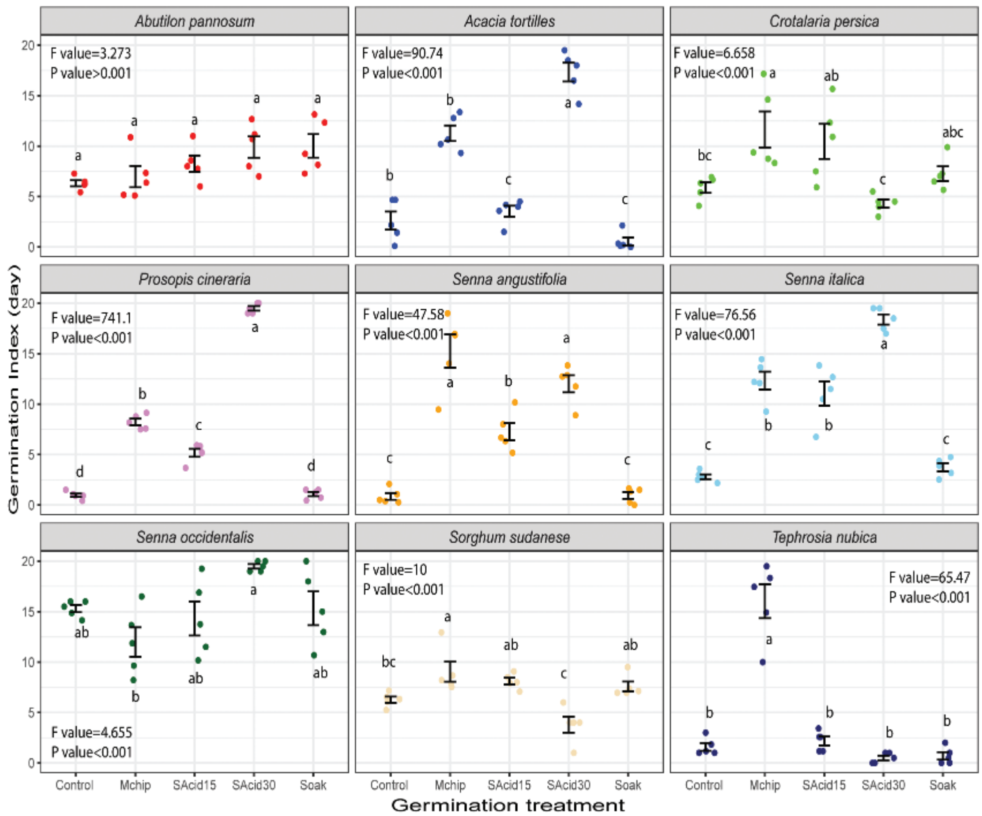

Figure 8. Germination Index (GI) mean values for the nine flowering species, as affected by 5 treatments (Control, Mechanical chipping (Mchip), 24 h soaking (Soak), Sulfuric Acid exposure for 15 minutes (SAcid15), and 30 minutes (SAcid30). The scatter plots represent the Mean values for each replica.

Discussion

In this research study, our primary objective was to identify the most effective pretreatment method for optimizing the germination of nine native flowering species in the arid conditions of the UAE. These species are characterized by strong seed coatings, an adaptation to survive in challenging environmental conditions that inhibit the introduction of germination. Our research addresses a critical need for understanding dormancy-breaking methods, offering implications for agricultural and reforestation strategies and contributing to the conservation of native species to lessen the risk of extinction.

Scarification and soaking, broadly recognized in the literature, regularly establish operational rates of improved germination and are particularly relevant to the conditions prevalent in the UAE.

We demonstrated a comprehensive collection of germination parameters, each providing distinct insights into various aspects of the germination process. Final Germination Percentage offered a complete assessment of overall success, while Mean Germination Time and Mean Germination Rate added insights into the timing and speed of germination, respectively. The Coefficient of Velocity of Germination helped to provide a detailed analysis of germination timing, while Germination Rate Index and Germination Index served as complete measures reflecting both uniformity and speed of germination.

Our methodology involved the application of these parameters to gain an understanding of the germination process under four distinct pretreatment methods. Mechanical scarification (Mchip) and Sulfuric Acid are particularly effective, enhancing at least one germination parameter in all species except *S. occidentalis*. Sulfuric Acid (Acid15) demonstrated effectiveness in improving at least one germination parameter in six species: *S. italica*, *T. nubica*, *S. angustifolia*, *A. tortilis*, *A. pannosum*, and *P. cineraria*. Soaking in room temperature water for 24 hours (Soak) proved valuable in improving at least one germination parameter in five species, including *S. italica*, *T. nubica*, *S. angustifolia*, *A. tortilis*, and *A. pannosum*.

While mechanical scarification is time consuming, our findings place it as the safest and most effective pretreatment method, given its simplicity and accessibility. This method demonstrated positive outcomes for eight out of the nine species studied. Sulfuric acid is the second most effective pretreatment method, mainly beneficial when a large quantity of seeds is required simultaneously. Although soaking displayed the lowest rate of germination improvement, its application could be considered for species showing significant differences in response.

Conclusion

In conclusion, our study provides valuable insights into the efficacy of various pretreatment methods, with the optimal choice dependent upon the specific species, available resources, and time restraints. This understanding contributes to the broader field of plant germination strategies, offering practical guidance for sustainable agriculture, reforestation, and biodiversity conservation efforts. The implications of our findings extend to both academic and practical domains, enhancing our understanding of plant physiology and facilitating informed decision-making in applied settings.

Authors contribution

Taoufik Ksiksi created the experimental design. Nour Debouza was responsible for seed collection, lab preparation for the experiments, generating graphs, and writing the initial draft of the manuscript. Sunil Mundra and Iltaf Shah helped with statistical analysis and editing.

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