FORESTRY IDEAS, 2021, vol. 27, No 2 (62): 380–395

# EVALUATION OF DORMANCY-BREAKING TREATMENTS ON SEED GERMINATION OF TWO LEGUMINOUS TREE SPECIES FROM CHOBE DISTRICT, NORTHERN BOTSWANA

Witness Mojeremane[1*], Kamogelo Makgobota[1], Thembinkosi Mathowa[2], Kakambi Obusitswe[3], Melusi Rampart[1], Demel Teketay[1], Gosiame Neo-Mahupeleng[4], Topoyame Makoi[1], and Ronnie Mmolotsi[1]

[1]Department of Range and Forest Resources, Faculty of Natural Resources, Botswana University of Agriculture and Natural Resources, Private Bag 0027, Gaborone, Botswana.
[*]E-mail: wmojerem@buan.ac.bw; wmojeremane@yahoo.com
[2]Department of Crop and Soil Sciences, Faculty of Agriculture, Botswana, University of Agriculture and Natural Resources, Private Bag 0027, Gaborone, Botswana.
[3]Department of Forestry and Range Resources, Ministry of Environment, Natural Resources Conservation and Tourism, P.O. Box 140, Kasane, Botswana.
[4]Department of Wildlife and Aquatic Resources, Faculty of Natural Resources, Botswana University of Agriculture and Natural Resources, Private Bag 0027, Gaborone, Botswana.

Received: 10 June 2021 Accepted: 02 November 2021

## Abstract

Seed germination experiments were conducted at Botswana University of Agriculture and Natural Resources to determine the best possible pre-sowing treatment methods that maximize seed germination of *Albizia versicolor* and *Faidherbia albida*. The experiments were laid out in a completely randomized design (CRD) with 10 pre-sowing treatments, namely the control, mechanical scarification, soaking in concentrated sulphuric acid with four levels of time exposure (15, 30, 45 and 60 min), immersion in boiling water with three levels of time exposure (1, 3 and 5 min) and soaking in hot water (allowed to cool for 24 h). Treated seeds were germinated for 30 days at room temperature (25 °C). The raw data were subjected to analysis of variance (ANOVA). The results showed that seeds treated mechanically, sulphuric acid (all levels), boiling water (1 and 3 min) and hot water had significantly ($p$ < 0.01) higher mean germination percentages than the control and boiling water (5 min) for *A. versicolor*, whereas for *F. albida* seeds treated mechanically and exposed to sulphuric acid (all levels) had significantly ($p$ < 0.01) higher mean germination percentages than the rest. Significant ($p$ < 0.01) mean germination time and index were revealed among the treatments for the two species.

**Key words:** *Albizia versicolor, Faidherbia albida*, germination index, germination mean time, germination percentage.

## Introduction

Natural forests and woodlands play a vital role in the existence and survival of most of the living organisms in Botswana and other parts of the world (Nduwayezu et al. 2015). They perform multiple functions, such as biodiversity and ecosystem conservation, and beautifying landscapes. In addition, they provide numerous goods to mankind and protect the environment (Watson and Dlamini 2003). Despite their importance, indigenous trees and shrubs have not been promoted in afforestation programmes in Botswana because information on their management is limited.

However, in recent years, there has been some effort to use indigenous trees and shrubs in planting programmes in Botswana. The Department of Forestry and Range Resources has been gradually introducing indigenous trees and shrubs in planting programmes as a way of maintaining or restoring the genetic and ecological integrity of local ecosystems. The planting of indigenous tree and shrub species in Botswana is also hindered by lack of information on their seed germination and growth requirements. For this reason, there has been a renewed interest in evaluating seed factors of indigenous trees and shrubs with a view to increase their propagation in the nursery. Seeds of trees and shrubs of arid lands often exhibit poor germination in the nursery and fields, partly because they are constrained by physical dormancy or hard seed coats that are impermeable to water and gaseous exchange (Baskin et al. 2000; Baskin and Baskin 2004, 2014; Linkies et al. 2009; Smýkal et al. 2014).

*Albizia versicolor* Welw. ex Oliv. (syn. *Albizia mossambicensis* Sim) belongs to the Fabaceae family (Venter and Venter 2016). It is native to Africa, distributed from the Democratic Republic of Congo to Kenya and south to South Africa and Angola (Palgrave 2002**),** and found in various types of open deciduous woodlands and grasslands up to 1700 m a.s.l. (Lemmens 2007). It is a multipurpose tree that provides numerous goods and services to local communities (Storrs 1995, Rukunga and Waterman 2001, Lemmens 2007, Venter and Venter 2016). The wood is locally used for small boats, tool handles, mortars and other kitchen implements, containers, casks, and musical instruments. It is suitable for light construction, light flooring, joinery, furniture, cabinet work, decorative work, veneer, plywood, draining boards, hardboard, and particle board. It is also used as firewood and for charcoal production. The bark has been used for tanning and the flowers serve as a source of nectar for honeybees. The inner bark is used for making rope. Roots boiled with water can be used as a substitute for soap. The species is planted as ornamental shade tree. Root and bark decoctions are used as an anthelmintic and purgative, and to treat swollen glands and venereal diseases. Dried and powdered roots are taken or sniffed to treat headache and sinusitis, and root maceration is taken against gonorrhoea. A bark decoction is used to treat anaemia, and it is applied externally to treat ophthalmia and skin rash. Bark maceration is taken against cough, and bark powder is sniffed for the same purpose (Lemmens 2007). The roots develop nodules containing nitrogen-fixing bacteria and therefore, *A. versicolor* has a good potential for planting in agroforestry systems.

*Faidherbia albida* (Delile) A. Chev. (Syn. *Acacia albida*) is a multipurpose leguminous woody tree that belongs to the family Fabaceae (Palgrave 2002, Koech et al. 2014, Venter and Venter 2016). It is widely distributed throughout Africa, from Senegal to Ethiopia and south through Kenya and Malawi into South Africa (Danthu et al. 2002, Orwa et al. 2009, Chuyong and Acidri 2015) and in the Middle East in Israel, Lebanon, Oman, Palestine, Saudi Arabia, Syria, and Yemen (Boffa 1999, Barnes and Fagg 2003, Sileshi et al. 2020). *F. albida* is well-adapted to a wide variety of soils (Ameri and Daldoum 2017) at low-medium altitudes (270–2700 m a.s.l.) (Barnes and Fagg 2003) in areas with mean annual rainfall of 250–1200 mm and temperatures of 18–30 ºC (Orwa et al. 2009).

*Faidherbia albida* has many uses, including in agroforestry systems, apiculture, charcoal, fodder, fuelwood and gums production, as well as for making ropes, as soap substitute and source of medicine (Teketay 1996a). The trees shed leaves during the start of the rainy season and re-grow them in the dry season, a phenomenon termed reverse phenology (Roupsard et al. 1999, Barnes and Fagg 2003, Sileshi et al. 2020), which allows farmers to grow crops under the trees during the rainy season without competition for water, light or nutrients (Roupsard et al. 1999, Ibrahim and Tibin 2003, Gassama-Dia et al. 2003, Haskett et al. 2019). Unlike other trees, *F. albida* remains leafless during the wet season and, thus, it hardly competes with crops for light and water, while it provides a microclimate favourable for growing crops (Boffa 1999, Barnes and Fagg 2003, Sileshi et al. 2020). The presence of trees in crop fields has been shown to increase yields, a phenomenon termed the 'albida effect' (Boffa 1999, Sileshi et al. 2020). This refers to better growth of crops or herbaceous plants under its canopy than in an open field (Akpalu et al. 2020). This phenomenon has been attributed to a combination of factors including improved soil physical and chemical properties (Akpo et al. 2005) reduced soil and air temperatures, symbiosis with rhizobium and arbuscular endomycorrhizae, termite activity and improved nutrient recycling (Haskett et al. 2019, Sileshi et al. 2020).

The green leaves of *Faidherbia albida* are also rich in protein and carbohydrates, providing a valuable fodder for livestock during the dry season. Pods fall towards the end of the dry season over a period of months, and these are consumed by livestock when other fodder is scarce. Crop yield improvement is the most important benefit of *Faidherbia*-based agroforestry systems, and additional benefits include fodder and fuelwood (Sileshi et al. 2020).

Seed dormancy is a mechanism that prevents seeds from germinating when exposed to suitable moisture, oxygen and soil conditions (Olmez et al. 2008, Rezvani et al. 2021). Seed dormancy is a bottleneck to propagating seeds of woody plants in arid and semi-arid areas. Seeds of woody plants of arid and semi-arid areas are characterised by physical dormancy or thick, tough seed coats impermeable to water and gaseous exchange (Baskin et al. 2000; Baskin and Baskin 2004, 2014; Linkies et al. 2009; Smýkal et al. 2014), which causes delayed and poor germination in the natural environment. Seed dormancy is cause of delayed and sporadic germination in many plants (Slator et al. 2013) and allows plant species to synchronize their germination with availability of favourable environmental conditions, which increases their chances of survival and establishment (Baskin and Baskin 2014, Renzi et al. 2020).

In nature, hard seed coats are scarified by fires (Mbalo and Witkowski 1997, Walters et al. 2004, Briggs and Morris 2008), fluctuating temperatures (Probers 1992), digestive acids in animal stomachs or abrasion by blowing sand (Russi et al. 1992), soil acids and soil organisms (Bewley and Black 1994). There are several methods used to help overcome seed dormancy. Different scarification methods that include mechanical, acid, as well as cold, hot and boiling water, have been used successfully to break seed dormancy and enhance germination (Teketay 1996a, 1996b, 1998, 2005; Morris et al. 2000; Alamgir and Hossain 2005; Cetinbas and Koyuncu 2006; Fang et al. 2006; Cirak et al. 2007; Al Absi 2010; Azad et al. 2011; Rasebeka et al. 2014; Fredrick et al. 2017; Mojeremane et al. 2017, 2018, 2020; Maldonado-Arciniegas et al. 2018; Opoku et al. 2018; Botumile et al. 2020).

Scarification methods break seed dormancy within a relatively short period of time (Tadros et al. 2011; Mojeremane et al. 2017, 2018; Odirile et al. 2019; Setlhabetsi et al. 2019), thereby improving germination. Each scarification method has advantages and disadvantages, which depend on the plant species. There is little information on the effect of pre-sowing treatments on breaking dormancy, and the germination response in indigenous trees and shrubs in Botswana. Therefore, the objective of this study was to evaluate characteristics of the seeds and identify the best scarification pre-sowing treatments that result in the fastest and highest, as well as uniform germination of *A. versicolor* and *F. albida*.

## Materials and Methods

### Study site

The study was carried out in the laboratory at the Botswana University of Agriculture and Natural Resources (BUAN) from January to February 2020. BUAN is located at Sebele (latitude 23°34' S and longitude 25°57' E, altitude of 994 m a.s.l.), about 10 km from the centre of Gaborone, the capital city of Botswana, along the A1 North-South highway.

### Collection of seed material

Seeds were collected from several mother trees during August 2018 and September 2019 at Kazungula village in the Chobe district, Botswana. Closed *F. albida* pods were picked from the ground under mother trees. For *A. versicolor*, closed pods were collected from tree crowns by shaking with long-hooked sticks. The pods were placed in paper bags and transported to the Department of Range and Forest Resources at BUAN for processing. At BUAN, seeds were extracted by crushing the pods using hands, followed by winnowing to separate the husk. Seeds were kept refrigerated at 5 °C until the experiments were initiated.

### Experimental design and treatments

The experiments were laid out in a completely randomized design (CRD) with 10 pre-sowing treatments, namely the control, mechanical scarification, soaking in concentrated sulphuric acid with four levels of time exposure (15, 30, 45 and 60 min), immersion in boiling water with three levels of time exposure (1, 3 and 5 min), and soaking in hot water (allowed to cool for 24 h). Treated seeds were germinated for 30 days at room temperature (25 °C). Before the experiment, seed viability was tested using a floatation method. This involved soaking seeds in water for few minutes and those that sank were regarded as viable, while those that floated were deemed unviable and not suitable for the experiments.

### Mechanical scarification

In this treatment, 100 seeds of the study species with four replications of 25 seeds each were used. The seeds were scarified by using a pair of scissors to cut away 1–2 mm of the seed coat on a convex edge opposite where the embryo is located. Cutting of the seed coat was carried out with care to avoid damaging the cotyledons.

### Sulphuric acid scarification

Four levels of time exposure (soaking) of seeds in concentrated sulphuric acid (98 %), i.e. 15, 30, 45 and 60 min, were used by applying the method described by Teketay (1996a). For each soaking time, four replicates of 25 seeds each were put into four 100 ml, heat-resistant, non-corrosive glass beakers containing sulphuric acid by making sure that all the seeds were covered by the acid. Seeds were hand stirred every five minutes during the specific soaking time to ensure they were uniformly exposed to the acid. After the specified periods of soaking, the seeds were sieved out of the acid using an acid-resistant sieve, while the acid was drained off simultaneously into another beaker. Seeds were then thoroughly washed and rinsed to remove all the acid using tap water first and subsequently using distilled water, successively.

### Boiling water

Three levels of time exposure (soaking) of seeds of the two study species, i.e. 1, 3 and 5 min. to boiling water were used. For each level of soaking, four replicates of 25 seeds each were put into four separate coffee filter papers and immersed into a cooking pot with boiling water for the specified period. At the end of each soaking period, seeds were removed and immersed in a small bucket containing distilled water to cool them down for a few minutes before sowing.

### Hot water scarification

Four replicates of 25 seeds each were put into four separate coffee filter papers and placed into a 250 ml beaker. Boiling water was then poured into the beaker and left to cool for 24 h.

### Control

Four replicates of 25 untreated seeds each were used as control for the two species.

In all the treatments, each replicate, containing the 25 seeds, was placed in 8 mm closed petri dishes lined with cotton wool. The cotton wool was continuously kept moist by adding distilled water whenever necessary until the end of the experiments. Seeds were considered to have germinated when the radicle penetrated the seed coat and reached 1–2 mm. The number of germinating seeds was recorded daily for 30 days. Germinated seeds were removed from petri dishes after counting and recording.

Data collected on germinated seeds were used to calculate germination percentage (GP) as indicate in formula (1):

$$\mathrm{GP} = \frac{\text{Total number of seeds germinated}}{\text{Total number of seeds sown}} \cdot 100,\ \% \qquad (1)$$

The mean germination time (MGT) was calculated following the formula (2) by Bewley and Black (1994):

$$\mathrm{MGT} = \frac{\sum (j \cdot n_j)}{\sum n_j},\ \text{days} \qquad (2)$$

where: $j$ is the number of days starting from the date of sowing and $n_j$ is the number of seeds that germinated at the $j^{th}$ day from sowing.

The germination index (GI) was calculated using the equation (3) by Esechie (1994):

$$\mathrm{GI} = (G_{1/1}) + (G_{2/2}) + ... + (G_{x/x}), \qquad (3)$$

where: G is the germination day 1, 2, …, and $x$ represents the corresponding day of germination.

### Data analyses

The data collected were subjected to both descriptive statistics and One-way ANOVA using Statistix Software, Version 10 (Statistix 10, 1984–2003). Before the ANOVA, the germination percentage data were arcsine transformed to meet the requirement of normality (Zar 1996). Significant differences of means were tested using Tukey's Honestly Significant Difference (HSD) at the significance level of $p < 0.05$.

## Results

### Seed germination

Germination percentage (GP), mean germination time (MGT) and germination index (GI) for *A. versicolor* were significantly ($p < 0.01$) affected by pre-sowing treatments (Table 1). The highest GP was observed in seeds treated with sulphuric acid (15, 30, 45, 60 min) with 90.10 %, boiling water (1 and 3 min) with 90.10 % and mechanical scarification (90.10 %), hot water (allowed to cool for 24 h) with 89.12 % whereas the untreated/control seeds (66.65 %) followed by boiling water (5 min) exhibited the lowest GP. There were no statistically significant differences across the treatments with the highest GP. The MGT for *A. versicolor* varied among treatments from 1 to 19 days. The highest MGT of 19 days was recorded in the control/untreated seeds. The lowest MGT of one day was recorded in seeds treated with sulphuric acid (15 and 30 min). The highest GI of 0.83 was recorded in seeds treated with sulphuric acid (15, 30, 45 and 60 min), boiling water (1 and 3 min), mechanical scarification and hot water (allowed to cool for 24 h). The lowest GI of 0.49 was recorded in seeds treated with boiling water (5 min).

**Table 1. Effect of seed pre-treatment on germination parameters of *A. versicolor*.**

| Treatments | Germination parameters | | |
|---|---|---|---|
| | Germination, % | GMT, days | GI |
| Control | 66.65b | 19.00a | 0.63b |
| Mechanical scarification | 90.10a | 1.08e | 0.83a |
| Boiling water | | | |
| 1 min | 90.10a | 7.69b | 0.83a |
| 3 min | 90.10a | 4.07c | 0.83a |
| 5 min | 50.17c | 3.04cd | 0.49c |
| Sulphuric acid (98%) | | | |
| 15 min | 90.10a | 1.00e | 0.83a |
| 30 min | 90.10a | 1.00e | 0.83a |
| 45 min | 90.10a | 1.15de | 0.83a |
| 60 min | 90.10a | 1.18de | 0.83a |
| Hot water (allowed to cool for 24 h) | 89.12a | 9.30b | 0.83a |

Note: Means separated using Tukey's Honestly Significant Difference (HSD) Test at $p \leq 0.05$. Means within columns followed by the same letters are not significantly different (GMT is germination mean time, GI is germination index.

There were significant differences across treatments for GP, GMT, and G1 in *F. albida* seeds (Table 2). The highest GP (90 %) was recorded in seeds treated with sulphuric acid (15 and 60 min) followed by those treated with sulphuric acid (30 and 45 min) and mechanical scarification (89.12 %). However, there were no statistically significant differences among these treatments with the highest germination percentages. The lowest GP was recorded in seeds treated with hot water (allowed to cool for 24 h), boiling water (1 and 3 min), untreated seeds and boiling water for 5 min (Table 2) The MGT for *F. albida* seeds ranged from 2 to 22 days. The highest MGT (22 days) was recorded in seeds treated with hot water (allowed to cool for 24 h), while seeds treated with sulphuric acid (15, 30, 45 and 60 min) exhibited the lowest MGT ranging from 2 to 2.3 days. GI ranged from 0.08 to 0.83, and seeds treated with boiling water (5 min) exhibiting the lowest GI of 0.08. The highest GI of 0.83 was recorded in seeds treated with sulphuric acid (15, 30, 45 and 60 min) and mechanical scarification (Table 2).

**Table 2. Effect of seed pre-treatment on mean germination parameters of *F. albida*.**

| Treatments | Germination parameters | | |
|---|---|---|---|
| | Germination, % | GMT, days | GI |
| Control | 6.40b | 16.00a | 0.10b |
| Mechanical scarification | 89.12a | 3.01b | 0.83a |
| Boiling water | | | |
| 1 min | 13.49b | 18.55a | 0.17b |
| 3 min | 13.40b | 21.33a | 0.17b |
| 5 min | 5.61b | 17.50a | 0.08b |
| Sulphuric acid (98%) | | | |
| 15 min | 90.10a | 2.15b | 0.83a |
| 30 min | 89.12a | 2.31b | 0.83a |
| 45 min | 89.12a | 2.13b | 0.83a |
| 60 min | 90.10a | 2.00b | 0.83a |
| Hot water (allowed to cool for 24 h) | 14.26b | 22.24a | 0.18b |

Note: Means separated using Tukey's Honestly Significant Difference (HSD) Test at $p \leq 0.05$. Means within columns followed by the same letters are not significantly different (GMT is germination mean time, GI is germination index.

**Seed germination rate**

*Albizia versicolor* seeds treated with mechanical scarification and sulphuric acid (15, 30, 45 and 60 min) exhibited the fastest and uniform germination, reaching 90 % cumulative germination within three days of sowing, whereas the rest of the treatments were below 40 % (Fig. 1). Seeds treated with boiling water (1 and 3 min) and hot water allowed to cool for 24 h reached >80 % cumulative germination 18 days after sowing. Seeds treated with boiling water (5 min) and their untreated/control counterparts exhibited the lowest germination rate of just above 50 % cumulative over the 30 days of the study.

*Faidherbia albida* seeds treated with sulphuric acid (15, 30, 45 and 60 min) and mechanical scarification exhibited the fastest and uniform germination and reached >88 % cumulative germination

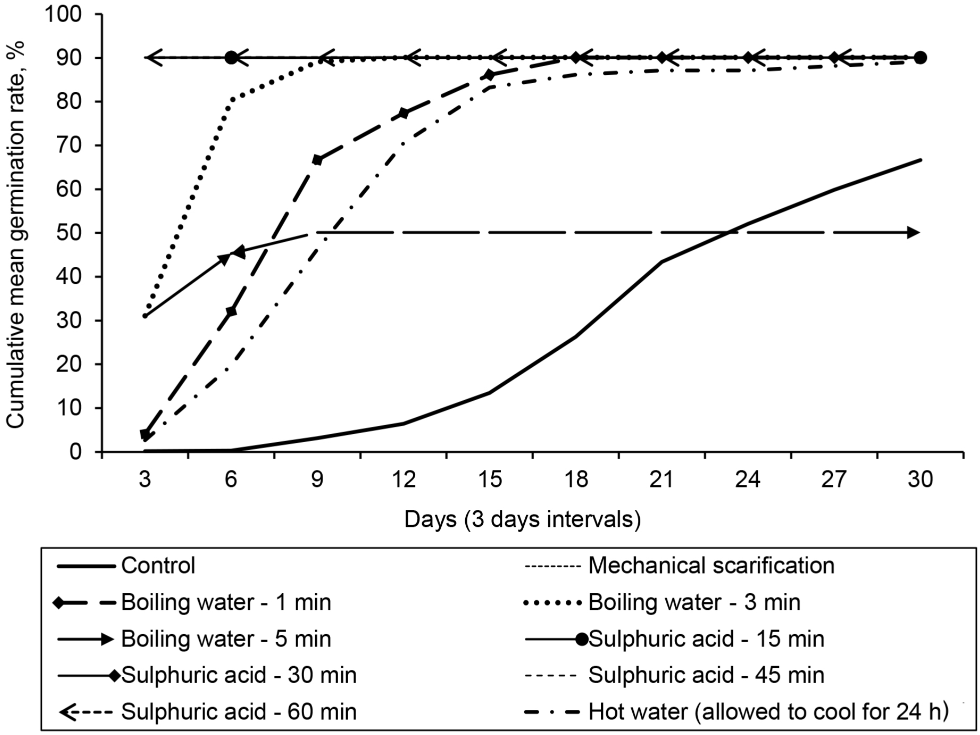


**Fig. 1. Cumulative mean germination rate of *A. versicolor* recorded over 30 days.**

within six days of sowing (Fig. 2). The untreated/control seeds and their counterparts treated with hot water allowed to cool for 24 h and boiling water (1, 3 and 5 min) exhibited not only the lowest GP, but also the slowest germination.

## Discussion

Poor germination is a common phenomenon in many tree and shrub species of arid lands, which limit their propagation in tree nurseries for use in planting programmes. The results of the present study show that seeds of *A. versicolor* and *F. albida* are characterised by hard seed coats, which are impermeable to water. Like in many other leguminous species (Amusa 2011, Aref et al. 2011, Smýkal et al. 2014), unscarified seeds of the two study species exhibited very low germination percentages. Therefore, breaking dormancy by cracking or softening the seed coat to allow imbibition and gaseous exchange is crucial in propagating tree and shrub seedlings in nurseries.

The results of the present study show that seed pre-sowing treatments affected GP, MGT and GI for both *A. versicolor* and *F. albida.* These results indicate that seeds of the two study species are characterized by physical dormancy, which was broken by mechanical and chemical pre-sowing treatments resulting in improved germination. Mechanical scarification, acid, boiling and hot water treatments improved germination of *A. versicolor* and *F. albida.*

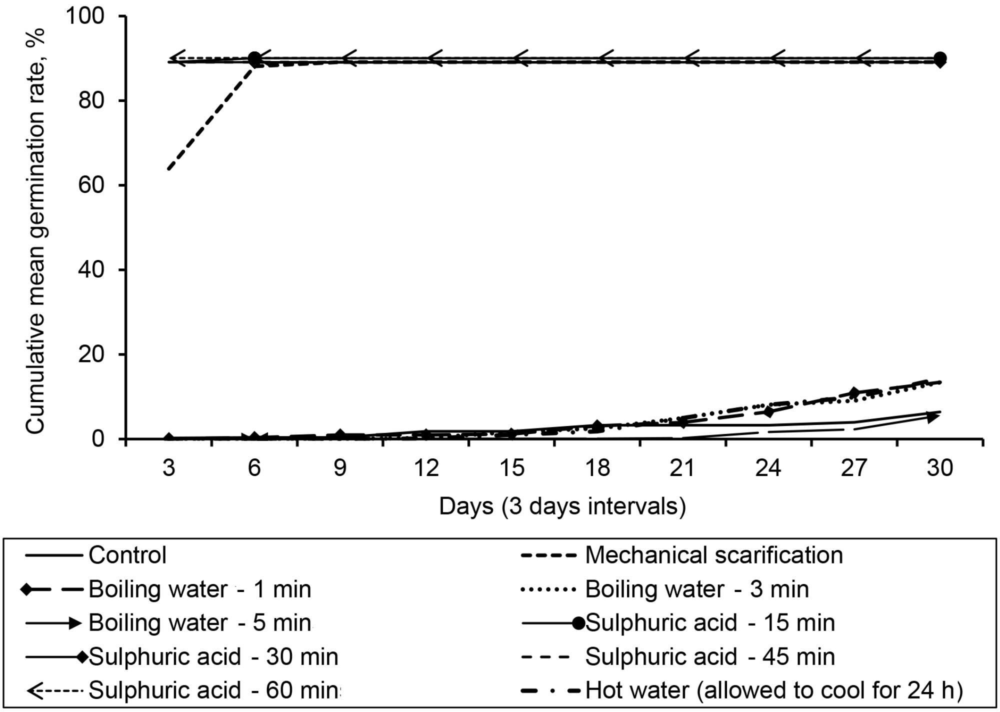


**Fig. 2. Cumulative mean germination rate of *F. albida* recorded over 30 days.**

Therefore, we can infer that seeds of the two studied species have physical dormancy imposed by hard seed coats. The hard seed coats are impermeable to water and gas-exchange, thus prevent the growth of the embryo (Nasr et al. 2013).

In this study, mechanical scarification significantly increased seed germination of *A. versicolor* and *F. albida* compared with untreated/control seeds. Mechanical scarification reduced MGT for *A. versicolor* and *F. albida* and exhibited higher GI than untreated/control seeds. The reduced MGT in mechanical scarification seeds could imply that dormancy in seeds was broken by partial cracking or cutting of the seed coat. Mechanical scarification create scars on the surface of the hard seed coat, thereby, increasing water imbibition, gas exchange and stimulating embryo expansion (Kmetz-Gontalez and Struve 2000, Azad et al. 2010, Olisa et al. 2010, Mwase and Mvula 2011, Jayasuriya et al. 2012). These results suggest that in nature very few seeds of *A. versicolor* and *F. albida* germinate due to hard seed coats.

The results are consistent with results of seed germination experiments conducted on several leguminous and other species (Danthu et al. 1995, Mackay et al. 1995, Diallo et al. 1996, Tigabu and Odén 2001, Baes et al. 2002, Shiferaw et al. 2004, Likoswe et al. 2008, Smýkal et al. 2014, Fredrick et al. 2017, Mojeremane et al. 2017, Müller et al. 2017, Botumile et al. 2020), which demonstrated that mechanical scarification is effective and efficient in enhancing seed germination. For example, Shiferaw et al. (2004) reported that mechanical scarification increased percent germination of *Prosopis juliflora* (Sw.) DC. seeds by 100 %. Diallo et al. (1996) and Fredrick et al. (2017) also reported increased percent germination in seeds of *F. albida* seeds treated by mechanical scarification.

Sulphuric acid (15, 30, 45 and 60 min.) increased germination of the two study species when compared with the control treatment. The sulphuric acid (15, 30, 45 and 60 min) treatment resulted in 89–90 % germination, reduced MGT and exhibited the highest GI for the two study species compared with untreated/control seeds. The highest percent germination observed in this treatment may have occurred because of the effectiveness of the acid in rupturing hard seed coats and speeding the imbibition process and gaseous exchange (Okunlola et al. 2011, Mojeremane et al. 2020), which resulted in rapid and uniform germination (Mojeremane et al. 2020). The fact that the sulphuric acid improved percent germination is an indication that the seed coat is a barrier to germination in *A. versicolor* and *F. albida.* An increase in percent germination, following sulphuric acid scarification, has also been reported in earlier seed germination studies conducted using leguminous and other species (Diallo et al. 1996; Teketay 1996a, 1998; Baskin et al. 1998; Baes et al. 2002; Righini et al. 2004; Finch-Savage and Leubner-Metzger 2006; Naim 2015; Fredrick et al. 2017; Odirile et al. 2019; Mojeremane et al. 2017, 2020; Botumile et al. 2020).

Hot water (allowed to cool for 24 h) was effective in increasing percent germination in *A. versicolor* compared with the untreated/control seeds. The hot water treatment reduced MGT and exhibited higher GI than the untreated seeds, which exhibited a MGT of 19 days and GI of 0.63. The improved germination could be attributed to the hot water, which softened the hard seed coat, resulting in water uptake, gaseous exchange, and stimulation of embryo expansion (Mwase and Mvula 2011). Odirile et al. (2019) reported that seeds soaked in hot water imbibe water and swell as the water cools. The hot water treatment substantially increased percent germination in *A. versicolor* seeds, as reported in other studies (Sajeevukumar et al. 1995, Tigabu and Oden 2001, Teketay 2005, Mwase and Mvula 2011, Odirile et al. 2019, São José et al. 2019, Botumile et al. 2020, Mojeremane et al. 2020). Hot water has been suggested as better, safe and cost-effective treatment when working with large numbers of seeds (Baes et al. 2002, Hopkinson and English 2004, Himanen et al. 2012). In contrast, the percent germination of *F. albida* seeds was not affected by hot water in this study. The lack of any increase in percent germination following hot water treatment has been reported in *F albida* elsewhere (Diallo et al. 1996, Ameri and Daldoum 2017, Fredrick et al. 2017) and other leguminous plants (Botsheleng et al. 2014; Hasnat et al. 2017, 2019; Mojeremane et al. 2017, 2020; Kanmegne et al. 2020).

The effect of boiling water on germination of different plant species is well documented (de Zwaan 1978; Bell and Bellairs 1992; Burrows et al. 2009; Mojeremane et al. 2017, 2020; Mmolutsi et al. 2020). In this study, boiling water (1 and 3 min) was effective in enhancing percent germination of *A. versicolor* seeds. This result could suggest that dormancy in this species is attributed to the hard seed coat. However, GP declined with increase in boiling beyond 3 min. Seeds treated with boiling water (5 min) exhibited lower GP than untreated seeds. The decline in GP with increasing boiling time has been reported in work undertaken on other tree species (Botumile et al. 2020, Mmolutsi et al. 2020). The decline could probably be attributed to lethal effects of hot water on embryos. In contrast, percent germination of *F. albida* was not affected by boiling water (1, 3 and 5 min). This could suggest that seeds of this species are sensitive to high temperatures. This result is consistent with results of experiments conducted on other legumes, which found that boiling water did not increase GP (Gill et al. 1990, Kahaka et al. 2018, Mojeremane et al. 2018, Botumile et al. 2020), suggesting that the boiling water caused a degree of damage to the seeds.

## Conclusion and Recommendations

The results of the present study show that dormancy in *A. versicolor* and *F. albida* is mainly caused by their hard seed coats, which inhibit water uptake and gaseous exchange to initiate germination. Therefore, the hard seed coat needs to be subjected to pre-sowing treatments before seeds can germinate. The study has demonstrated that mechanical scarification, acid, boiling and hot water (boiling water allowed to cool for 24 h) treatments are the most effective methods in improving seed germination of *A. versicolor* and reducing mean germination time. Mechanical scarification and acid treatments are the most effective methods in improving seed germination and reducing mean germination time of *F. albida* seeds. Mechanical scarification, boiling and hot water (boiling water allowed to cool for 24 h) are recommended as cheaper and less hazardous techniques of pre-treating *A. versicolor* seeds in tree nurseries. Mechanical scarification is also recommended for pre-treating *F. albida* seeds. Although sulphuric acid was effective in improving germination and reducing mean germination time for the two species, it is not recommended for use in tree nurseries because it is expensive, corrosive and hazardous to nursery workers and requires proper handling techniques.

## Acknowledgments

The authors thank Botswana University of Agriculture and Natural Resources for the financial support and facilities for the research activities.

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