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Evaluating the Germination Response of Indigenous Trees and Shrubs to Presowing Seed Treatments in Southern Oromia's Borana Zone

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ABSTRACT

Introduced tree species in dryland areas of Borana face survival issues, while native trees and shrubs that are crucial for ecosystem restoration and biodiversity conservation face seed dormancy and poor germination. This study evaluated the effects of presowing seed treatments on the germination of selected indigenous tree and shrub species in Borana Zone. Fruits of nine (9) tree species were collected, and their seeds were extracted manually. The seeds were subjected to mechanical, chemical scarification, hot water, cold water, and control treatments. The experiment was conducted in a tree nursery from October 1, 2021, to April 10, 2022. The treated seeds were sown in pots in a randomized design with three replications for each species in the tree nursery. Data of sees emergence and the number of seeds emerged daily were collected and analyzed using SAS and GLM procedures. The highest germination % for Psydrax schimperiana was recorded under 12-h' cold water and 5-min concentrated H_2SO_4 treatments. For Mimusops kummel seeds, the highest germination % was recorded under cold water, while the lowest was recorded under control treatments. In the case of Grewia villosa, the highest germination rate (76.67%) was recorded under hot water. For the Terminalia brownie, the maximum germination % was recorded under mechanical scarification (50%). For the Pappea capensis, Boswellia microphylla, Commiphora myrrha, and Commiphora corrugatais species, soaking seeds in cold water is a more effective technique to get a better seed germination percentage. For Acacia tortilis, the highest germination % was observed under 5-min concentrated H_2SO_4 treatments ($81.33 \pm 6.41\%$), followed by 36 HR cold water treatment ($74.33 \pm 6.41\%$). Cold water treatments are being recommended as a cheaper and less hazardous presowing treatment method. The improvement of germination with the application of pretreatments implies that pretreatments have an advantageous effect on seed germination. Therefore, nursery managers and foresters use these seed pretreatments for the domestication of these tree species in the study area.

1 | Introduction

Indigenous tree and shrub species contribute significantly to biodiversity, ecosystem stability, and various ecological services, particularly in terms of food security and nutrition for local communities [1]. Initiatives on forest and landscape restoration and agroforestry practices in drylands to promote poverty alleviation and environmental rehabilitation in developing countries seek the integration of indigenous tree species into the system [2]. However, the germination of many indigenous tree and shrub species seeds is often hindered by natural dormancy mechanisms, protective seed coats, or other environmental factors.

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Seed dormancy is a state in which viable seeds show no or only little germination within a certain time, although all environmental conditions (moisture, light, and air) are adequate for germination. Regardless of the seed class (recalcitrant, intermediate, or orthodox groups), seed dormancy is an important factor that can affect the germination of each group at any stage [3]. Several reports on the germination behavior of tree seeds indicate that seed dormancy is prevalent among orthodox seeds compared to recalcitrant seeds [3]. Dormancy of seed can be caused by the special quality of the seed coat, such as hard layers of cells, the water impermeability of the coat, or the existence of germination-inhibiting substances in the seed coat, such as oil. Some dormancy is also caused by undeveloped seed [4].

Seed dormancy is categorized into primary and secondary types. Primary dormancy is attributed to maternal factors, including embryo immaturity and inhibition of water uptake, influenced by environmental conditions like temperature and light. Secondary dormancy occurs postharvest, primarily due to poor seed handling and storage [3, 5]. In addition to seed dormancy, the geographic source of seeds significantly affects most germination parameters [6]. To enhance germination of indigenous tree and shrub species, various seed pretreatments are employed, which include mechanical and chemical methods aimed at breaking dormancy and initiating germination. These treatments, such as scarification and cold water soaking, must be tailored to the specific dormancy characteristics of the seeds [7–10].

In semi-arid areas, Southern Oromia's Borana Zone, where native trees and shrubs are essential for preserving biodiversity, enhancing soil fertility and sustaining pastoral and agro-pastoral livelihoods, sustainable management and restoration of dryland ecosystems continue to be significant challenges. The majority of the trees and shrubs planting as green legacy and watershed management in the Borana rangeland are exotic species, and their survival rate under Borana conditions is very low. There is a rising need for seedlings of native tree and shrub species like *Terminalia brownie*, *Pappea capensis*, *Commiphora myrrha*, *Boswellia microphylla*, *Psydrax schimperiana*, *Acacia tortilis*, *Commiphora corrugatais*, *Grewia villosa,* and *Mimusops kummel in Boarana area*. However, germination issues plague the majority of these native tree and shrub species. *Terminalia brownii* has a hard samara fruit coat that prevents germination and leads to mechanical dormancy in its seeds [11, 12]; in contrast, the hard, impermeable seed coat of *Acacia tortilis* causes physical dormancy in its seeds [13]. The seeds of *Boswellia microphylla*, *Commiphora myrrha*, and *Commiphora corrugata* are reported to have a problem of low germination rate for producing planting materials under nursery management [14]. Direct data on seed dormancy are scarce for *Grewia villosa*, *Psydrax schimperiana*, *Mimusops kummel*, and *Pappea capensis*. However, under regular nursery management in the study area, the germination rate of these species' seeds was low. Information on seed germination of major indigenous species is crucial for the restoration of dryland ecosystems and agroforestry initiatives. Therefore, this study was undertaken to identify appropriate seed pretreatments for enhancing the germination of selected indigenous tree and shrub species in study areas.

2 | Material and Methods

2.1 | Description of the Study Area

The study was conducted in the Borana Zone of southern Oromia, which is situated in Oromia National Regional State at 570 km south of Addis Ababa. The zone lies between 4° 3′ N to 5° N and 37° 4′ E to 38° 2′ E with a total area of approximately 95,000 km^2. The elevation of the zone ranges from 1000 to 1600 m a.s.l. [15]. Borana is a zone known for its diverse ecosystems, ranging from arid to semiarid landscapes and has a bimodal rainfall pattern with the main rainy season (Ganna) between March and May with the peak in April [15]. The short rainy season (Hagayya) extends from September to November with a peak in October. Historically, the mean annual rainfall of the zone ranges from 352 mm in the southern part to 605 mm, with the mean annual rainfall of 587.2 mm and the mean annual temperature varying from 15°C to 24°C [15]. The vegetation in Borana often includes a mix of grasslands, shrublands, and scattered trees. Acacia species are commonly found in the area and are adapted to arid conditions.

The seeds of tree species selected for this study were collected from the Yaballo, Dhas, Elwoya, and Gomole districts of the Borana zone. The seed germination experiments were conducted on a station at the tree nursery of Yaballo Pastoral and Dryland Agriculture Research Center, Yaballo (Figure 1).

2.2 | Methods

2.2.1 | Species Selection

Before starting the experiment, important tree species in the context of agrosilvopastoral production systems were identified through key informants and local elders' interviews across the districts of the Borana Zone. Moreover, the phonologies (flowering time, seed production seasons, and seed collection time) of those important tree species were identified (Table 1). Then, the fruits of the selected tree species were collected from where they were most commonly found in Borana rangeland.

2.2.2 | Seed Collection and Preparation

Fruits of selected indigenous tree species were collected from lowland agroecology Borana Zones. *Terminalia brownie*, *Pappea capensis*, *Commiphora myrrha*, *Boswellia microphylla*, *Psydrax schimperiana*, *Acacia tortilis*, *Commiphora corrugatais*, *Grewia villosa,* and *Mimusops kummel* were among the tree species selected for this experiment (Figure 2). From these tree species, the mature fruits were collected from promising mother trees, and their seeds were extracted manually. The extracted seeds were air-dried and sorted at room temperature (24°C–26°C) 1–4 weeks, depending on the species, to keep the seeds viable for the germination. Before experimenting, the collected seeds were initially sorted to eliminate diseased and injured seeds.

2.2.3 | Experimental Designs

Presowing seed treatments were applied following the method used and recommended by other studies [6–9, 16].

Seeds of each species were subjected to four presowing methods for a total of eight (8) treatments. (1) Mechanical scarification: seeds were sacrificed manually by cutting/rubbing the seed coat

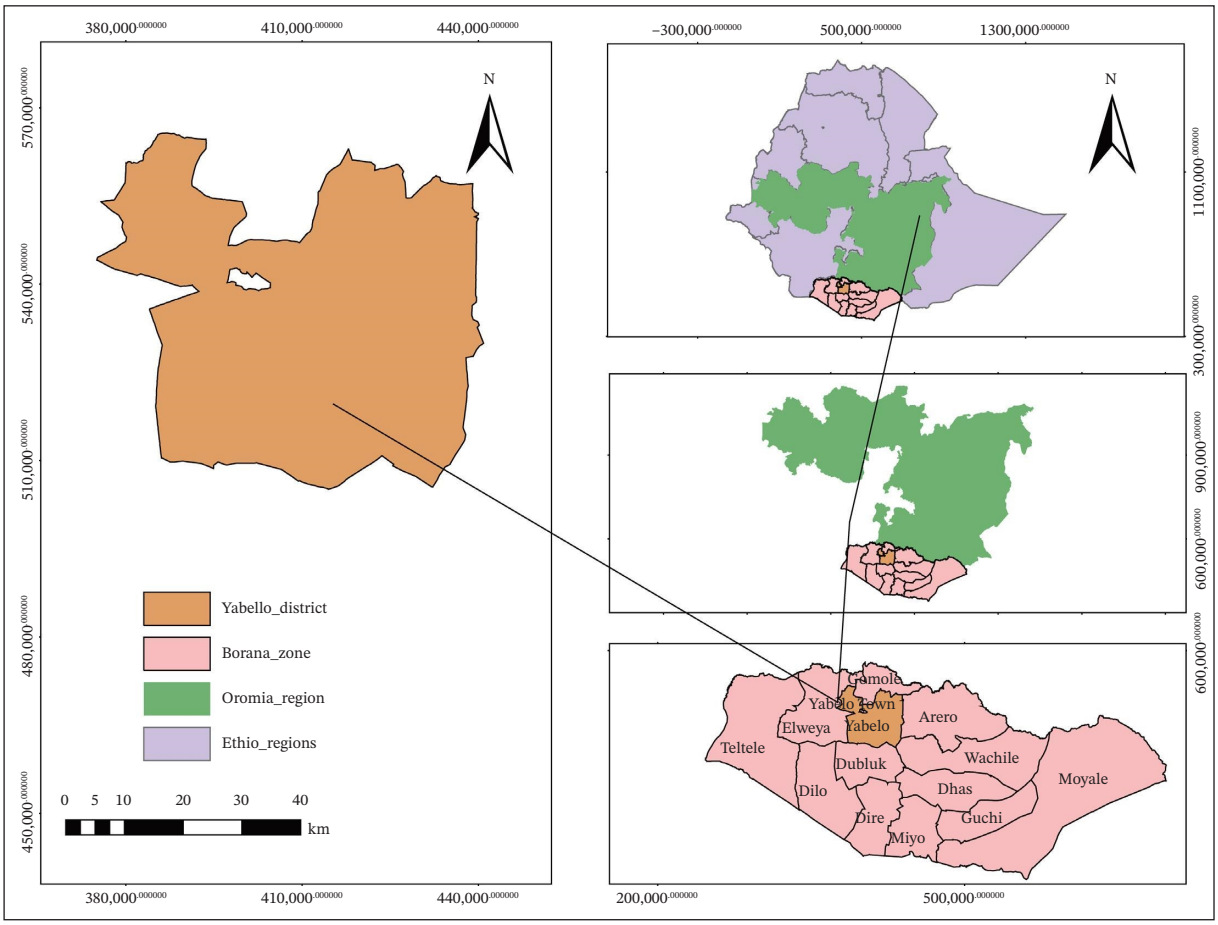


FIGURE 1 | Map of the study area.

at the opposite side of the hilum; (2) chemical scarification: seeds were soaked in concentrated sulfuric acid (98%) for 5 and 15 min, and after treatments, seeds were thoroughly rinsed in tap water and finally air-dried; (3) hot water: seeds were soaked in boiling distilled water at 100°C and left for 5 and 15 min; (4) normal water, room temperature water, typically ranges between temperature 20°C and 25°C: seeds were soaked in tap water for 12 and 36 h. (5) Control: no seed presowing treatment was applied. The presowing treatments were as follows:

T1: mechanical scarification

T2: soaking in concentrated H_2SO_4 for 5 min.

T3: soaking in concentrated H_2SO_4 for 15 min.

T4: soaking in boiled water for 5 minutes

T5: soaking in boiled water for 15 minutes

T6: soaking in cold water for 12 hours

T7: soaking in cold water for 36 hours

T8: control

The experiment was conducted from October 1, 2021, to April 10, 2022, in a nursery management facility using polythene tubes with an 8 cm diameter. The treated seeds were sown in the recommended soil mixing ratio (1:1:1, forest, agriculture soils, and animal manure, respectively). The pots were arranged in a nursery bed in a completely randomized design (CRD) with three replications. Each replication consisted of 30 pots, which were used as a plot, and in each pot, two seeds were sown. There were 8 treatments multiplied by 3 replications, resulting in a total of 24 plots (Figure 3).

The seed pots were watered twice daily following standard nursery management practices. Weeds were controlled by hand to prevent competition. The soils used in the nursery as growing media were collected from the nearby *Juniper's procera* natural forest, agriculture land, and farmyard manure. To determine their nutrient contents, samples were taken from collected soils, air-dried, crushed in a mortar and pestle, sieved through a 2-mm sieve, and analyzed in laboratory for their nutrient contents (Table 2).

2.3 | Data Collection

Data were collected on seed emergence and the number of emerged seedlings daily after the day of the first germination to the end of germination.

2.4 | Data Management and Statistical Analysis

Percentage seed germination (GP) and germination rate (GR) were estimated with the following equations:

1. Number of days to start germination: was determined by counting the number of days after sowing to the first day germination observed.

TABLE 1 | Importance of tree species selected for this study in the Borana agrosilvopastoral production system.

No.	Tree species	Growth form	Importance	Seed collection time	Seed types	Type of the seed dormancy
1	*Acacia tortilis*	Tree	Fodder (pods), shade, and ritual values.	February to March	Orthodox	External
2	*Boswellia microphylla*	Tree	Source of gum and incense, hygienic and perfuming, fodder.	February to March	Recalcitrant	Interna
3	*Commiphora corrugatais*	Tree	Source of gum and incense, hygienic and perfuming, fodder.	February to March	Intermediate	External
4	*Commiphora myrrh*	Tree	Source of gum and incense, medicinal plant	February to March	Orthodox	External
5	*Grewia villosa*	Shrub	Fruits have food and ethnomedical value, fodder	February to March	Orthodox	External
6	*Mimusops kummel*	Tree	Fruits have food and ethnomedical value, firewood, and charcoal	February to March	Orthodox	External
7	*Pappea capensis*	Tree	Fodder, wild edible, medicinal, and firewood	January to February	Intermediate	External
8	*Psydrax schimperiana*	Tree	Wild edible, medicinal plant, construction, and firewood	January to March	Orthodox	Interna
9	*Terminalia brownie*	Tree	Fodder, hygienic and perfuming, construction, and firewood	January to March	Intermediate	Interna

2. Seed germination percentage (GP); the number of germinated seeds as a percentage of the total number of tested seeds is given as GP = (germinated seeds/total tested seeds) × 100%

3. Germination meantime: was taken according to [17] as GMT = ∑Ti Ni/S

where Ti is the number of days from the beginning of the experiment, Ni is the number of seeds germinated per day, and S is the total number of seeds germinated.

4. Germination index (GRI): was calculated for each treatment using the following equation: GRI = (G1/1) + (G2/2) +...+ (Gx/x),

where *G* is the germination days 1 and 2, and x represents the corresponding day of germination [18].

The data were subjected to analysis of variance following a GLM using SAS statistical software. The treatment means that significantly different at a 5% level of significance was separated using the LSD test.

3 | Results and Discussion

3.1 | Effect of Presowing Seed Treatments on Germination of *Psydrax schimperiana*

The percentage of seed germination of *Psydrax schimperiana* differed substantially among presowing treatment techniques ($p < 0.05$), with soaking in cold water for 12 h and soaking in concentrated (98%) H_2SO_4 for 5-min treatments, recording the highest mean percentage germination of 76.33% each and the lowest percentage germination (37.67%) being produced under the control treatment. Seeds soaked in cold water for 12 and 36 h both recorded the highest percentage of germination compared to other treatments, except seeds immersed in 98% sulfuric acid concentration for 5 min, which had a similar germination percentage with cold water treatments (Table 3). This is consistent with [19] finding that cold water treatment contributes to the high mean germination of tree seeds. The germination indices (GI) were similarly significantly different among the pretreatments, and seeds were treated with cold water and seeds immersed in 98% sulfuric acid concentration for 5 min, recording the highest germination indices compared to other treatments (Table 3). The capacity of cold water to improve seed coat permeability may be the reason why the cold water treatment recorded the greatest percentage and quickest time to first seed emergence. This made it possible for the embryo to be transformed into a seedling via enzymatic hydrolysis and gaseous exchange without adversely compromising the seed's functioning organs [20]. This concurs with the findings of [21] who determined that water is needed for seed germination.

Pretreatments with socking in 98% concentrated sulfuric acid for 15 min and hot water treatments recorded a low germination rate compared to cold water pretreatment (Table 3). A lower percentage of seeds germinated after hot water pretreatment than after cold water pretreatment is most likely because of the high temperature to which the seeds were exposed. The study by [22] found that using hot water as a pretreatment may likely be harmful to enzymatic activity at higher temperatures. The comparatively low proportion of seeds that germinated after



FIGURE 2 | The collected seeds of indigenous tree species.



FIGURE 3 | Pots arrangement in the nursery site and germinated seeds.

TABLE 2 | Mean ± Std of soil physicochemical values for forest and agricultural soil collected from the upper surface (0–30 cm).

Soil properties	*N*	Forest soil			Agricultural soil		
		Min	Max.	Mean ± std	Min.	Max.	Mean ± std
% carbon	5	0.70	2.73	1.67 ± 0.91	1.40	1.79	1.51 ± 0.16
% Total nitrogen	5	0.04	0.19	0.90 ± 0.06	0.06	0.17	0.101 ± 0.04
pH	5	6.02	7.00	6.47 ± 0.4	6.94	7.03	6.98 ± 0.04
EC (mmhos/cm at 25°C)	5	0.02	0.07	0.04 ± 0.02	0.08	0.14	0.10 ± 0.02
Av.K (ppm)	5	296.00	397.50	329.3 ± 42.46	14.50	139.50	67.50 ± 56.92
Av. P (ppm)	5	1.84	15.46	7.31 ± 7.39	1.24	11.12	5.30 ± 4.24
Ca (meq/100 m soil)	5	15.00	20.00	18.30 ± 2.07	14.25	19.25	16.50 ± 2.15
Mg (meq/100 m soil)	5	5.75	12.00	9.35 ± 2.35	6.00	12.00	9.30 ± 2.47
Exch. Na (ppm)	5	0.07	0.13	0.11 ± 0.03	0.02	0.11	0.05 ± 0.03
exch. K (ppm)	5	0.08	0.32	0.19 ± 0.11	1.01	1.16	1.06 ± 0.06
%sand	5	51.00	57.00	53.80 ± 2.28	63.00	69.00	65.80 ± 2.68
% silt	5	24.00	30.00	27.60 ± 2.61	8.00	20.00	13.20 ± 4.38
% clay	5	17.00	21.00	18.60 ± 1.67	11.00	25.00	21.00 ± 6.16
Textural classes				Sandy loam			Sandy clay loam

TABLE 3 | Effect of different pretreatments on percentage germination, days to emergence, germination meantime, mean germination rate, and germination indices of *Psydrax schimperiana* (Gaallee).

Presowing treatments	Germination (%)	Days to emergence (no.)	Germination meantime	Mean germination rate (seedlings/day)	Germination indices (GI)
Mechanical scarification (nicking)	42.33 ± 5.69^{bc}	46.33 ± 1.12^{a}	4.80 ± 0.28^{ab}	0.209 ± 0.01^{ab}	3.09 ± 0.62^{c}
Soaking in concentrated H_2SO_4 for 5 min.	76.33 ± 5.69^{a}	37 ± 1.12^{b}	5.35 ± 0.28^{a}	0.24 ± 0.01^{a}	5.86 ± 0.62^{b}
Soaking in concentrated H_2SO_4 for15 min.	56.67 ± 5.69^{b}	44 ± 1.12^{a}	4.80 ± 0.28^{ab}	0.21 ± 0.01^{ab}	5.34 ± 0.62^{b}
Soaking in boiled water for 5 min	41.00 ± 5.69^{bc}	45 ± 1.12^{a}	4.55 ± 0.28^{ab}	0.22 ± 0.01^{ab}	4.19 ± 0.62^{bc}
Soaking in boiled water for 15 min	55.67 ± 5.69^{b}	43.33 ± 1.12^{a}	4.76 ± 0.28^{ab}	0.21 ± 0.01^{ab}	5.03 ± 0.62^{b}
Soaking in cold water for 12 HRs	76.33 ± 5.69^{a}	37.33 ± 1.12^{b}	4.47 ± 0.28^{b}	0.22 ± 0.01^{ab}	7.76 ± 0.62^{a}
Soaking in cold water for 36 HRs	69.00 ± 5.69^{ab}	39 ± 1.12^{b}	4.04 ± 0.28^{b}	0.25 ± 0.01^{a}	7.86 ± 0.62^{a}
Control	37.67 ± 5.69^{c}	46 ± 1.12^{a}	4.35 ± 0.28^{b}	0.187 ± 0.01^{b}	3.05 ± 0.62^{c}
LSD	17.05	3.35	0.84	0.04	1.87
CV%	17.35	4.58	10.45	11.59	20.44
R^2	0.0004	< 0.0001	0.1364	0.043	0.0002

Note: Means within a column that shares a superscript letter do not differ substantially at a significance level of 0.05.

being immersed in 98% sulfuric acid for 15 min seems to indicate that *Psydrax schimperiana* seeds are sensitive to greater concentrations of this chemical. This is consistent with [23] finding that sulfuric acid could harm seed embryos.

In comparison to most pretreatments (cold water, 98% sulfuric acid, and hot water), the control treatment and mechanical scarification (nicking) often reported low percentage germination, an indication of some level of dormancy in *Psydrax schimperiana* seeds. This implies that pretreatments have an advantageous effect on *Psydrax schimperiana* seed germination, which may be advantageous to nursery managers and foresters for the domestication of the species.

3.2 | Effect of Presowing Seed Treatments on Germination of *Mimusops kummel*

The germination rate showed a significant difference among various seed treatments ($p < 0.0001$). A higher percentage of *M. kummel* seed germination was recorded after soaking seeds in cold water for 36 h (79%), followed by soaking seeds in cold water for 12 h (57.67%), and the lowest germination rate was recorded under control treatments (21.33%) (Table 3). Cold water treatment not only improves the germination rate but also significantly increases the mean germination rate and germination indices; moreover, it significantly reduces the days until the emergence of seeds (Table 4). These would be because cold water assists in softening the hard coat of the seeds without damaging the pulp and facilitates easier seed germination. A similar result was reported, a higher germination percentage of *M. kummel* seeds treated with cold water [24]. A study by [19] also found that cold water treatment contributed to the high mean germination rate of tree seeds. The low germination rate under controlled treatment, which improved after seed treatments, indicated that the seed dormancy of *M. kummel* belongs to morphological dormancy. A study by [24] indicated that *M. kummel* seed exhibits non-physiological dormancy, which makes it simple to germinate in a controlled setting.

3.3 | Effect of Presowing Seed Treatments on Germination of *Grewia villosa*

The effects of various pretreatments on seed germination of *Grewia villosa* are significantly different ($p < 0.0001$), as presented in Table 5. The seeds treated with hot water germinated more than with other treatments. The maximum germination rate is recorded for seeds soaked in boiled water for 5 min (76.67%), followed by the seeds soaked in boiled water for 15 min (61.33%). Moreover, the hot water treatments significantly improved the days to start emergence and germination indices for *Grewia villosa* seeds. The lowest germination rate was recorded under seeds soaked in concentrated H_2SO_4 for 15 min. No significant variation was observed among mechanical scarification, soaking in concentrated H_2SO_4 for 5 min, cold water treatments, and control (Table 5). *Grewia villosa* seed dormancy was successfully broken by hot water treatments, which outperformed other techniques by weakening the hard seed coat without causing undue harm. Through thermal expansion and pectin hydrolysis, hot water scarification softens the impermeable seed coat, facilitating radicle emergence and water absorption. In contrast to extended acid exposure, which excessively erodes

TABLE 4 | Effect of different presowing treatments on percentage germination, days to emergence, germination meantime, mean germination rate, and germination indices of *Mimusops kummel*.

Presowing treatments	Germination (%)	Days to emergence (no.)	Germination meantime	Mean germination rate (seedlings/day)	Germination indices (GI)
Mechanical scarification (nicking)	36.67 ± 3.21^{c}	75 ± 4.98^{ab}	4.39 ± 0.30^{ab}	0.23 ± 0.02^{ab}	2.91 ± 0.48^{c}
Soaking in concentrated H_2SO_4 for 5 min.	31.00 ± 3.21^{cd}	87 ± 4.98^{a}	3.98 ± 0.30^{ab}	0.26 ± 0.02^{ab}	2.61 ± 0.48^{c}
Soaking in concentrated H_2SO_4 for15 min.	25.33 ± 3.21^{de}	81.67 ± 4.98^{a}	3.74 ± 0.30^{b}	0.28 ± 0.02^{a}	2.64 ± 0.48^{c}
Soaking in boiled water for 5 min	27.67 ± 3.21^{cde}	87.67 ± 4.98^{a}	4.87 ± 0.30^{a}	0.21 ± 0.02^{b}	1.84 ± 0.48^{c}
Soaking in boiled water for 15 min	24.33 ± 3.21^{de}	80.67 ± 4.98^{a}	3.64 ± 0.30^{b}	0.28 ± 0.02^{a}	2.28 ± 0.48^{c}
Soaking in cold water for 12 HRs	57.67 ± 3.21^{b}	65 ± 4.98^{b}	3.59 ± 0.30^{b}	0.28 ± 0.02^{a}	6.01 ± 0.48^{b}
Soaking in cold water for 36 HRs	79.00 ± 3.21^{a}	65 ± 4.98^{b}	3.69 ± 0.30^{b}	0.27 ± 0.02^{a}	8.62 ± 0.48^{a}
Control	21.33 ± 3.21^{e}	88 ± 4.98^{a}	4.01 ± 0.30^{ab}	0.25 ± 0.02^{ab}	1.77 ± 0.48^{c}
LSD	9.61	14.93	0.8944	0.0566	1.4268
CV%	14.67	10.95	12.95	12.76	22.98
p-values	< 0.0001	0.0142	0.0923	0.1168	< 0.0001

Note: Means within a column that share a superscript letter do not differ substantially at a significance level of 0.05.

layers, shorter times (5 min) maximize this without destroying viable tissue. Acids present handling risks that are inappropriate for community nurseries, while mechanical methods physically abrade the testa but run the risk of injury. A study on the related Grewia species, Grewia damine, showed that applying hot water treatment for 5 minutes resulted in a 55% germination rate [13].The current finding contrasts with studies by [25], who indicated mechanical scarification pretreatment for breaking seed dormancy in *Grewia villosa* seeds, and [26], who identified cold water as a suitable seed treatment method for *Grewia villosa* seeds. The main causes of variations in the *Grewia villosa* seed pretreatment efficacy between studies are seed provenance, collection timing, and dormancy intensity, resulting in optimal techniques that are context-specific. The seeds used for these treatments were collected during the drought time in Borana. Sourced seeds may have thicker testa that are adapted to arid lowlands and drought; hot water performed better than mechanical scarification and cold water.

3.4 | Effect of Presowing Seed Treatments on Germination of *Terminalia brownie*, *Pappea capensis,* and *Acacia tortilis*

Presowing treatments have a significant effect on the germination percentage of *T. brownie* seeds ($p < 0.0001$), and the number of days to seedling emergence is significantly different ($p = 0.0018$). The maximum germination rate was recorded under the seed treatment of mechanical scarification (50%), and the lowest germination rate was recorded under the control treatment (19%). Moreover, mechanical scarification significantly reduced the number of days to seedling emergence compared to other treatments. In addition to mechanical scarification, cold water treatment significantly increased the germination rate of T. brownie seeds when compared to the control treatment; the *T. brownie* seeds soaked in cold water for 36 h germinated at 45.67%, and those treated by soaking in cold water for 12 h germinated at 42% (Table 6). Mechanical scarification breaks down tough seed coats of *T. brownie* to allow for the penetration of water and oxygen. In arid pastoral systems with little rainfall, this technique improves germination and shortens emergence time, which is essential for timely seedling establishment. Cold water treatments (soaking for 12 and 36 h) probably improved metabolic activation and mimicked natural wet-season conditions by softening the seed coat through imbibition without causing any damage. In the study area, encouraging *T. brownie* regeneration through these techniques supports livestock resilience in the face of climate variability, soil stabilization, and fodder production. The result is in line with the finding of [27], which indicated that the average germination performance of *T. brownie* was 50%. A study on *Terminalia chebula* by [28] reported that the highest germination percentage (70.6%) was observed in the mechanical breaking of the seed coat. Achieving the maximum germination rate of *T. brownie* seeds is still challenging. [26] also indicated that *T. brownie* seeds have low germination rate behavior and removal of wings as a recommended seed pretreatment. The various sources of seed germination failure could be the seed's exogenous or endogenous factors. A study found that *Penicillium* seed-borne fungi affected the seed germination of *T. browni* [29].

Pappea capensis is an important tree species that receives development attention as a forage resource in the Borana

TABLE 5 | Effect of different presowing treatments on percentage germination, days to emergence, germination meantime, mean germination rate, and germination indices of *Grewia villosa* (Ogomdii).

Presowing treatments	Germination (%)	Days to emergence (no.)	Germination meantime	Mean germination rate (seedlings/day)	Germination indices (GI)
Mechanical scarification (nicking)	52 ± 4.2^{cd}	31.67 ± 1.91^{a}	4.36 ± 0.31^{a}	0.23 ± 0.03^{b}	3.91 ± 0.66^{bc}
Soaking in concentrated H_2SO_4 for 5 min.	46.67 ± 4.2^{cd}	23 ± 1.91^{b}	3.45 ± 0.31^{ab}	0.29 ± 0.03^{ab}	5.06 ± 0.66^{b}
Soaking in concentrated H_2SO_4 for15 min.	27.67 ± 4.2^{e}	27 ± 1.91^{ab}	3.07 ± 0.31^{b}	0.33 ± 0.03^{a}	2.98 ± 0.66^{c}
Soaking in boiled water for 5 min	76.67 ± 4.2^{a}	23 ± 1.91^{b}	3.49 ± 0.31^{ab}	0.29 ± 0.03^{ab}	8.51 ± 0.66^{a}
Soaking in boiled water for 15 min	61.33 ± 4.2^{b}	23 ± 1.91^{b}	3.23 ± 0.31^{b}	0.32 ± 0.03^{a}	7.63 ± 0.66^{a}
Soaking in cold water for 12 HRs	35.33 ± 4.2^{de}	26.33 ± 1.91^{ab}	3.41 ± 0.31^{b}	0.3 ± 0.03^{ab}	3.76 ± 0.66^{bc}
Soaking in cold water for 36 HRs	43.33 ± 4.2^{cd}	25 ± 1.91^{b}	3.48 ± 0.31^{ab}	0.29 ± 0.03^{ab}	4.17 ± 0.66^{bc}
Control	47.67 ± 4.2^{cd}	28.33 ± 1.91^{ab}	3.38 ± 0.31^{b}	0.3 ± 0.03^{ab}	4.63 ± 0.66^{bc}
LSD	12.60	5.74	0.92	0.08	1.98
CV%	14.91	12.80	15.23	15.80	22.59
p-values	< 0.0001	0.0541	0.2240	0.3882	0.0002

Note: Means within a column that shares a superscript letter do not differ substantially at a significance level of 0.05.

rangeland. The species propagate by seed, and an efficient and effective seed germination method is necessary for producing planting materials. Different presowing seed treatments were applied to the collected seeds. There was a significant difference between treatments in the number of days it took for seedlings to emerge ($p = 0.0005$) and the percentage of seeds that germinated ($p < 0.0001$). Compared to the other treatments and the control, seeds treated by soaking in cold water for 36 h emerged sooner and had a greater germination percentage (61%), followed by seeds soaked in cold water for 12 h (50%) (Table 6). The lowest germination rate was observed for seeds treated with hot water and concentrated H_2SO_4.

The other important dryland tree species naturally found in the Borana zone, which is currently across the Borana rangeland, is *Acacia tortilis* (Fork). To conserve such important tree species, an effective and efficient seed germination method is necessary for producing planting materials. There were significant variations ($p = 0.0005$) in the proportion of seeds that germinated among other treatments. The highest germination percentage was observed with the seed soaking in concentrated H_2SO_4 for 15 min ($81.33 \pm 6.41\%$), followed by the seed soaked in cold water for 36 h ($74.33 \pm 6.41\%$) and the seed soaked in concentrated H_2SO_4 for 5 min ($73.33 \pm 6.41\%$). The lowest seed germination was recorded under the control treatment (25.67%) (Table 6). The study by [30] found that acid treatments are the most effective method in improving seed germination of *F. albida* species. The findings of this study are comparable with the previous study, which recommended soaking the seed in water until root protrusion as a presowing seed treatment for *A. tortilis* [31]. Both studies of [30, 31] indicated that mechanical scarification is another option for acacia species seed pretreatment, which is different from our finding. This may be attributed to differences in the way mechanical scarification was performed.

3.5 | Effect of Presowing Seed Treatments on Germination of *B. microphylla*, *C. myrrha,* and *C. corrugatais* Tree Species

Boswellia microphylla, *Commiphora myrrha,* and *Commiphora corrugata*is are among the resin-bearing tree species naturally found in the Borana rangeland. The seeds of these species have a problem of low germination rate for producing planting materials under nursery management [14]. This experiment of presowing treatments was conducted to improve their germination rate.

Significant differences in the germination rate and days to start germination were observed among treatments (Table 7). The highest germination rates recorded under seeds treated with cold water were seeds soaking in cold water for 36 h, which had the highest germination rate (61%), followed by seeds soaking in cold water for 12 h (58.67%). Next to cold water, mechanical scarification improved the germination rate of *B. microphylla* seeds (41%). The lowest germination rate was observed under seeds soaking in concentrated H_2SO_4 for 15 min and seeds soaking in boiled water for 15 min at 27.67% and 28.67%, respectively. Moreover, cold water treatments significantly reduced the days to start germination of *B. microphylla* seeds compared to other treatments. The findings of this study are similar to those studies on other *Boswellia* species, which indicated that the seeds of *Boswellia sacra* soaked in cold water had the highest germination rate and germinated quickly [32, 33].

TABLE 6 | Effect of different presowing seed treatments on germination % and days to emergence of some selected tree species (*T. brownie, P. capensis, and A. tortilis*).

Presowing treatments	*Terminalia brownie*		*Pappea capensis*		*Acacia tortilis*	
	Germination (%)	Days to emergence (no.)	Germination (%)	Days to emergence (no.)	Germination (%)	Days to emergence (no.)
Mechanical scarification	50 ± 1.94^{a}	23 ± 1.83^{c}	39 ± 0.2^{c}	38.66 ± 2.62^{cb}	62 ± 6.41^{bc}	11 ± 1.28^{bc}
Soaking in conc. H_2SO_4 for 5 min.	32.33 ± 1.94^{cd}	31 ± 1.83^{ab}	32 ± 0.2^{cde}	40 ± 2.62^{b}	73.33 ± 6.41^{ab}	9 ± 1.28^{c}
Soaking in conc. H_2SO_4 for15 min.	34.67 ± 1.94^{c}	31 ± 1.83^{ab}	24.33 ± 0.2^{e}	40 ± 2.62^{b}	81.33 ± 6.41^{a}	9 ± 1.28^{c}
Soaking in boiled water for 5 min.	27.67 ± 1.94^{de}	32.33 ± 1.83^{a}	27.67 ± 0.2^{de}	40 ± 2.62^{b}	52.33 ± 6.41^{c}	12 ± 1.28^{bc}
Soaking in boiled water for 15 min.	23.33 ± 1.94^{ef}	32.33 ± 1.83^{a}	26.67 ± 0.2^{de}	39.33 ± 2.62^{b}	60 ± 6.41^{bc}	13 ± 1.28^{b}
Soaking in cold water for 12 HRs	42 ± 1.94^{b}	23 ± 1.83^{c}	50 ± 0.2^{b}	38 ± 2.62^{c}	65.33 ± 6.41^{abc}	12 ± 1.28^{bc}
Soaking in cold water for 36 HRs	45.67 ± 1.94^{ab}	23 ± 1.83^{c}	61 ± 0.2^{a}	38 ± 2.62^{c}	74.33 ± 6.41^{ab}	12 ± 1.28^{bc}
Control	19 ± 1.94^{f}	25.67 ± 1.83^{bc}	33.33 ± 0.2^{c}	42 ± 2.62^{a}	25.67 ± 6.41^{d}	21.67 ± 1.28^{a}
LSD	5.83	5.47	7.84	1.45	19.21	3.84
CV%	9.805	11.429	12.33	2.13	17.96	17.80
p-values	< 0.0001	0.0018	< 0.0001	0.0005	0.0005	< 0.0001

Note: Means within a column that share a superscript letter do not differ substantially at a significance level of 0.05.

TABLE 7 | Effect of different presowing seed treatments on germination % and days to emergence of *B. microphylla*, *C. myrrha*, and *C. corrugatais*

Presowing treatments	*Boswellia microphylla*		*Commiphora myrrha*		*Commiphora corrugatais*	
	Germination (%)	Days to emergence (no.)	Germination (%)	Days to emergence (no.)	Germination (%)	Days to emergence (no.)
Mechanical scarification	41 ± 2.88^{b}	12 ± 0.41^{bc}	47.67 ± 3.41^{ab}	16 ± 0.41^{ab}	61 ± 3.97^{c}	10.67 ± 0.53^{a}
Soaking in conc. H_2SO_4 for 5 min.	34.67 ± 2.88^{bc}	12 ± 0.41^{bc}	$40 \pm 3.41b^{cd}$	16 ± 0.41^{ab}	73.33 ± 3.97^{ab}	10 ± 0.53^{a}
Soaking in conc. H_2SO_4 for15 min.	27.67 ± 2.88^{c}	11.33 ± 0.41^{cd}	41 ± 3.41^{bc}	15.33 ± 0.41^{bc}	65.67 ± 3.97^{abc}	10.67 ± 0.53^{a}
Soaking in boiled water for 5 min.	34.67 ± 2.88^{bc}	12 ± 0.41^{bc}	35.67 ± 3.41^{cd}	16 ± 0.41^{ab}	72.33 ± 3.97^{abc}	11.33 ± 0.53^{a}
Soaking in boiled water for 15 min.	28.67 ± 2.88^{c}	12.67 ± 0.41^{b}	37.67 ± 3.41^{bcd}	16.67 ± 0.41^{a}	63.33 ± 3.97^{bc}	10.67 ± 0.53^{a}
Soaking in cold water for 12 HRs	58.67 ± 2.88^{a}	10.67 ± 0.41^{de}	55.67 ± 3.41^{a}	14.67 ± 0.41^{cd}	74.33 ± 3.97^{ab}	10 ± 0.53^{a}
Soaking in cold water for 36 HRs	61 ± 2.88^{a}	10 ± 0.41^{e}	53.33 ± 3.41^{a}	14 ± 0.41^{d}	75.33 ± 3.97^{a}	10 ± 0.53^{a}
Control	39 ± 2.88^{b}	14 ± 0.41^{a}	30 ± 3.41^{d}	16 ± 0.41^{ab}	41.33 ± 3.97^{d}	11.33 ± 0.53^{a}
LSD	8.62	1.22	10.22	1.22	11.88	1.58
CV%	12.25	5.98	13.84	4.53	10.43	8.62
p-values	< 0.0001	0.0002	0.0008	0.0059	0.0003	0.4010

Note: Means within a column that share a superscript letter do not differ substantially at a significance level of 0.05.

In the case of *C. myrrha*, even though the germination percentage of the species was not satisfactory to promote the seed pretreatments, a significant difference was observed among the presowing treatments ($p = 0.0008$) (Table 7). It was found that seeds soaked in cold water for 12 and 36 h germinated more than other treatments (55.67% and 53.33%, respectively), and the lowest germination rate was recorded for the untreated seeds (30%). All other pretreatments did not substantially differ from one another or resulted in a considerably lower germination rate. The low germination rate may be due to soil or water salinity problems. A study discovered that the increase in salinity level significantly reduced the seed germination percentage and seedling growth of *Commiphora boranensis*, *Commiphora habessinica*, and *Commiphora corrugate* species [34].

Similar to *C. myrrha*, the seed germination percentage of *Commiphora corrugata*is among the treatments showed significant ($p = 0.0003$) differences (Table 7). Seeds soaked in cold water for 36 h had the highest germination percentage (75.33 $\pm$ 3.97%), followed by seeds that were soaked in cold water for 12 h (74.33 $\pm$ 3.97%), which were not statistically different from seeds soaked in concentrated H_2SO_4 for 5 min and seeds soaked in boiled water for 5 min, whereas the control, which represented no pretreatment applied, had the least (41.33 $\pm$ 3.97%). Presowing treatment has no significant effect ($p = 0.4010$) on days to emergence after sowing of *C. corrugata*is. The finding of this study is comparable to previous findings on other *Boswellia* and *Commiphora* species, which indicated that the seeds soaked in cold water had the highest germination percentage compared to control [32, 33, 35].

4 | Conclusion

Presowing seed treatments greatly increase the germination rates of native tree and shrub species, helping in the restoration of the degraded land with native trees and shrubs. Mechanical scarification and cold water soaking (12–36 h) were the most successful for species such as *Psydrax schimperiana*, *M. kummel*, *Grewia villosa*, *Terminalia brownii*, *Pappea capensis*, *Boswellia microphylla*, *Commiphora myrrha*, *Commiphora corrugata*, and *Acacia tortilis*, frequently producing 50%–81% germination. In comparison to most pretreatments, the control treatment often reported a low percentage of germination, which is an indication of some level of seed dormancy in these tree species. Achieving the maximum germination rate for these tree and shrub species is still challenging.

5 | Recommendation

The improvement of germination with the application of pretreatments implies that pretreatments have an advantageous effect on seed germination. Cold water treatments are being recommended as cheaper and less hazardous presowing treatments for most species. For *Terminalia brownie* seeds, mechanical scarification is more effective, while for *Grewia villosa* seeds, boiled water treatment is recommended as an effective presowing seed treatment in the study area. Nursery managers and foresters could use these seed pretreatments for the domestication and multiplication of these tree species in the study area. Future study needs to examine the impact of storage duration on the germination rate, seedling vigor, and viability of important species. Additionally, thorough germination trials are

essential for other key local species that are prioritized by pastoralist communities to enhance nursery propagation and support natural regeneration in the Borana rangelands.

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Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

Research data are not shared.

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