

Effect Of Various Pre-Sowing Treatments On Germination Performance Of Multipurpose Agroforestry Tree Seeds At Wondo Genet, Ethiopia

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ABSTRACT

Since the function of a seed is to establish a new plant, it seems curious that **dormancy** is a delay between seed shedding and germination. A **laboratory experiment** was undertaken to determine the effect of seed pre-sowing treatment methods on the germination of *Acacia polyacantha*, *Acacia mearnsii* and *Faidherbia albida*. Seeds were subjected to fourteen treatments under **scarification** pre-sowing methods. Germination percentage (**GP**), Mean germination time (**MGT**), Mean germination rate (**MGR**), and Germination value (**GV**) were calculated and the data was subjected to **ANOVA**. The study revealed significant ($p < 0.05$) differences in seed treatments of all studied parameters. Highest germination percentage (GP) in *Acacia polyacantha* was yielded at (**ABA**, **Nicking**, and **Cold water**) with 86.6% each. The lowest GP was obtained in **sulfuric acid treatments** (28.3%). High **MGT** was recorded in **control** at (12.1) days. While lowest **MGT** in **Nicking** at (10.1) days. The highest **MGR** was in **Nicking** at 0.098 and the lowest in control at 0.06. For *Acacia mearnsii* the highest GP was yielded in **Nicking** (100%) and lowest in **Control** (0%), with the lowest **MGT** in control (0 days) and highest in **ABA 45** (23.07) days. The highest **MGR** and **GV** was observed **Nicking** (0.09) and (46.0). The control treatments had the lowest **MGR** and **GV** with a value of 0 and 7.15 respectively. As for *Faidherbia albida* results showed that the highest GP was in the **hot water treatment** (95%) and the lowest in **sulfuric acid** (6.6%). This species exhibited the highest **MGT** in seed soaked in hot water for 15 minutes (32.9) days and the lowest in **Nicking** (7.4). the highest **MGR** was in **nicking** (0.13) and the lowest in seeds soaked in 98% concentrated **sulfuric acid** for 5 minutes (0.01); highest **GV** was in **nicking** (26.8) and the lowest in the control. Therefore, it's suggested that soaking seeds in cold water overnight for seeds of *Acacia polyacantha*; **Nicking** (by cutting the opposite side of the hilum) for *Acacia mearnsii*, and using hot water for *Faidherbia albida* is recommended as they are cheaper and less hazardous pre-sowing treatments to improve germination.

Key words- Germination, Pre-sowing Treatment, Seed dormancy, Germination performance

1. INTRODUCTION

A seed becomes dormant when the growth potential of the embryo falls below the restraining force of its covering structure. Dormancy and germination are determined by the co-action of the growth potential of the embryo and the restraints imposed by the tissues surrounding (Mousavi *et al.*, 2011). Seed dormancy is defined as the state in which mature and viable seeds will not germinate even when exposed to favorable growth conditions (water, temperature) (Bradford *et al.*, 2000).

Agroforestry is defined as “a dynamic, ecologically based natural resources management system that through the integration of trees in farmland and rangeland, diversifies and sustains production for increased social, economic, and environmental benefits for land users at all levels (Leakey, 2017). It is a form of sustainable land-use system that integrates trees with crops or animal husbandry to initiate an agroecological succession (Buttoud *et al.*, 2013). In the agroforestry context, multipurpose trees are understood as those trees and shrubs which are deliberately kept and managed for more than one preferred use, product, and/or service the retention or cultivation of these trees are usually economically but also some times ecologically motivated, in multiple out-put land-use system (Wood and Burley, 1991).

Despite the economic and environmental importance of multipurpose tree species, the propagation of those MPTs from seed has been complex due to lack of precise knowledge of their seed biology, seed germination characteristics, and germination physiology (Hartmann *et al.*, 1997). In this study three MPTs have been selected due to physical dormancy type; where seeds of *Faidherbia albida* are characterized by a seed coat that is impervious to water (Clode, 2011). The dormancy of *Acacia polyacantha* is induced by the presence of a hard seed coat, which stops the water supply to the embryo. This phenomenon is widespread in the Leguminosae to abrasion and is covered with a wax-like layer (Zulu, 1990). *Acacia mearnsii*'s physical dormancy is due to the presence of a water-impermeable layer of palisade cells in the testa (Dessi *et al.*, 2021).

In Ethiopia, most agroforestry research studies strongly emphasize on the bio-physical and socio-economic contribution of agroforestry practices and other similarly related studies. However, there is little emphasis on the propagation of those multipurpose tree species seeds. Most seed studies focus on germinating a few selected plant species seed (Negash, 2010) or on horticultural crops, and other fruit trees. Pre-sowing seed treatment had not been widely used in the seeds of agroforestry tree species to achieve early germination and initial seedlings.

Therefore, this study, makes its trial to use different pre-sowing treatments and assess the germination potential on (*Acacia polyacantha*, *Acacia mearnsii*, and *Faidherbia albida*) to break their dormancy, speed up the process of germination and identify the most convenient pre-sowing treatment for achieving uniform germination. Indeed this study contributes to the overall understanding of the seed germination behavior of these species, which is essential for the sustainable production, protection, and conservation of the species diversity.

2.MATERIALS AND METHODS

2.1.Study Site Description

The study was carried out at Wondo Genet College of Forestry and Natural Resources General Laboratory starting from December 2022 to end of March 2023.

2.1.1.Criteria for species selection

The present study includes three multipurpose agroforestry tree species seeds. These species have been acknowledged as multipurpose agroforestry tree species which provide many benefits both socio-economically, ecologically, and environmentally. They also had been identified as species with the problem of dormancy. *Faidherbia albida*, *Acacia mearnsii*, and *Acacia polyacantha* have hard seeds which produce seeds with a tough or hard seed coat (Baskin, 2009).

2.1.2.Seed source

Seeds of the selected multipurpose tree species were collected by a certified local seed collector in Wolayita sodo. Seeds were collected at the beginning of September 2022. The seed was taken from mature trees by using stand tree seed collection methods in the natural forest of Damot Monkonisa.

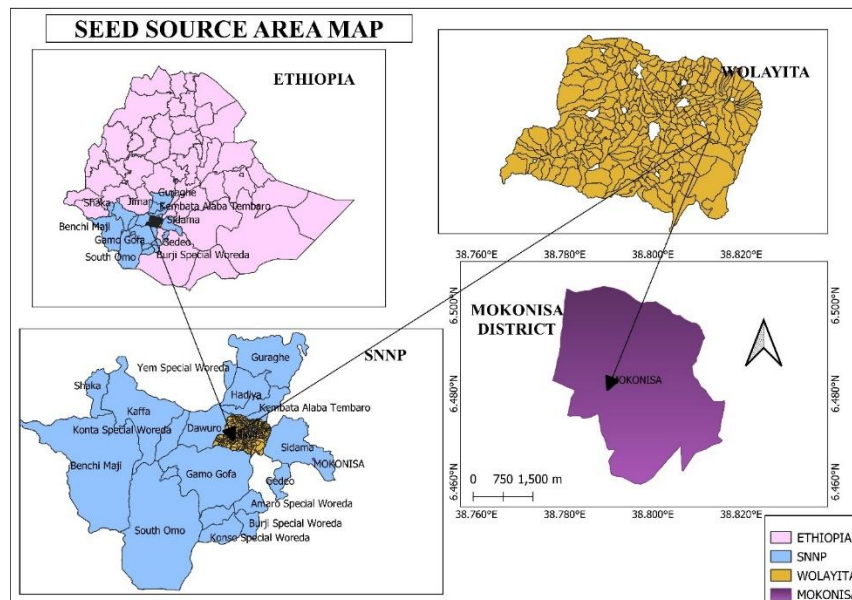


Figure 1. Location map of seed collected area, Damot Monkonisa district, Wolayita sodo

2.2.Experimental design and treatments

Treatments were laid out in completely randomized design (CRD) with 14 treatments, 3 replications, 3 species, 20 seeds per petri dishes a total of 2,520 seeds were used for CRD assessment.

Table 1. Description of pre-sowing treatments used on this study

Treatment	Pre-sowing seeds treatment parameters
CW72	Seeds soaked in cold water for 72 hours at room temperature 22.3-25 ⁰ C
CW48	Seeds soaked in cold water for 48 hours at room temperature at 22.3-25 ⁰ C
HW15	Seeds immersed in hot water at 98 ⁰ C for 15 minutes.
HW10	Seeds immersed in hot water at 98 ⁰ C for 10 minutes.
GA345	Soaking the seeds in 10 mg/L GA3 for 45 minutes.
GA330	Soaking the seeds in 10 mg/L GA3 for 30 minutes.
GA315	Soaking the seeds in 10 mg/L GA3 for 15 minutes.
ABA45	Soaking the seeds in 10 mg/L ABA for 45 minutes.
ABA30	Soaking the seeds in 10 mg/L ABA for 30 minutes.
ABA15	Soaking the seeds in 10 mg/L ABA for 15 minutes.
A5	Soaking the seeds in 98%. concentrated H ₂ SO ₄ for 5 minutes.
A2	Soaking the seeds in 98%. concentrated H ₂ SO ₄ for 2 minutes.
N	Nicking.
C	Control(seeds without the application of any treatments.)



Figure 2. CRD arrangement of the experiment in Laboratory

2.3.Data collection and analysis

The number of germinated seeds were counted in each petri-dishes from each treatment when the radicles are about 2mm long. The test continues until germination ceases. The total germination dates for *Acacia polyacantha* 18 days, *Acacia mearnsii* 29 days and *Faidherbia albida* 39 days was taken. Raw data collection, arrangements, and management are done in Microsoft Excel V.2021. Data on the germinated seed were subjected to a one-way analysis of variance using the STATISTIX V.10. program. Treatment means were separated using Tukey's Studentized Range (HSD) Test at $p \leq 0.05$. The graphical figures on the document were built up using Microsoft Excel V.2021.

A. Germination percentage (GP)

$$GP(\%) = \left(\frac{\text{germinated seeds}}{\text{total tested seeds}} \right) * 100 \dots \dots \dots \text{Eq1}$$

B. Mean Germination Time (MGT)

Mean germination time (MGT) was calculated using the following (Botsheleng *et al.*, 2014) formulas

$$MGT(\text{days}) = \Sigma TiNi/Si \dots \dots \dots \text{Eq2}$$

Where,

Ti= Number of days from the beginning of the experiment

Ni= Number of seeds germinated per day and

Si= Total number of seeds germinated

C. Mean Germination Rate (MGR)

Mean Germination rate will be calculated using (Labouriau and Viladares, 1976) formula

$$MGR = \sum_{k=0}^n \frac{ni}{niti} \dots \dots \dots \text{Eq3}$$

Where,

Ti= Number of days from the beginning of the experiment

Ni= Number of seeds germinated per day

D. Germination Value (GV)

The germination value computed by using (Djavanshir and Pourbeik, 1976) formula

$$GV = \frac{DGS}{N} * GP * C \dots \dots \dots \text{Eq4}$$

Where

GV- germination value

DGS- The daily germination speed computed by dividing cumulative germination percentage by the number of days since the onset of germination

N - It's the frequency or number of DGS calculated during the test

GP- the germination percentage

C- is 10 constant

3.Results

3.1.1.Germination Percentage and Germination value for *A.polyacantha*

The highest number of seed germination was observed on day 12 with 45% on treatment CW72. The analysis results indicated that Nicking, Coldwater, and the hormone Absciscic acid were the effective treatment for the germination percentage. GP showed a strong significant ($p=0.0000$). Over all the highest germination percentage at termination of the experiment was yielded in CW 48, N, ABA 45, and ABA 30 with (86.6%), followed by GA3 15 (85%), ABA 15 (75%) compared to the other treatments and no statistical difference is found between these pre-sowing treatments but it does have shown a statistical difference with the remaining pre-sowing treatments specially with A5 and C. Minimum germination percentage was yielded at A2 in (61.6%), followed by CW 72 (56.6%) and HW 10 (51.6%). The lowest germination percentage was yielded in A5 and C (28.3%) and (33.3%) respectively

Total germination value varied from 41.2-3.6. Although the highest GV was yielded in N (41.26), followed by GA3 30 (36.1). Minimum germination values yielded in ABA 15 (28.9), A2 (22.0), and HW 15 (21.5). Finally, the lowest germination values were yielded in A5 (3.7) and C (3.6). Over all the germination value has a significant difference ($p<0.0003$).

3.1.2.Mean Germination Time and Mean Germination Rate for *Acacia polyacantha*

The result for MGT indicates that they are strongly significant ($p=0.0000$) in which; C and A5 yielded the highest mean germination time of 13.4 and 16 days respectively. Followed by CW 72 10.73 and GA3 30 10.81 days. The lowest mean germination time yielded in N (10.18) days. The mean germination rate indicates the highest result in N (0.098) followed by CW 72 (0.095) and the lowest mean germination rate at C (0.06); although the mean germination rate is significant ($p<0.002$).

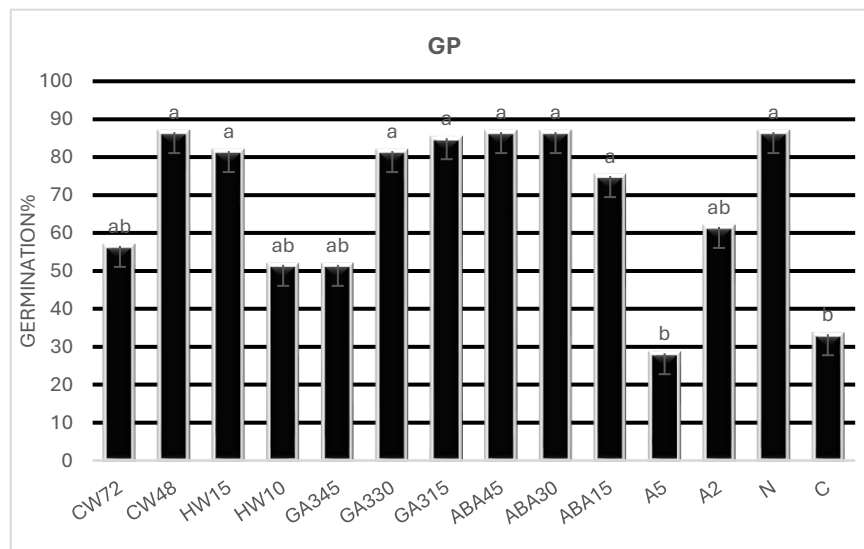


Figure 3.Germination percentage of *A. polyacantha* seeds.

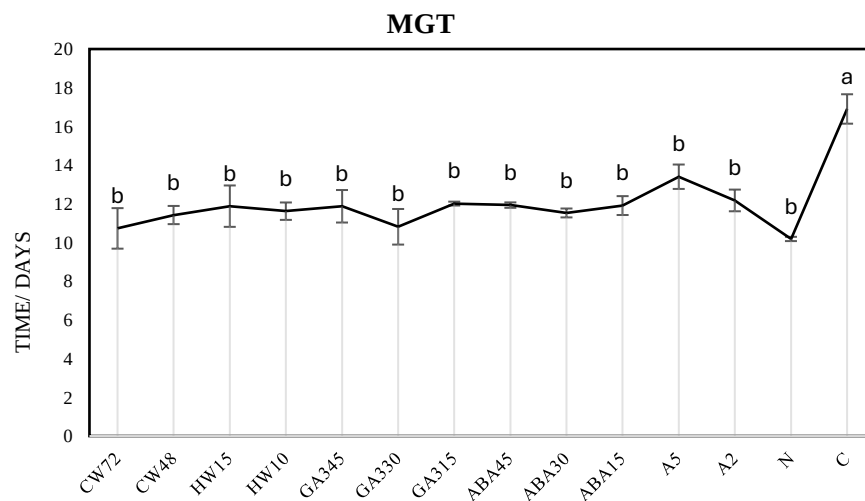


Figure 4.Mean germination time (MGT) of *A. polyacantha* seeds subjected to different pre-sowing treatments

3.2.1. Germination Percentage and Germination value for *A. mearnsii*

The first radicle emergence happened on day 5th in HW10, A5, A2, N, and HW15 with 29 days of total germination period. The highest number of seed germination resulted in day 16th in HW15 with 95% on seed germination.

The result indicated that there was a strong significance difference in GP where ($p=0.0000$). The highest germination percentage was yielded in N (100%) followed by HW 10 (86%), GA3 45 (80%), and HW 15 (78.3%) with inferior germination percentages with no significance difference among the pre-sowing treatment but they do have a significance difference with other pre-sowing

treatments. The minimum number of germination percentage results was yielded in CW 48 (65%), followed by ABA 30 (63%), and CW 72 (58%). The lowest final germination percentage is in C (0%).

In this case, the germination value varied from 46.06 - 0 large germination value was in N treatment (46.062) which statistically differ across the remaining treatments and was superior to HW 10 (30.18), followed by HW 15 (25.4) whereas they do not significantly differ among pre-sowing treatments. GA3 45 (18.8), ABA 45 (16.6), and ABA 15 (15.29) resulted in a minimum germination value superior to GA3 30 (8.45), A3 (7.15) and C yielded with lowest germination value of 0.0 throughout the germination period and the GV for this species shows a strong significance at ($p=0.0000$).

3.2.2. Mean germination time and mean germination rate for *Acacia mearnsii*

Although the mean germination time indicates there is a significance difference at ($p<0.001$). The highest MGT was yielded by ABA 45 (24.07 days) followed by GA3 45 (24.04 days), ABA 15 (23.79 days), ABA 30 (23.62 days), and GA3 30 (23.43 days) in which they do not statistically differ among themselves but they do with the remaining treatments.

The minimum number of mean germination times resulted on A2 (20.8 days), A5 (16.6 days), HW15 (14.5 day), and HW10 (13.5 days). However, N and C decrease with their mean germination time through their germination period of 11.10 and 0.0 days. The highest mean germination rate has resulted in N (0.09) inferior to HW 10 (0.07) they do have a significant difference. The lowest mean germination rate was yielded C which is 0 and the minimum amount of MGR was yielded A5 (0.06), A2 (0.048) followed by CW 48 (0.043).The result in MGR indicates there is a strong difference between this index ($p=0.0000$)

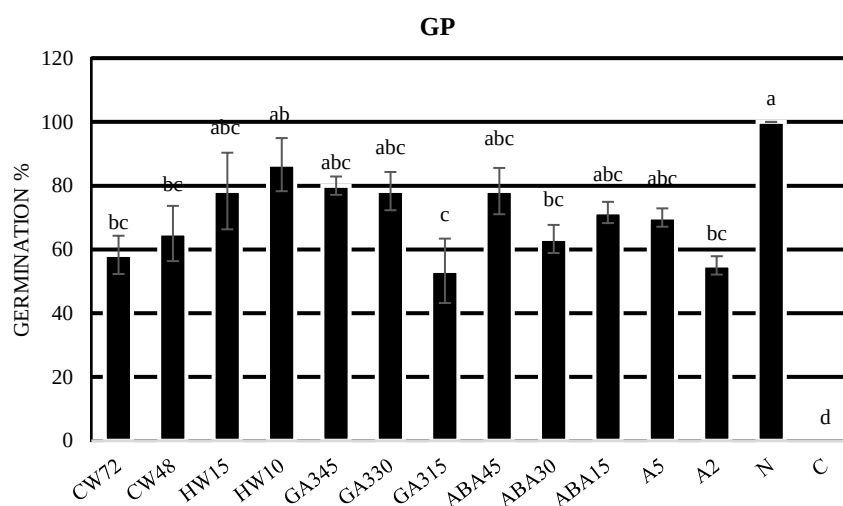


Figure 5. Germination percentage of *A.mearnsii* seeds subjected to different pre-sowing treatments

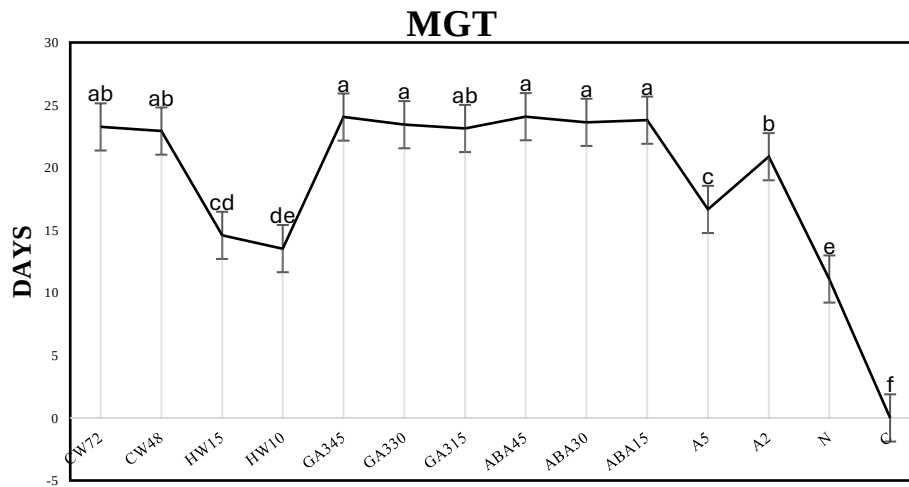


Figure 6. Mean germination time (MGT) of *A. mearnsii* seeds subjected to different pre-sowing treatments

3.3.1. Germination Percentage and Germination value for *Faidherbia albida* Del A. Chev

With 39 days of total germination period the highest number of seed germination was yielded on day 39 with 90% on GA345, but the first radicle emergence happened on day 21 at HW10, CW72, HW15, ABA45, and ABA 30.

The effect of pre-sowing treatment on *Faidherbia albida* has a significant difference ($p < 0.001$) in the GP. So, HW 15 (95%) higher germination percentage which is a statistical difference between the treatments followed by GA3 45 (70.0%), N, and ABA 45 with 68% and 63.3% where they do not statistically differ between themselves but they do with the remaining treatments. The Minimum germination percentage resulted in HW 10 (55%) followed by CW 72 (51%) then followed by ABA 15 (48.3%). Lowest germination percentage was observed in the C (8.3%) and A5 (6.6%) respectively.

As indicated by the total result the GV for *Faidherbia albida* shows a significant difference at ($p < 0.003$). Higher GV was yielded in N (26.8). The lowest germination value was obtained A5 and C with 0.4 and 0.2 values respectively.

3.3.2. Mean germination time and mean germination rate for *Faidherbia albida*

Whereas on germination mean time indicates a strong statistical significance at ($p = 0.0000$), however, HW 15 does have a high mean germination time of 32.9, followed by HW 10 (32.3 days). With the lowest mean germination time in N 7.4 days. Results in mean germination rate revealed a strong significance difference at ($p = 0.0000$). The highest MGR was obtained N (0.13) followed by C (0.04), A2 (0.035), and for A5 with lowest MGR (0.01).

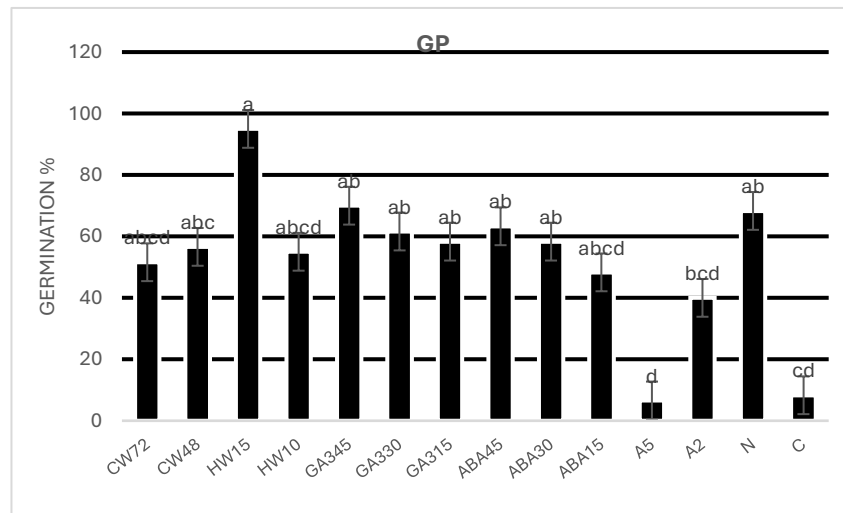


Figure 7.Germination percentage (GP) of *F.albida* seeds subjected to different pre-sowing treatments

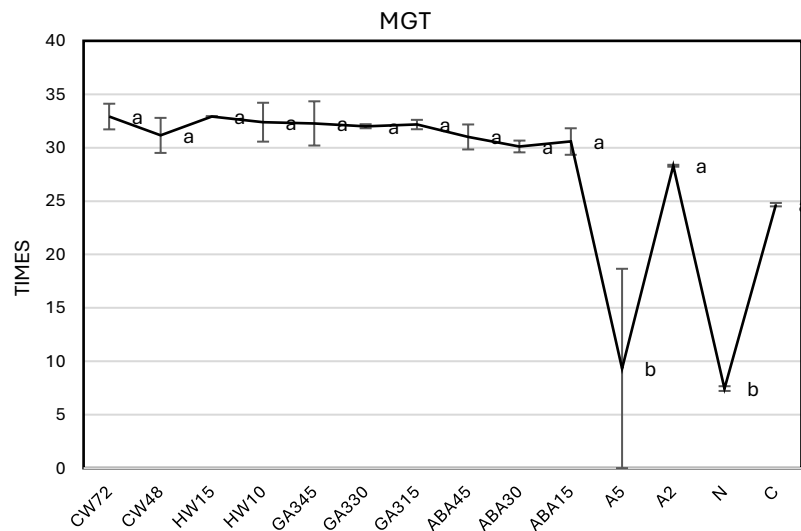


Figure 8.Mean germination Time (MGT) of *F.albida* seeds subjected to difference pre-sowing treatments

DISCUSSIONS

(Catalan and Macchiaveloli, 1991) mentioned that physical seed dormancy may be overcome either by manual scarification of seed-coat by piercing, nicking, clipping, filing, or burning with the aid of a knife, needle, hot wire burner, or abrasion paper. Similarly hot water treatment (Kobmoo and Hellum, 1984; Khasa, 1992; Airi *et al.*, 2009;) or acid treatment (Kobmoo and Hellum, 1984) can also overcome physical dormancy. Because the Entry of water and gaseous

exchange results in enzymatic hydrolysis and thus transferring the embryo into a seedling. This shows the importance of the present study which is supported by Nainar *et al.*, (1999) who used different pre-sowing treatments in *Terminalia chebula* Retz. seeds and found that mechanical scarification gave the highest germination percentage of 60%, likewise, Botsheleng *et al.*, (2014) conducted research on the germination of Pod Mahogany (*Afzelia quanzensis*) where mechanical scarification resulted in a 100% of seed .

In the case, of cold water (at room temperature) treatment the present study is in agreement with the results reported for *T.chebula* where the application of cold water used to break dormancy. Seeds soaked in cold water increased germination speed, germination percentage, and other indices compared with control (Jackson *et al.*, 1994). *T.chebula* pre-treated by being soaked in cold water for 48 hours with successive treatments by 10%. (Jackson *et al.*, 1994).

A study on *B. plurijuga* seeds also proved the efficiency of hot water treatment with 100% of germination (Botsheleng *et al.*, 2014) immersion in hot water produces showed that the highest performance for all the vegetative characteristics studies in *A. polycantha* (Missanjo, 2014). As hot water treatment was reported that 82% of seed germination yielded in *A.procera* seed (Azad *et al.*, 2012). Munie *et al.* (2022) also found that seeds soaked in hot water treatment for 10 min resulted high germination percentage in seeds of *D.steudneri* in which these researches are in consistence with it.

The mechanism of dormancy release and germination stimulation by GA3 treatments is often attributed to the mobilization of stored reserves (Sivakumar *et al.*, 2006) and weakening of the mechanical resistance of the endosperm cells around the radicle tip due to increased activities of cell wall degrading enzymes (Downie *et al.*, 1997). Contrary to the findings in the present study, a study by Munie *et al.*, (2022) on *Dracaena steudenerui* scheweinf Ex.Engl did not show any effect by the application of ABA and GA3 hormones these finding contradicts this study since over 80 % of germination by the application of hormones on the selected tree species shows a positive and fruitful results ; likewise, the findings of Tang *et al.*,(2019), are also in contradiction with our findings, in their study revealed that the application of GA3 did not break the seed dormancy problem of *Sorbus alnifolia* after two months of incubation. Confounding this by Raji and Siril (2018), in the case of *E. serratus* the GA3 treatment was ineffective to improve germination or reduce MGT.

Acid treatment is an efficient method of increasing and accelerating seed germination of species with hard impermeable seed coats (MacDonald and Omoruyi, 2003; Likoswe *et al.*, 2008) . The findings in the present study are in total contradiction, as in the tested species, this treatment was found to be inefficient in the present study. Specifically, findings in *Acacia polyacantha*, and *Faidherbia albida* shows that the control samples (seeds) have better seed germination than those subjected to the sulfuric acid treatment. In seeds of *Acacia mearnsii* it gave a better result; we consider that this is mainly due to the concentration and dipping time of sulfuric acid as the tested concentrations damage the embryo by the chemical instead of survival no matter how they break their dormancy. Schmidt (2000) observed a decline in seed germination at 12 min attributed to

excessive burning of the seed coat which damaged the embryo of *Faidherbia albida*. This fact is supported by MacDonald and Omoruyi (2003).

Conclusion

It's true that in this study; the applied treatments were effective for improving their germination potential. Among the applied 14 pre-sowing treatment the cold-water treatment, nicking, and hot-water treatments have been identified as the convenient (suitable) for breaking their dormancy; because they are effective to produce a maximum number of seedlings within a short time since they are simple, safe, economical, and requires a minimum skill.

Funding

This research was supported by Dr.Stacy Denis Hammond Hammond under the project (Publication and Research Development for Education in Life science at Hawassa University, 23-PKVV-10) and my parents support.

Acknowledgement

The author gratitude goes Dr Stacy Denis Hammond in the assistance and financials support. Other thanks to Bogale Tadesse, Meseret Lema, Amanuel Kassa, and Sisay Negash.

Conflict of Interest

The authors declare no conflict of interest.

REFERENCE

1. Airi, S., I. Bhatt, A. Bhatt, R. Rawal, and U. Dhar. (2009). Variations in seed germination of *Hippophae salicifolia* with different presoaking treatments. *Journal of Forestry Research*, 20, 27–30.
2. Azad,S., R. K. Biswas and A. Matin. (2012). Seed germination of *Albizia procera* (Roxb.) Benth. in Bangladesh: A basis for seed source variation and pre-sowing treatment effect. *Forestry Studies in China*, 14(2), 124–130.
3. Baskin, J. M. (2009). The woody plant seed manual. *Native Plants Journal*, 10(3), 300–301.
4. Belay, T. (2016).Climate-growth Relationship of *Pinus patula* Schldl. Et Cham. *Wondo Genet, South Central Ethiopia. J Climatol Weather Forecasting*, 4(181), 2.
5. Botsheleng, B., T. Mathowa and W. Mojeremane. (2014). *Effects of Pre-Sowing Methods on the Germination of Pod Mahogany (Afzelia quanzensis) and Mukusi (Baikiaea plurijuga) Seeds*.
6. Bradbeer, J. W. (1988). *Seed Dormancy and Germination*. Springer US.
7. Bradford, K. J., F. Chen, M. B. Cooley, P.Dahal, B.Downie, , K. K. Fukunaga, , O. H Gee, S. Gurusinghe, R. A. Mella, , H. Nonogaki, C. T. Wu, H. Yang, and K. O. Yim. (2000). Gene expression prior to radicle emergence in imbibed tomato seeds. *Seed Biology: Advances and*

Applications. Proceedings of the Sixth International Workshop on Seeds, Merida, Mexico, 1999., 231–251.

8. Buttoud, G., F. Place, and M. Gauthier. (2013). *Advancing agroforestry on the policy agenda: A guide for decision-makers*. FAO.
9. Catalan, L., and R. Macchiaveloli, (1991). Improving germination in *Prosopis flexuosa* DC and *P. alba* Griseb. With hot water treatments and scarification. *Seed Science and Technology*, 19(2), 253–262.
10. Clode, D. (2011). *Direct seeding Faidherbia albida (syn. Acacia albida) in the Sahel*.
11. Dessì, L., Podda, L. Brundu, G. Lozano, A.V. Carrouée, E. Marchante, H. Marchante, Y. Petit, M. Porceddu, and G. Bacchetta. (2021). Seed Germination Ecophysiology of *Acacia dealbata* Link and *Acacia mearnsii* De Wild.: Two Invasive Species in the Mediterranean Basin. *Sustainability*, 13(21), 11588.
12. Downie, B., H. W. Hilhorst, and J. D. Bewley. (1997). Endo- β -mannanase activity during dormancy alleviation and germination of white spruce (*Picea glauca*) seeds. *Physiologia Plantarum*, 101(2), 405–415.
13. Hartmann, H. T., D. E. Kester, F. T. Davies, and R. L. Geneve. (1997). Plant propagation: Principles and practices. *Plant Propagation: Principles and Practices.*, Ed. 6.
14. Jackson, J. K., C. Stapleton, and J.-P. Jeanrenaud. (1994). Manual of afforestation in Nepal.
15. Khasa, P. (1992). Scarification of Limba Seeds With Hot Water. *Tree Planters' Notes*, 43(4), 150–152.
16. Kobmoo, B., and A. Hellum, (1984). Hot water and acid improve the germination of *Cassia siamea*. Britt. Seeds. *The Embryon*, 1(1), 27–33.
17. Leakey, R. B. (2017). Definition of Agroforestry Revisited. In *Multifunctional Agriculture* (pp. 5–6). Elsevier.
18. Likoswe, M. G., J. P. Njoloma, W. F. Mwase, , and C. Z. Chilima, (2008). Effect of seed collection times and pretreatment methods on germination of *Terminalia sericea* Burch. Ex DC. *African Journal of Biotechnology*, 7(16).
19. MacDonald, I., and O. Omoruyi. (2003). Effect of seed pre-treatment on germination of two surface types of *Dialium guineense*. *Seed Technology*, 41–44.
20. Missanjo, E. (2014). Effects of Different Pretreatments to the Seed on Seedling Emergence and Growth of *Acacia polyacantha*. *International Journal of Forestry Research*, 2014, 1–6.
21. Mousavi, S. R., M. Rezaei, and A. Mousavi, (2011). A General Overview on Seed Dormancy and Methods of Breaking It. *Advances in Environmental Biology*, 5, 3333–3337.
22. Munie, S. A., H. Habrová, , K. Houšková, and L. Karas, (2022). Effect of Different Presowing Treatments to Break Seed Dormancy and Seed Collection Methods on the Germination of *Dracaena steudneri* Schweinf. Ex Engl. *Forests*, 13(8), 1232.

23. Nair, P. K. R. (1991). State-of-the-art of agroforestry systems. *Forest Ecology and Management*, 45(1–4), 5–29.
24. Negash, L. (2010). A selection of Ethiopia's indigenous trees: Biology, uses, and propagation techniques. Addis Ababa University Press.
25. Negash, M. (2007). Trees management and livelihoods in Gedeo's agroforests, Ethiopia. *Forests, Trees and Livelihoods*, 17(2), 157–168.
26. Negash, M., and M. Starr, (2015). Biomass and soil carbon stocks of indigenous agroforestry systems on the south-eastern Rift Valley escarpment, Ethiopia. *Plant and Soil*, 393(1), 95–107
27. Sivakumar, V., R. Anandalakshmi, , R. Warriar, , Tigabu, M., P. Odén, , S. Vijayachandran, S. Geetha, and B Singh. (2006). Effects of presowing treatments, desiccation and storage conditions on germination of *Strychnos nux-vomica* seeds, a valuable medicinal plant. *New Forests*, 32, 121–131.
28. Tang, Y., K., Zhang, Y. Zhang, and J. Tao, (2019). Dormancy-breaking and germination requirements for seeds of *Sorbus alnifolia* (Siebold and Zucc.) K. Koch (Rosaceae), a mesic forest tree with high ornamental potential. *Forests*, 10(4), 319.
29. Tura, B. (2018). Biology of seed development and germination physiology. *Advances in Plants and Agriculture Research*, 8(4).
30. Wood, P. J., and Burley, J. (1991). A tree for all reasons: An introduction and evaluation of multipurpose trees for agroforestry. ICRAF Science and Practice of Agroforestry (ICRAF).
31. Zulu, J. N. (1990). Germination studies on *Acacia polyacantha* seeds. *Ghana Journal of Science*, 30(1–2), Article 1–2.

