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Effects of Different Pre-Sowing Treatments on Germination of *Pericopsis angolensis* seeds of Tabora Miombo Woodlands, Tanzania

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ABSTRACT

Pericopsis angolensis species survival is reported to be low in nurseries. Given the high dormancy tendency of Legume family, it is speculated that, pre-sowing treatment of *Perocopsis angolensis* seeds may result in improved germinability. Different attempts of breaking the dormancy to enhance germination have been done. However, the difference in environmental conditions - soil pH, temperature, and water availability - which parental plants experienced during their growth and seed maturation, have an impact on seed germination patterns. This study assessed the effects of pretreatments (soaking in cold and boiling water at different time intervals) on the germination of *Pericopsis angolensis* seeds collected in Tabora, Tanzania. Analysis of Variance (ANOVA) was done to show differences in seed germination parameters under different pretreatments. Results show that, there was significant ($P<0.001$) difference in germination parameters between the control and pretreated seeds except for the Mean Germination Time ($P>0.05$). The highest Germination Value, Germination Percent and Germination Capacity were found under control. The findings prove that pretreating *Pericopsis angolensis* seeds by soaking in cold and hot water have no additional effect on germination. Thus, the study suggests that the restoration of the forests using *Pericopsis angolensis* species can be achieved even without seed pretreatments.

Keywords: Seed pre-sowing treatments - Germination Parameters - *Pericopsis angolensis* - Miombo woodlands.

INTRODUCTION

Miombo woodland ecosystem forms an extensive range of tropical deciduous woodland in Africa, covering an area of approximately 2.7 million km^2 in Southern, Central, and Eastern Africa (Timberlake *et al*. 2020, Mgumia 2017, Shirima *et al*. 2011). The ecosystem supports unique and rich flora dominated by tree species in the family Leguminosae, subfamily Caesalpinioideae, with genera of *Brachystegia*, *Julbernardia*, and *Isoberlinia* (Mgumia, 2017). Miombo woodlands support millions of rural and urban dwellers, with the majority of them relying on miombo wood, fuelwood, traditional medicines, food and charcoal as a source of energy (Mgumia *et al*. 2017, Njana *et al*. 2013, Dewees *et al*. 2010, Frost, 1996). Majority of the neighboring communities contribute to the problems of overexploitation when extracting potential resources from Miombo woodlands, through conversion of woodlands to farmland, seasonal forest fires, and livestock grazing (Campbell *et al*. 2007, Fors 2002, Campbell 1996). It is through this nexus of concerns that knowledge about the ability of the trees to regenerate, succession, and re-colonize degraded areas is of particular importance.

Germination of seeds is among the biodiversity restoration and conservation methods that have saved many threatened indigenous plant species worldwide (Vodouhè *et al*. 2011) through propagation of seeds for mass production. However, seeds of many native species in Miombo woodlands are difficult to regenerate naturally (Luna *et al*. 2011). This may be due to suffering from intense seed latency, which may be due to undeveloped embryo, and impermeable thick seed coat which resist the growth of the embryo (Amoakoh *et al*. 2017). This is considered the main problem in establishing forests of legume species which makes them hard to germinate (Opoku *et al*. 2018). Different approaches of breaking seed dormancy in order to enhance germination rate and increase the germination process have been suggested by many authors (Bano *et al*. 2021; Nourmohammadi *et al*. 2019, Airi *et al*. 2009). However, the conditions necessary to allow seeds to break dormancy and germinate easily varies among family members, species or among seed sources of the same species. For example; *Acacia nilotica* and *Leucaena leucocephala* , require hot water soaking before germinating while *Brachystegia spiciformis* does not need pretreatment (PROTA, 2022).

Pericopsis angolensis (Baker) Meeuwen belongs to the Fabaceae/Leguminosea family found in Miombo woodlands (Deklerck *et al*. 2017). The species is highly useful for firewood, timber, charcoal making (Manyanda *et al*. 2020), carvings (Frost, 1996) and has long been used as a medicinal plant; where leaves, bark and roots are commonly used to cure ailments such as; diarrhea (Chingwaru *et al*. 2019). However, little is documented about the germination performance of *Pericopsis angolensis* seeds in nurseries. *Pericopsis angolensis* survival is reported to be extremely low in a study by Vyamana *et al*. (2007), that attempted to test the effect of nursery practices on seedling survival of five selected Miombo species. Moreover, given the high dormancy tendency of Legume family, it was speculated that, pre-sowing treatment of *Perocopsis angolensis* seeds may result in improved germinability of the seeds hence high performance in the nursery. However, a study conducted in Burundi wet Miombo woodlands by Nkengurutse *et al*. (2016), found that seed pretreatment such as sulfuric acid, scraping, or boiling water on *Pericopsis angolensis* seeds decreased germination percentage, demonstrating the absence of dormancy.

In Tanzania on the other hand, where forest sector operations are governed by the Forest and Beekeeping Division (FBD) through Technical Orders, information on plant propagation such as seed germination of some tree species, including *Pericopsis angolensis*, is lacking (FBD, 2021). Despite, the findings by Nkengurutse *et al*. (2016) that *Pericopsis angolensis* seeds of Burundi wet Miombo woodland lack dormancy, the environmental conditions that the parental plants were exposed to during their growth and seed maturation have impacts on the seed germination patterns. Depending on the species locality, difference in environmental factors, such as; soil pH, temperature, and water availability, affects the ideal conditions for seed germination (Farooq *et al*. 2021, Daddario *et al*. 2017). This study, therefore sought to evaluate the effects of seed pre-sowing treatments on germination of *Pericopsis angolensis* in a laboratory setting as for the seeds from Tabora dry Miombo woodland. According to research, imbibition is the simplest way to increase seed germination rates and establishment under stressful conditions (Mwami *et al*. 2017, Merou *et al*. 2011, Choudhury *et al*. 2009). Mwami *et al*. (2017) argued that water imbibition is crucial for germination because it activates enzymes and speeds up the metabolism of the starch and protein that are stored in the seed. Thus, our study evaluated the effects of pre-sowing treatments (soaking in normal water at different time intervals and hot water) on seed germination of *Pericopsis angolensis*. The study assessed the effects of pretreatments (soaking in cold and boiling water at different time intervals) on the germination of *Pericopsis angolensis* seeds collected in Tabora.

MATERIALS AND METHODS

The study was conducted as on station experiment in the laboratory of Tree Seed Production Station (TSPS – TFS) Headquarters in December 2021. The station is in Morogoro municipality at 6.8278° S and 37.6591° E with an altitude of 550 m.a.s.l; 3 km from Msamvu bus stand on the road to Dodoma, Tanzania.

Seed Collection and Sample Preparation

Seeds of *P. angolensis* was obtained from Shinyanga Tree Seed Centre (STSC) in November 2021. The obtained seeds were formally collected from the dry Miombo woodlands of Tabora, Tanzania. Most of Miombo tree species experience fruits and seed dispersal in dry season i.e., July – Dec, (Campbell, 1996). Seed sample for experiment was drawn from seed-lot storage by using Riffle Sample Divider to avoid biasness, and enough samples was repacked and labeled prior to information available for further procedure.

Experimental Design, Seed Pre-sowing Treatments and Germination

The experiment was laid out using a complete randomized block design (CRBD) with four (4) replications and five (5) pretreatments: T1 = soaking seed in normal water (at room temperature = 25^{0}C) for 6 hrs., T2 = soaking seed in normal water for 12 hrs., T3 = soaking seed in normal water for 24 hrs., T4 = soaking seed in boiled water till it cools and T0 = untreated seeds. For T4, water was firstly boiled at 100°C and then poured into seeds and the seeds were left till the water has cooled down to room temperature (25^{0}C) before sawing. Each replicate contained 50 seeds, making a total of 200 seeds per pretreatment. Sand was sterilized by oven dry method at 180°C for 2 hrs. prior to seed sowing (Sinegani and Hosseinpur, 2010).

The study was done in a temperature-controlled Plant Growth Chamber with temperatures set at a maximum of 28°C during the day and a low of 18°C at night, respectively. The seeds were placed on top of sand and arranged in square manner at a space of approximately its seed size. A layer of 0.5 cm thick of sand was then used to cover the seeds. To maintain adequate moisture for germination and seedling growth, sawn seeds were watered once a day (morning) using watering spray bottle and each replicate/germination tray received 200 ml of distilled water for four weeks (28 days).

Data Collection

The effects of pretreatments on seed germination was assessed by counting and recording germinated seeds at an interval of four (4) days until no further germination took place (Likoswe *et al.* 2008, Msanga, 1998). There was no more germination after four weeks. A seed was regarded to be germinated if there is a visible radicle emergence (Tian *et al.* 2014). At the end of experiment (before termination), ungerminated seeds from each treatment were tested for viability by cutting test, where the seeds with white, firm embryos were recorded as viable, while those with brownish-yellow, squishy embryos were recorded as non-viable (Fan *et al.* 2016).

Data Analysis

To assess the effects of pre-sowing treatments on germination of *Pericopsis angolensis* in the laboratory, germination parameters under different pre-sowing treatment conditions were assessed. Seed germination parameters were firstly computed (Table 1) for each seed pre-sowing treatment and then, one-way analysis of variance (ANOVA) was performed to determine treatment effects on seed germination. For the germination parameters which were significantly different between pre-sowing treatments, a pair-wise test using Tukey HSD comparison was done. Germination computation was done by package "*GerminaR*" and ANOVA and Tukey HSD test were performed by the '*stats*' package in the R software (v. 4.1.2).

Table 1: Seed Germination Parameters

Germination parameter	Code	Formula	Reference
Mean Germination Time	MGT	$MGT = \frac{(n1 \times d1 + n2 \times d2 + \cdots n \times dn)}{\text{Total number of seeds germinated}}$ n = number of germinated seed and d = number of days	(Mojeremane *et al.* 2017)
Germination Percentage	GP	$GP = \frac{\text{Germinated seeds (GS)}}{\text{Total seed sown (TSS)}} x100$	(Mwendwa *et al.* 2020).
Germination Index	GI	$GI = \frac{n}{d}$ n = number of seedlings emerging on day 'd' and d = day after planting	(AOSA, 1983)
Germination Value	GV	$GV = \frac{\sum DGS}{N} X(GP \ X \ 10)$ DGS = Daily germination speed GP = Germination percentage	(Djavanshir and Pourbeik, 1976)
Germination Capacity	GC	$GC = \frac{\sum GS + \sum \text{Ungerm. sound seeds}}{\text{Total seeds tested}} \ x \ 100$ GS = Germinated seeds	(Paul, 1972)

RESULTS

Effects of Seed Pre-sowing Treatments

Mean Germination Time (MGT)

The germination of *Pericospsis angolensis* seeds started on the fourth and eighth day in pretreatments (T0 and T1) and (T2, T3 and T4) respectively. Meanwhile the germination was completed on the twelfth and sixteenth day in pretreatments (T0, T1, T2 and T3) and (T4) respectively. At the end of this period, 57.2% of seeds had germinated in all pretreatments, while 42.8% of the remaining seeds did not germinate. The mean germination time (MGT) for *Pericopsis angolensis* seeds was approximately 8 days under all pre-sowing conditions (Table 2). Moreover, there was no significant difference (*P > 0.05*) in MGT between the treatments.

Table 2: Summary information (Mean ± SD) and post-hoc analysis of mean effects of different pre – treatment tests on germination parameters of *Pericopsis angolensis* seeds

Treatments	MGT (days)	GP (%)	GI (Seeds/day)	GV	GC (%)
T0	8 ±0.15[(a)]	94 ±4.32[(a)]	5.75±0.20[(a)]	48 ±4.16[(a)]	94 ±3.27[(a)]
T1	8±0.00[(a)]	50±3.00[(b)]	3.04±0.19[(b)]	13.3±5.50[(b)]	56±3[(b)]
T2	8±0.18[(a)]	52±2.31[(b)]	3.25±0.14[(b)]	16.3±3.83[(b)]	52±2.31[(b)]
T3	8±0.16[(a)]	44±1.91[(c)]	2.7±0.09[(c)]	9.3±3.21[(b)]	44±1.91[(c)]
T4	8±0.07[(a)]	44±3.46[(c)]	2.7±0.34[(c)]	10.3±1.28[(b)]	44±3.46[(c)]

[Difference in letter labels (a, b, c) in a plot shows that there is significance difference among the respective pre-treatments and vice-versa.]

Germination Percentage (GP)

The cumulative germination percent GP of *Pericopsis angolensis* seeds, gradually increased from the fourth day (4th) and reached its maximum values on the eighth (8th) day with the exception of seeds under T0 and T1, where the GP slightly increased up to the 12th day. During the following days (up to the 28th day), the curve was almost constant (Figure 1). There was significant difference ($F_{(4,15)} = 193.2, P < 0.001$) in GP between seeds under control and treated seeds, whereas the highest GP (94%) was obtained in seeds under control, with lower numbers of ungerminated seeds compared to most of the treatments. T2 had a germination slightly higher (55%) compared to the treatments which had < 50%. Soaking the seeds in water did not work well, where seeds in both T3 and T4 resulted in lowest GP (44%). However, there was no significant difference in GP between T1 and T2 and T3 and T4 treatments (Fig 1).

Germination Index (GI)

Similar to GP, the highest GI values were obtained in seeds under control (6 seeds/day) compared to other sowing treatments. Untreated seeds differed significantly ($F_{(4, 15)} = 173.9, P < 0.001$) from treated seeds while *Pericopsis angolensis* seeds under T1 and T2 (3 seeds/day) had significantly higher GI value ($P > 0.05$) than T3 and T4 (Figure 2).

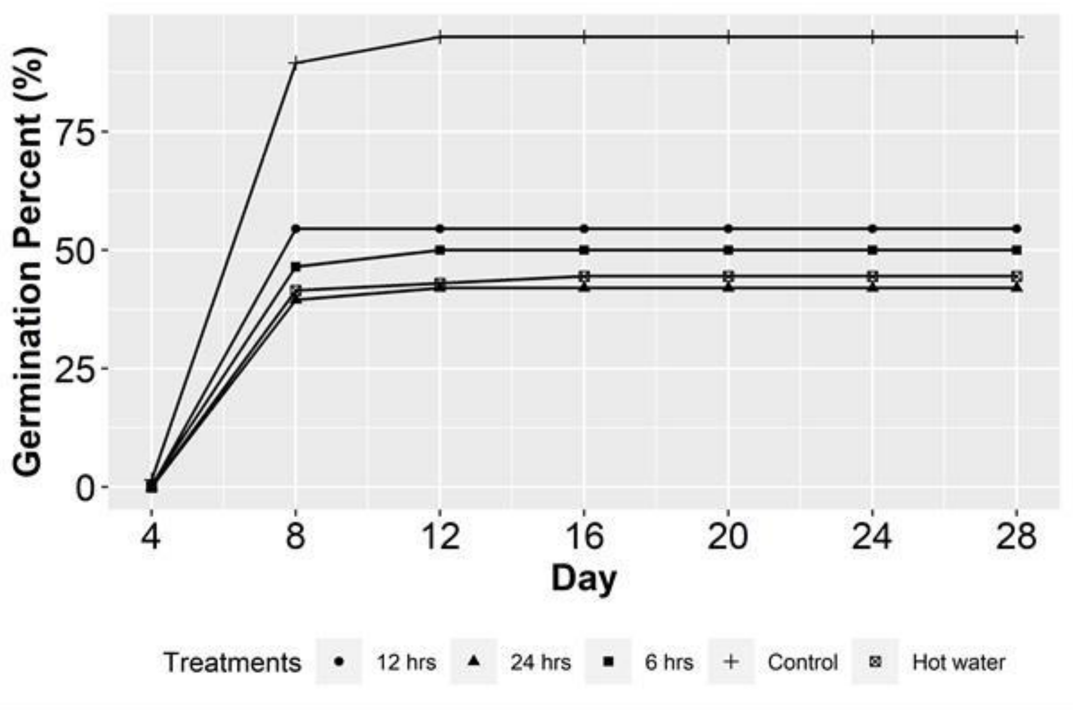

Figure 1: The trend cumulative Germination of *Pericopsis angolensis* seeds under different pre-sowing treatment conditions

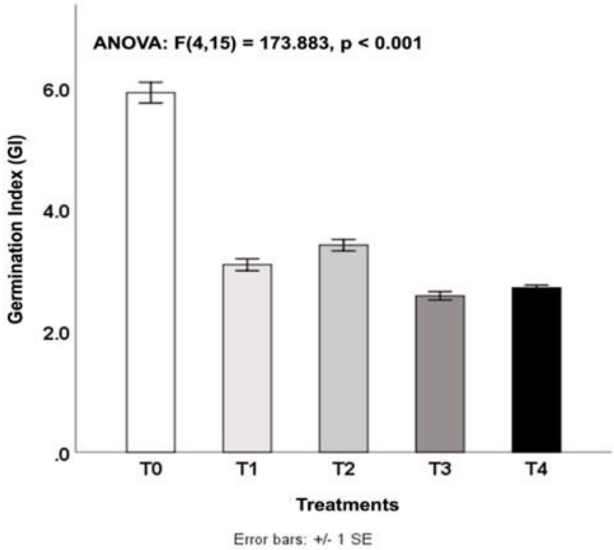

Figure 2: Germination index (GI) of *Pericopsis angolensis* at different pre-sowing treatment conditions. [The vertical line outside the box represents the minimum and maximum values. Difference in letters (a, b, c) signifies that, GI differs among the specified pre-treatment conditions.]

Germination Value (GV)

One-way ANOVA of final germination showed significant variation in seed GV among treatments were significant ($F_{(4, 30)} = 15.52$, $P < 0.001$). Germination value of *Pericopsis angolensis* was approximately three times higher under control condition (T0) compared to pre-treated seeds. For T0, germination value increased significantly up to the 12th day (GV = 62) and then started to drop on the following days. Meanwhile, the remaining pre-treated seeds peaked on the 8th day, except for seeds under T1, where the GV slightly increased up to the 12th day and then decreased (Fig 3). The highest GV in T0 was followed by soaking seeds in water for a period of 12 hrs (T2). However, difference in GV ($P > 0.05$) among all the pre- treated seeds were not significant.

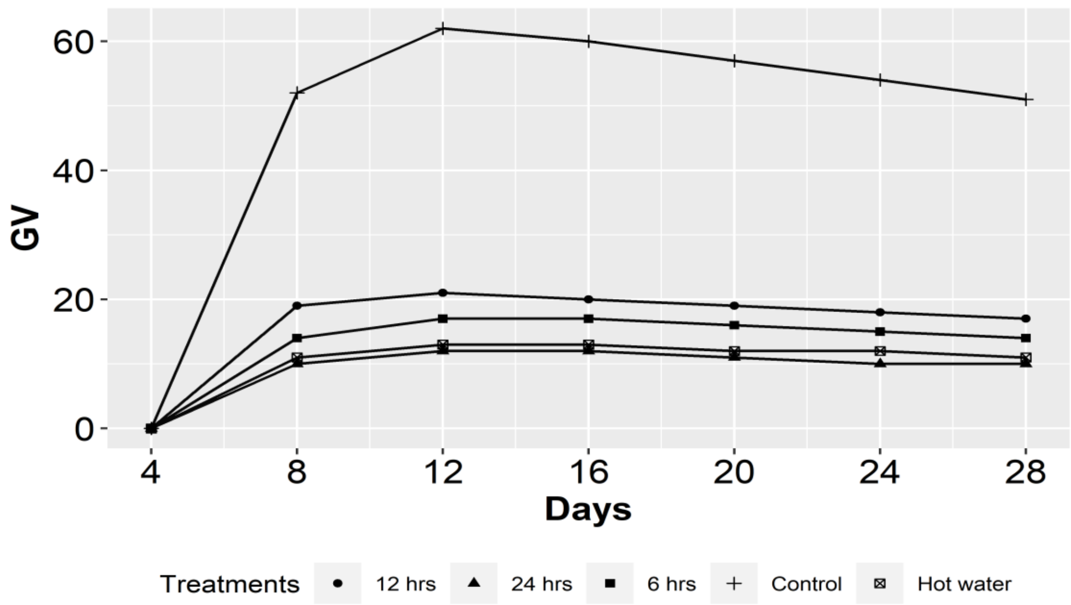

Figure 3: Germination value of *Perocopsis angolensis* under different pre-sowing treatment conditions. [The treatments indicate the difference in soaking (imbibition) period of *Pericopsis angolensis* species]

Germination Capacity (GC)

The highest germination capacity of *P. angolensis* seeds was obtained under control condition (T0) (94%), followed by seeds soaked in water for a period of 6 hrs. (T1). Generally, the mean GC decreased with increase in time of imbibition (Table 2). There was significant difference between in GC between treated and untreated seeds ($F_{(4,15)} = 224.1, P < 0.001$) . The seeds of treatment T1 and T2 had the same GC (>55%), that were significantly higher than ($P > 0.05$) between T3 and T4 (Fig 5).

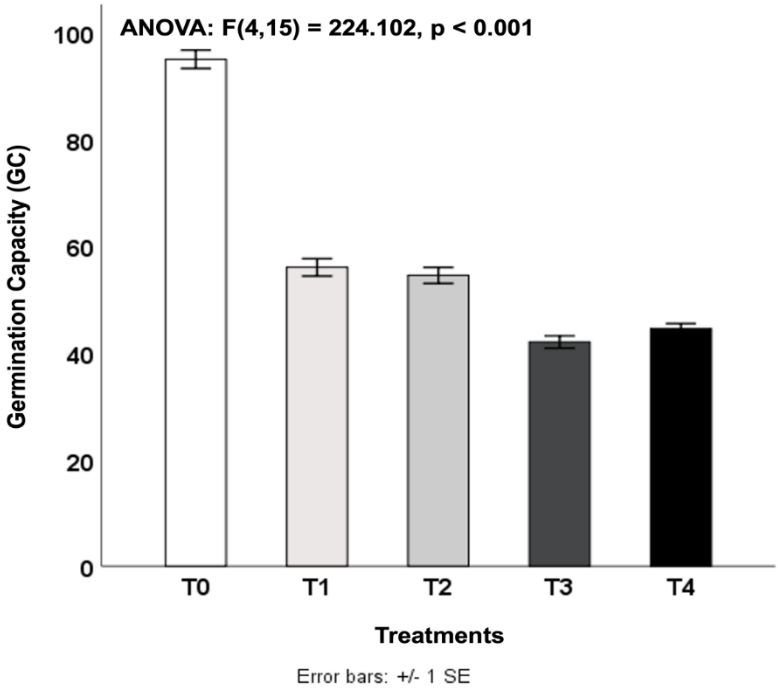

Figure 4: Germination capacity (GC) of *P. angolensis* seeds under different pre-sowing treatments. [The vertical line outside the box represents the minimum and maximum values. Difference in letters (a, b, c) signifies that GC differs among the specified pre-treatment conditions.]

DISCUSSION

Tropical indigenous tree seeds, especially those of Miombo woodlands, are reported to have difficulty in germinating due to seed dormancy tendencies (Martins *et al.* 2019, Malmer 2007, Msanga 1998). Many seeds from legume family species including *Pericopsis angolensis* are reported to have physical dormancy (Jaganathan 2020, Mira *et al.* 2017). As a consequence, different seed pre-sowing treatment methods have been used to break dormancy and stimulate prompt and uniform germination of seeds (PROTA 2022, Mojeremane *et al.* 2017).

This study found out that all germination parameters were lower in treated *Pericopsis angolensis* seeds, compared to those under the control treatment. The findings are in agreement with Nkengurutse *et al.* (2016), who reported that seeds of some indigenous Fabaceae tree species in Burundi wet Miombo woodland including *Pericopsis angolensis, Brachystegia microphylla*, *Brachystegia utilis*, *Brachystegia bussei* and *Julbernardia globiflora* did not require special germination condition however the study was testing the effects of germination temperature and imbibition time on germination. However, despite the effort of National Tree Seed Programme and earlier Tanzania Tree Seed Agency to conduct germination trials for many indigenous tree species including of dry Miombo woodlands, the information on seed germination of *Pericopsis angolensis* has not been documented in Tanzania (TTSA 2017, Msanga 2017, Msanga 1998).

It was also found in this study that, germination percentage (GP) was highest for untreated seeds/control (94%), compared to pre-treated seeds (T1, T2, T3 and T4) (Figure 1). Observation on germination test revealed that any seed pre-sowing treatment of *Pericopsis angolensis* (soaking in tap water for 6 hrs, 12 hrs, 24 hrs, and boiling water) had lower germination percentage. This indicates that *Pericopsis angolensis* seeds do not need pre-treatment since they might have no dormancy (Nkengurutse *et al.* 2016).

It was also, observed that both pretreated and unpretreated seeds shared the same mean germination time/day (MGT); where on day 8 both seed pre-sowing treatments attained higher germination (Table 2). Nevertheless, the MGT were not improved by pre-treatment condition of the seed at different durations implying another proof of absence of dormancy of the seed.

Moreover, results on other germination parameters including germination capacity (GC), germination index (GI) and germination value (GV) scored higher values in control/untreated seeds (T0) compared to other remaining pretreatments (T1, T2, T3, and T4). There was no significant difference in GC of pretreatments T1 and T2 and T3 and T4 (Figures 4). In general, for a seed to activate the embryo and begin the process of cell division, differentiation, and multiplication to grow into a seedling, it needs an optimal level of moisture rather than fall saturation. Sabongari and Aliero (2004), reported that, too much soaking time exposure e.g., T3, causes seeds to have higher concentrations of Carbon dioxide, ethanol, and lactic acids and lower levels of Oxygen, which results in poor germination. Moreover, the effect of hot water treatment on seed embryo was also reported by (McDonnell *et al.* 2012, Hopkinson and English, 2004) to have negative effects on germination as happened in T4. The immersion of seeds in boiling water of temperatures above 80^{o}C was reported to be too hot water, which could result into injuring or killing of the seed embryo , and resulting in lower GC which is unsound in seedlings production (McDonnell *et al.* 2012).

Generally, this study found that, soaking time exposure and temperature of water used to pretreat seeds have no positive additional effect in comparable to untreated seeds. Considering the same germination time between treated seeds and untreated seeds, then pre-treatment of *Pericopsis angolensis* seeds by soaking in water proves to be unnecessary. This is in contrast to several researches which argue that species of Fabaceae family such as *Acacia nilotica, Faidherbia albida, Vachellia rehmanniana, Pterocarpus angolensis, Leucaena leucocephala* and *Dicrostachys cinerea*, presents high physical dormancy, and hence requiring pretreatments before germinating (Gilani *et al.* 2019, Kheloufi *et al.* 2018, Mojeremane *et al.* 2017, Idu and Omonhinmin 1999, Msanga 1998). However, sometimes all viable seeds in batch do not germinate at a limited/set period of time; some fail due to unforeseen factors that happen during the process of germination (Fan *et al.* 2016, Pace *et al.* 2016) other than dormancy of the seeds.

CONCLUSION AND RECOMMENDATIONS

Conclusion

Understanding the ability of the common suspected dormant tree seeds, to germinate after pre-sowing treatment is of particular importance for sustainable forest management, including the recovery of the desired native species composition. The findings of this study suggest that pre-treating *Pericopsis angolensis* by soaking the seeds at different time exposure and temperature of water have no positive additional effect on germination of the seeds. This suggests that *Pericopsis angolensis* seed species do not require any pretreatment before sowing or planting, implying that they have no physical seed dormancy. This is different from what has been reported about tree seeds from the legume family, having hard seed coats and thus being the most dormant. Thus, our study provides baseline report that the restoration of Miombo woodlands through the use of indigenous *Pericopsis angolensis* species can be easily achieved even without seed pre-treatments.

Recommendations

In order to ensure sustainable conservation and restoration of Miombo woodland are successful taking in place in Tanzania the government through Tanzania Forest Services Agency (TFS), local government authorities, communities, and other stake holders should establish plantations of native tree species including *Pericopsis angolensis* because the seeds do not require pre-sowing treatment. However, further studies on field performance especially from nursery stage of this species should be taken.

REFERENCES

Airi, S., Bhatt, I.D., Bhatt, A., Rawal, R.S. & Dhar, U. 2009. Variations in seed germination of Hippophae salicifolia with different presoaking treatments. *Journal of Forestry Research*, 20(1), 27–30. https://doi.org/10.1007/s11676-009-0005-3.

Amoakoh, O.A., Nortey, D.D.N., Sagoe, F., Amoako, P.K. & Jallah, C.K. 2017. Effects of pre-sowing treatments on the germination and early growth performance of Pouteria campachiana. *Forest Science and Technology*, 13(2), 83–86. https://doi.org/10.1080/21580103.2017.1315961.

Bano, H., Rather, R.A., Bhat, J.I.A., Bhat, T.A., Azad, H., Bhat, S.A., Hamid, F. & Bhat, M.A. 2021. Effect of pre-sowing treatments using phytohormones and other dormancy breaking chemicals on seed germination of *Dioscorea deltoidea* Wall . Ex Griseb .: an Endangered Medicinal Plant Species of North. *Ecology, Environment and Conservation, December*, S253–S260.

Campbell, B.M. 1996. The miombo in transition: Woodlands and welfare in Africa. In *CIFOR*. CIFOR. https://doi.org/10.1016/0960-8524(91)90110-6

Campbell, B.M., Angelsen, A., Cunningham, A.B., Katerere, Y., Sitoe, A.A. & Wunder, S. 2007. Miombo woodlands – opportunities and barriers to sustainable forest management. *Observatory*, *June*, 41.

Chingwaru, C., Tanja, B. & Chingwaru, W. 2019. Aqueous Extracts of Pericopsis angolensis and Swartzia madagascariensis with High Antimicrobial Activities against Escherichia coli O157, Shigella spp. and Salmonella enterica subsp. enterica (Serovar typhi). *African Journal of Biotechnology*, *18*(29), 831–844. https://doi.org/10.5897/ajb2019.16854.

Choudhury, B.I., Khan, M.L. & Das, A.K. 2009. Seed dormancy and germination in *Gymnocladus assamicus*: An endemic legume tree from Northeast India. *Seed Science and Technology*, *37*(3), 582–588. https://doi.org/10.15258/sst.2009.37.3.07

Daddario, J.F.F., Bentivegna, D.J., Tucat, G. & Fernández, O.A. 2017. Fatores ambientais que afetam a germinação de sementes de cardos comuns (Dipsacus fullonum). *Planta Daninha*, *35*, 1–11. https://doi.org/10.1590/S0100-83582017350100065.

Deklerck, V., Finch, K., Gasson, P., Van den Bulcke, J., Van Acker, J., Beeckman, H. & Espinoza, E. 2017. Comparison of species classification models of mass spectrometry data: Kernel Discriminant Analysis vs Random Forest; A case study of Afrormosia (Pericopsis elata (Harms) Meeuwen). *Rapid Communications in Mass*

Spectrometry, *31*(19), 1582–1588. https://doi.org/10.1002/rcm.7939.

Dewees, P.A., Campbell, B.M., Katerere, Y., Sitoe, A., Cunningham, A.B., Angelsen, A. & Wunder, S. 2010. Managing the miombo woodlands of Southern Africa: Policies, incentives and options for the rural poor. *Journal of Natural Resources Policy Research*, *2*(1), 57–73. https://doi.org/10.1080/19390450903350846.

Fan, S.G., Wang, Y.R., Baskin, C.C., Baskin, J.M. & Hu, X.W. 2016. A rapid method to determine germinability and viability of Agriophyllum squarrosum (Amaranthaceae) seeds. *Seed Science and Technology*, *44*(2), 410–415. https://doi.org/10.15258/sst.2016.44.2.01.

Farooq, S., Onen, H., Tad, S., Ozaslan, C., Mahmoud, S.F., Brestic, M., Zivcak, M., Skalicky, M. & El-Shehawi, A.M. 2021. The influence of environmental factors on seed germination of Polygonum perfoliatum L.: Implications for management. *Agronomy*, *11*(6), 1–14. https://doi.org/10.3390/agronomy11061123.

FBD 2021. *Technical Order No 1 of 2021*. Forestry and Beekeeping Division, Ministry of Natural Resources and Tourism. Dodoma, Tanzania. pp 1-13.2021.

Fors, L. 2002. *Tree seed survival across a miombo woodland fragmentation gradient in Tanzania* (Issue August). Uppsala University, Sweden.

Frost, P. 1996. The Ecology of Miombo Woodlands. *The Miombo in Transition: Woodlands and Welfare in Africa*, *January 1996*, 266. http://books.google.com/books?hl=nl&lr=&id=rpildJJVdU4C&pgis=1

Gilani, M.M., Ahmad, I., Farooq, T.H., Wu, P., Yousaf, M.S., Khan, M.W., Yousaf, T. Bin & Ma, X. 2019. Effects of pre-sowing treatments on seed germination and Morphological growth of Acacia nilotica and Faidherbia albida. *Scientia Forestalis/Forest Sciences*, *47*(122), 374–382. https://doi.org/10.18671/scifor.v47n122.20.

Hopkinson, J.M. & English, B.H. 2004. *Germination and hardseededness in desmanthus*. *38*, 1–16.

Idu, M. & Omonhinmin, A.C. 1999. Effect of oven - Heat and boiling on the germination and seedling development of Dichrostachys cinerea (L) Wight and Arn (Fabaceae). *Agronomie*, *19*(8), 671–676. https://doi.org/10.1051/agro:19990802.

Jaganathan, G.K. 2020. *Plant Science Today Do Fabaceae species with physical dormancy occur mostly in the temperate ecosystems ? A rebuttal to using global biodiversity information facility (GBIF) analysis*. *7*, 109–111.

Kheloufi, A., Mounia Mansouri, L., Aziz, N., Sahnoune, M., Boukemiche, S. & Ababsa, B. 2018. Breaking seed coat dormancy of six tree species. *Reforesta*, *5*, 4–14.

Likoswe, M.G., Njoloma, J.P., Mwase, W.F. & Chilima, C.Z. 2008. Effect of seed collection times and pretreatment methods on germination of *Terminalia sericea* Burch. ex DC. *African Journal of Biotechnology*, *7*(16), 2840–2846.

Luna, T., Wilkinson, K.M. & Kasten Dumroese, R. 2011. Seed germination and sowing options [Chapter 9]. *Tropical Nursery Manual - Seed Germination and Sowing Options*, 163–183.

Malmer, A. 2007. *General ecological features of miombo woodlands and* *considerations for utilization and management*. *February*, 34–42.

Manyanda, B.J., Nzunda, E.F., Mugasha, W.A. & Malimbwi, R.E. 2020. Estimates of Volume and Carbon Stock Removals in Miombo Woodlands of Mainland Tanzania. *International Journal of Forestry Research*, *2020*. https://doi.org/10.1155/2020/4043965.

Martins, A.A., Opedal, Ø.H., Armbruster, W.S. & Pélabon, C. 2019. Rainfall seasonality predicts the germination behavior of a tropical dry-forest vine. *Ecology and Evolution*, *9*(9), 5196–5205. https://doi.org/10.1002/ece3.5108

McDonnell, A., Grant, M. & Coons, J. 2012. Effects of Hot Water on Breaking Seed Dormancy of the Endangered Kankakee Mallow (Iliamna remota Greene (Malvaceae). *Erigenia*, *25*, 8–13.

Merou, T., Takos, I., Konstantinidou, E., Galatsidas, S. & Varsamis, G. 2011. Effect of different pretreatment methods on germination of Albizia julibris sin seeds. *Seed Science and Technology*, *39*(1), 248–252. https://doi.org/10.15258/sst.2011.39.1.26.

Mgumia, F.H. 2017. Traditional Uses of Miombo Woodland Tree Species in Sikonge District, Tanzania. *International Journal of Natural Resource Ecology and Management*, *2*(4), 69. https://doi.org/10.11648/j.ijnrem.20170204.11.

Mgumia, F.H., Nkonoki, J. & Safari, J. 2017. Traditional Uses of Miombo Woodland Tree Species in Sikonge District, Tanzania. *International Journal of Natural Resource Ecology and Management*, *2*(4), 69. https://doi.org/10.11648/j.ijnrem.20170204.11.

Mira, S., Schnadelbach, A., Correa, E.C., Pérez-García, F. & González-Benito, M.E. 2017. Variability of physical dormancy in relation to seed mechanical properties of three legume species. *Seed Science and Technology*, *45*(3), 540–556. https://doi.org/10.15258/sst.2017.45.3.11.

Mojeremane, W., Mathowa, T., Teketay, D., Stimela, T., Kopong, I. & Rampart, M. 2017. Presowing seed treatment methods to overcome dormancy in seeds of Vachellia rehmanniana Schinz. *The Journal "Agriculture and Forestry," 63*(1), 171–181. https://doi.org/10.17707/agricultforest.63.2.15.

Msanga, H.P. 1998. *Seed germination of indigenous trees in Tanzania*. Canadian Forest Service.

Mwami, B., Nguluu, S., Kimiti, J.M. & Kimatu, J.N. 2017. Effects of Water Imbibition of Selected Bean Varieties on Germination Rhizobia-Legume symbiosis for efficient biological nitrogen fixation View project Epigenetic modifications View project. *International Journal of Agricultural Research and Review*, *5*(1), 579–587. https://www.researchgate.net/publication/312832693.

Njana, M.A., Kajembe, G.C. & Malimbwi, R.E. 2013. Are miombo woodlands vital to livelihoods of rural households? Evidence from Urumwa and surrounding communities, Tabora, Tanzania. *Forests Trees and Livelihoods*, *22*(2), 124–140. https://doi.org/10.1080/14728028.2013.803774.

Nkengurutse, J., Khalid, A., Mzabri, I., Kakunze, A.C., Masharabu, T. & Berrichi, A. 2016. Germination optimization study of five indigenous fabaceae tree species from Burundi miombo woodlands. *Journal of*

Materials and Environmental Science, *7*(12), 4391–4403.

Nourmohammadi, K., Kartoolinejad, D., Naghdi, R. & Baskin, C.C. 2019. Effects of dormancy-breaking methods on germination of the water-impermeable seeds of Gleditsia caspica (Fabaceae) and seedling growth. *Folia Oecologica*, *46*(2), 115–126. https://doi.org/10.2478/foecol-2019-0014.

Opoku, J.A., Amissah, J.N., Essilfie, M.E. & Norman, J.C. 2018. *Effect of Pre-Sowing Treatments on Seed Germination and Seedling Growth of Silver Butterfly Tree (Bauhinia rufescens)*. *6*(3).

Pace, B.A., Alexander, H.M., Emry, D.J. & Mercer, K.L. 2016. *Reliable Method for Assessing Seed Germination , Dormancy , and Mortality under Field Conditions*. *November*, 1–6. https://doi.org/10.3791/54663.

PROTA. 2022. *Brachystegia spiciformis Benth.* [Internet] Record from PROTA4U. Lemmens, R.H.M.J., Louppe, D. & Oteng-Amoako, A.A. (Editors). PROTA (Plant Resources of Tropical Africa / Ressources végétales de l'Afrique tropicale), Wageningen, Netherlands.

Sabongari, S. & Aliero, B.L. 2004. Effects of soaking duration on germination and seedling growth of tomato (Lycopersicum esculentum Mill). *African Journal of Biotechnology*, *3*(1), 47–51.

Shirima, D.D., Munishi, P.K.T., Lewis, S.L., Burgess, N.D., Marshall, A.R., Balmford, A., Swetnam, R.D. & Zahabu, E.M. 2011. Carbon storage, structure and composition of miombo woodlands in Tanzania's Eastern Arc Mountains. 332–342.

Sinegani, A.A.S, & Hosseinpur, A. 2010. Evaluation of effect of different sterilization methods on soil biomass phosphorus extracted with NaHCO3. *Plant, Soil and Environment*, *56*(4), 156–162. https://doi.org/10.17221/86/2009-pse.

Tian, Y., Guan, B., Zhou, D., Yu, J., Li, G. & Lou, Y. 2014. Responses of seed germination, seedling growth, and seed yield traits to seed pretreatment in maize (Zea mays L.). *Scientific World Journal*, *2014*. https://doi.org/10.1155/2014/834630

Vodouhè, R., Dansi, a, Avohou, H.T., Kpèki, B. & Azihou, F. 2011. Plant domestication and its contributions to in situ conservation of genetic resources in Benin. *International Journal of Biodiversity and Conservation*, *3*(February), 40–56.

Vyamana, V.G., Chamshama, S.A.O. & Mugasha, A.G. 2007. Effect of nursery practices on seedling survival and growth of selected Miombo tree species, Morogoro, Tanzania. In *Discovery and Innovation* (Vol. 19, Issues 1–2, pp. 122–138). https://doi.org/10.4314/dai.v19i1-2.15779.