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Germination Dynamics of Acacia Species Driven by Soil Type and Pre Sowing Soaking of Seed for Nursery Raising

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ABSTRACT

Development of seedlings is a common barrier in dry lands is due lack of awareness about seed biology and germination of valued species in dry climates leads to poor specie germination performances. The effects of seed soaking times and soil types on germination at the nursery level received very little attention in the literature so far. The germination of seeds of two acacia species (Acacia nilotica and Acacia modesta) have been studied to determine variances in germination. The results confirmed that A. nilotica germination performance was best in clay soil without soaking (0HRS), which was tailed by 12HRS soaking of seed. Interestingly, in sandy soil, the germination rate was favored by 36HRS soaking followed by 24HRS seed soaking whereas minimum germination was observed in control (0HRS). Although A. modesta seed germination performance was best observed at 36HRS soaking timing in both soil types followed by 24HRS, 12HRS and untreated seed (Control) respectively. Our study's findings hold significance for restoration bodies that are concerned with improving germination in dry regions for rehabilitation and transplantation. A. nilotica nursery can easily be developed in clay soil. Based on the observations it is recommended that seeds of A. nilotica nursery should be grown directly in clay soil whereas the seeds require pre-sowing soaking for sandy soil. A. modesta is of different nature and need soaking prior to sowing for at least 36 and 24HRS in both soil types.

INTRODUCTION

Acacia species are known for its quick growth, nitrogen fixation potential, and excellent drought adaptation in dry environments and best fit tree species to promote agro-social forestry projects. Globally, tree plantations are considered one of the most effective solutions in tackling the climate crisis, and incorporating trees, agroforestry plays as essential role in mitigating climate change. However, the productivity and sustainability of commendable solutions are often impeded by the wide range of abiotic stresses. Climate change pushes Pakistan to 6th position among the climate change affected countries, where the combination of different variables promotes country vulnerability (Khan et al. 2021; Maqsood et al. 2024) i.e., low adaptability, annual floods, deforestation, and water stress (Khan 2015; Shah et al. 2020). Additionally, climate change increased the water demands across the world especially in deserts (Ahmed et al. 2020). To overcome the deforestation, developed countries rely on agro-forestry. Exponential declining of Pakistan forests and growth of social and agroforestry exhibit an indirect relation in dry environments. Acacia is one of the best plants for agroforestry systems that can withstand climate change in arid climate (Devi et al. 2023). Numerous variables, particularly those related to afforestation and restoration, impact the choice of tree species. For many tree species, dispersion, and germination are crucial processes (Blate et al. 1998). Almost all acacia species, however, are propagated from seeds with an exceptionally hard seed coat, which would take a very long time to germinate in the wild (Dessì et al. 2021). The germination of acacia species in a certain microenvironment is influenced by three factors: water availability, seed dormancy, and type of soil (Mugunga and Sahinkuye 2020), therefore several acacia species failed to germinate properly (ALHaithloul et al. 2022). These seeds are the sole way to propagate the acacia species exacerbates the dilemma (Ahmed 2008). The lack of understanding concerned to seed biology in different conditions, yet it has crucial consequences in the process of establishing and managing a nursery (Boydak et al. 2003; Choinski Jr and Tuohy 1991; Kassa et al. 2010; Kozlowski and Pallardy 2002). An increasing demand of acacia by rural inhabitants as a source of fuelwood, build agricultural equipment and furniture (Mengistu 2020; Singh et al. 2020). Furthermore, the significance of acacia products adapted to extremely variable weather conditions and are regarded species protective environmental circumstances (Eisa et al. 2008). Besides timber production, limited efforts have been made to plant acacia species that generate non-timber forest products (NTFPs) in farmlands to support climate resilient agroforestry systems (Gupta et al. 2020; Keprate et al. 2024). NTFPs improve the livelihood of communities, contributing to food security and household income (Tadesse et al. 2015; Tadesse 2015). Agroforestry help rural populations if provided primary education of understanding seed quality and environmental factors affecting seed germination prior to nursery development (Mukhlis et al. 2022). However, dormancy remains the primary reason of low germination rates for dry agroforestry tree species, therefore basic scientific understanding of the physiology of seeds and variations in dormancy rates are necessary (Schmidt 2000b). Low seed germination and delayed initial establishment in the nursery level limit the acacia large-scale installation in agroforestry and restoration projects (Alamgir and Hossain 2005). Species selection is always considered as one of the major challenges in a drought-prone area to ensure maximum productivity and decline tree mortality. It has been shown how pre-treatment techniques affect some tree species seed germination (Azad et al. 2011b), still limited study has been conducted on the effects of various soil types and pre-sowing treatments for acacia species. Based on the dry climate, two acacia species namely, *Acacia nilotica* and *Acacia modesta* were chosen for the experiments, the most significant plants in arid ecology and producing lucrative goods. This study explores the best methods of raising acacia seedling at the nursery level in arid climate for the end users. This study ensures maximum seed germination and initial seedling growth by using optimal soil type and pre-sowing soaking strategy.

MATERIALS AND METHODS

The experiment was conducted at PARC-Arid Zone Research Centre (AZRC), Dera Ismail Khan, Khyber Pakhtunkhwa-Pakistan. The experimental layout was established in a 2x4 factorial manner with five replications in completely randomized design (CRD). The experiment had two factors, soil type two levels i.e., S1=Clay soil (sand:silt:clay::1:1:2) and S2=Sandy soil (sand:silt:clay::2:1:1) and seed soaking in tape water i.e., T1=0HRS, T2=12HRS, T3=24HRS and T4=36HRS. A total of seeds 250 Seed per species in each replication, and 2000 seeds in total for both soil type.

Initially, the seeds were scarified in sand for 10 days which was followed by hot water treatment (52 °C) for one hour to break the dormancy. After the initial scarification, the seeds were soaked for different times to soften the hard seed coat. The conditions for the germination test were selected as natural arid climate.

The germination of the seed was monitored as; a seed was considered to have germinated if the radicle had emerged at least 1 mm from the integument. The test was observed from March 28, 2024, to April 18, 2024, a period of twenty days.

Transparent polythene bags (10cmx25cm) were filled with an equal volume of potting mixture (S1 and S2). Pre-soaked seeds (10 seeds bag^{-1}) accompanied by unsoaked seeds (control) were placed on the top of the soil and covered with a thin layer of potting mixture. All pots received adequate water for seed germination based on condition. Percent germination data were recorded using the following equation Pahla et al. (2014).

$$\text{Emergence \%} = \frac{\text{No. of seeds emerged}}{\text{Total No. of seeds}} \text{x}100$$

Data Analysis

The seed germination data was collected at four days time interval for 20 days after sowing (DAS) and further analysis were completed by using statistical package "GraphPad-prism 8.0.1" at a 5% significance level. The least significant difference (LSD) was tested to separate the treatment means (Steel 1997). The bar graphs represent the mean percent germination data whereas the error bars in the graph represent deviation from the means.

RESULTS

The germination data was recorded five times for 20DAS with four days time interval. Complete details of each of the two species namely: *Acacia nilotica* and *Acacia modesta* have been discussed as below.

Acacia Nilotica

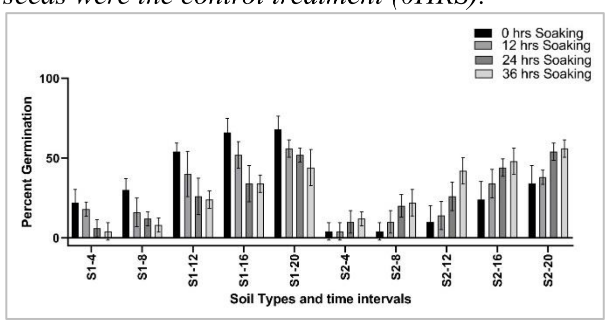
Germination percentage in *A. nilotica* was high in control (0HRS or un-soaked seeds) in clay soil at 4 days after sowing (DAS). The control was followed by 12HRS soaked seeds whereas minimum seeds germinated in those treated for 24, 36HRS. Similarly, on 8DAS, the maximum germination was observed in control that was followed by the same pattern as previously observed. A significant increase of germination observed at 12DAS in unsoaked seed (54%) followed by 12HRS and 24HRS soaked seed (40% and 26% respectively), however, significantly minimum germination observed was 24% in seeds soaked for 36HRS. Similarly, at 16DAS, it was found that a same pattern described the overall germination where significantly maximum percent germination was observed in control.

In the experiment, it was noticed that percent germination observed maximum on the other time intervals with soaking time remain persistent at 20DAS. Therefore, control (un-soaked seeds) germinated to the best of their potential during this experiment and secure the top position among all the treatments, where germination percentage accounts for the control are 68% followed by 12HRS (56%) soaking and 24HRS (52%). However, the least gemmation (44%) was noticed in 36HRS soaking treatment in clay soil.

In sandy soil the reverse germination pattern was observed. The maximum germination was 12% (36HRS) followed by 10% (24HRS) and 4,4% (12HRS and control respectively) at 4DAS. An increase at 8DAS in germination about 10% in both 36 and 24HRS soaking treatment, (12,0 HRS 6% and control remained 4% while a significant increase in germination rate observed at 12DAS and recorded 20% increase in 36HRS soaking treatment and 10% in 12HRS soaking treatment. An increase of 6% was recorded in seeds soaked for 12HRS while no increase observed in control. Similarly, at 16DAS, the data showed that 20% increase in the rate of germination in 12HRS soaking, 18% in 24HRS, 14% in control 6% in 36HRS soaking. The last interval (20DAS), the highest germination percentage in observed in 36HRS soaking (56%) followed by 24HRS soaking (54%) and 12HRS (38%) while the minimum germination recorded in control (34%) (Figure 1).

Figure 1

Effect of germination percentage of A. nilotica favored by clay and sandy soil with different time intervals (4, 8, 12, 16 and 20DAS). The seeds were soaked for 12, 24 and 36HRS, while unsoaked seeds were the control treatment (0HRS).



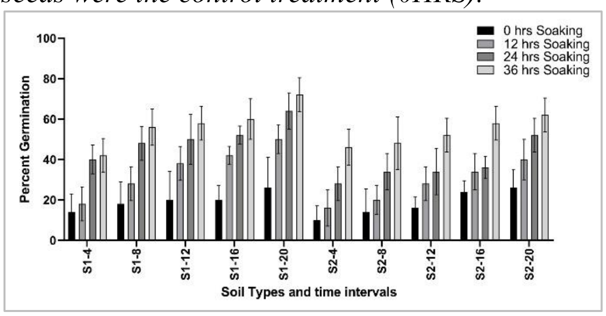
Acacia Modesta

The germination data observed at 4DAS (days after sowing), initially maximum number of seeds germinated in 36HRS soaking in clay soil, which is second by 24HRS, achieved superior performance compared to 12HRS soaked and un-soaked seeds. At 8DAS, 36HRS soaking time consistently ranked on the top followed closely by 24HRS, while 12HRS-soaked and control (un-soaked) seeds had significantly reduced germination rates. In the experiment, seeds soaked for 36HRS maintained the maximum germination percentage, particularly visible 12DAS and 16DAS, followed by 24HRS soaking treatment. An impressive percent germination (72%) was recorded in S1 at 20DAS in seeds soaked for 36HRS, the most effective pre-sowing treatment for clay soil. By comparing S1 with S2, the germination pattern was similar, where 36HRS soaking treatments resulting in the maximum germination second by 24HRS soaking on 4, 8, 12, 16 and 20DAS respectively. However, unlike in clay soil, sandy soil showed greater fluctuations in germination patterns across the soaking treatments and was generally less supportive of germination than S1 therefore overall germination remained lower in sandy soil (Figure 2).

The observations focusing dominancy of *A. modesta* seeds soaked for 36HRS in both soil types (S1 and S2), however overall germination rate was maximum in S1 rather than S2.

Figure 2

Effect of germination percentage of A. modesta favored by clay and sandy soil with different time intervals (4, 8, 12, 16 and 20DAS). The seeds were soaked for 12, 24 and 36HRS, while unsoaked seeds were the control treatment (0HRS).



DISCUSSION

There have been innumerable studies focusing on the effect of water regime, temperature and chemical treatments on the germination of acacia species (Danthu et al. 2003). However, these studies failed to provide information related to seeds pre-soaking, soil regime impact on the germination of *A. nilotica* and *A. modesta* species in arid climate. Different approaches have been extensively studied to break seed dormancy and enhance seed germination (Azad et al. 2011a; Azad et al. 2011b; Salim Azad et al. 2010). Various methods have been reported that allow seeds to germinate include physical scarification of seed coat by nickeling, knife etc. (Schmidt 2000a) whereas other techniques i.e., acid treatment (Kobmoo and Hellum 1984; Pipinis et al. 2011) or hot water treatment might be used to overcome physical seed dormancy. Hossain et al. (2013) recommended pre-sowing seed treatments for species with hard and impermeable seed coats; however, breaking of seed dormancy varies from species to species. Therefore, here this article explores the effects driven by soil medium and soaking time relationship that enhances seed germination process of two acacia species at nursery level. The variations triggered by soil type and soaking time; clay soil found to be best medium for the germination of both species at nursery level. However, a significant difference was observed in soaking time in *A. nilotica* such that the best seed germination observed in control and 12HRS soaked seeds in clay soil whereas in sandy soil type the overall germination was reduced (Rasebeka et al. 2014). Clay soil type claims highest germination rate in *A. nilotica*, and found the best soil for germination in arid climate (Aref et al. 2011) (Olatunji et al. 2013) Similarly, 12HRS soaking treatment proved more effective than 36HRS in *A. nilotica* in breaking dormancy (Vasques et al. 2014) .

Compared to *A. nilotica*, in *A. modesta*; 36 and 24HRS soaking were the suitable time for both soil types, however the overall germination percentage was high in clay soil (Aduradola and Shinkafi 2010; Olatunji et al. 2013). Additionally, the germination percentage is greatly supported by increased soaking time for sandy soil while moderate soaking for clay soil (Oboho and Ogana 2011). The porosity and aeration effect of sandy soil allow the seed to dry in no time while the germination is driven by the moisture content of seed as well as the medium therefore 36HRS soaking is required to retain the viability for long time in sandy soil than clay soil. Sufficient water availability (36HRS soaking) to the seeds of *A. nilotica* and *A. modesta* in sandy soil considerably enhanced percent germination than those observed in control, 12 or 24HRS soaking. The germination ability in plants varies from specie to specie therefore the rate of germination in *A. modesta* is greater than that of *A. nilotica* (Bognounou et al.

2010; Nasr et al. 2013) however, this study explored that maximum germination was observed at 4 and 8DAS time interval in clay soil. Intriguingly, in *A. nilotica*, the best germination recorded in control followed by 12HRS soaking that gradually increased up to 20DAS in clay soil in view of the fact that all acacia species characterized by a very hard and impermeable seed coat, which results in temporary dormancy and influence the germination process (Mozumder and Hossain 2013). Successful seedling production depends on germination capacity from damping off, survivorship and good soaking time which increase changes of germination (Aduradola and Shinkafi 2010; Olatunji et al. 2013). Therefore, dormancy in *A. modesta* seeds can be minimize using the conventional scarification that is followed by pre-sowing treatment with 12, 24 and 36HRS soaking for both clay and sandy soil to enhance germination percentage and growth performance in arid climate. Extra care i.e., no soaking is required for growing *A. nilotica* nursery in clay soil.

CONCLUSION

The study concludes that clay soil provided a suitable and conducive environment for acacia seed germination compared to sandy soil that exhibited more fluctuations and decrease in overall germination rates. Therefore in *A.* modesta, 36HRS soaking treatment was optimal for both soil types, but clay soil supported a more gradual and higher germination success. The process of germination continued to 20 days after sowing. *A. nilotica* behave differently than *A. modesta*, which requires 36HRS soaking for sandy soil while soaking is not mandatory for clay soil. Based on our results, it is recommended that pre-sowing treatments to sandy soil type for optimal germination outcomes in arid environments for both species. For clay soils no soaking is recommended for *A. nilotica* nursery. More research is needed to follow their field performance and adaptation under different dry land conditions and explore native climate resilient species.

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