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Propagation of *Pterocarpus erinaceus* Poir. seeds from four vegetation zones of Nigeria, using different pre-sowing treatments and sowing media

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Abstract

Pterocarpus erinaceus Poir. is a tree species of the family Leguminonaseae distributed across West and Central Africa. The surging demand for its wood has hampered its natural regeneration in Nigeria. Effects of pre-sowing treatments and soil media on the germination of its seeds were examined using stratified random sampling. Seeds were sourced from Guineo-Sudanian savanna, Southern Guinea savanna, Derived/Guinea savanna and Northern/Southern Guinea savanna. Pre-sowing treatments including: water (27^{o}C, 50^{o}C, and 75^{o}C for 8 hours, 16 hours and 24 hours), mechanical scarification (nicking at micropyle, 50% and 100% seed coat removal); and acid scarification (25%, 50% and 75% H_2S_{O4} for one minute, four minutes and seven minutes). Sowing media used included river sand, topsoil and mixture of river sand and topsoil at ratio 1:1. Cumulative germination percentage, germination rate, number of days to germination and germination spread were recorded. Data were analyzed using: ANOVA and descriptive statistics. Pre-sowing treatments and sowing media had significant effects ($p < 0.05$) on all the variables assessed, but the latter did not significantly affect cumulative germination percentage. The study shows that seeds of African rosewood soaked in water at room temperature for 24 hours had highest cumulative germination when sown in equal proportion of river sand and topsoil.

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Introduction

The challenges faced by the tropical forest in the recent decades include rapid loss of biodiversity due to pressures for food, shelter, medicine and furniture among others. This has resulted in rapid loss of forest resources; and ecosystem degradation (Ouinsavi *et al.*, 2019). The incessant utilization of woods, coupled with the practice of unsustainable agriculture, and urbanization are threatening the sustainability of increasing number of forest tree species. Barstow (2018) observed that *P. erinaceus* was one of the multipurpose wood species used for fodder, rural income, socio-cultural activities, and health needs of the people. This has resulted in scarcity of seeds and unfortunately, limited success had been recorded for its propagation (Kyei, 2017).

African rosewood (*Pterocarpus erinaceus* Poir.) is an indigenous deciduous tree species predominantly found in West and Central Africa, with a distribution gamut of over 2 million km² (Adjonou *et al.*, 2020). Its distribution cuts across Benin, Cameroon, Central African Republic, Côte d'Ivoire, Ghana, Gambia, Guinea-Bissau, Guinea, Mali, Niger, Nigeria, Senegal, Sierra Leone and Togo (Segla *et al.*, 2016). The species is found mainly in the derived through guinea savanna regions of Nigeria (Keay *et al.,* 1989). It belongs to the family Leguminonaseae, subfamily Papilionaceae (Kyei, 2017); it grows up to 25m tall and takes an estimated 40 years to reach an exploitable diameter of roughly 40cm at breast height (Winfield *et al.*, 2016). It is slightly buttressed when old and its diameter is up to 75cm (Tropical Plants Database, 2019). Wood from *Pterocarpus erinaceus* is commonly used for furniture, musical instruments, fuel-wood and charcoal production (Duvall, 2008).

However, the species is presently experiencing a high rate of population decline due to increased rate of exploitation for timber and fodder which has destabilized the natural population, with many small trees and fewer seed-bearing individuals (Barstow, 2018). Trading in the species is currently greatest from Nigeria, where population decline was estimated to be as high as 80% between 2009 and 2015 (Barstow, 2018). This disturbing situation of *Pterocarpus erinaceus* could be ascribed to threats such as; illegal logging, low regeneration capacity, and deforestation (Ouinsavi *et al.*, 2019). This rapid decline could also be driven by the high demand for African rosewood timbers from China, which led to 15 folds increase in exports (Ahmed *et al.*, 2016). The current extent of extraction is unsustainable and threatens the survival of the species in the wild (Barstow, 2018). This has resulted in *Pterocarpus erinaceus* being categorized on the IUCN Red List as an endangered species (Barstow, 2018; IUCN, 2020).

Although, numerous studies have been conducted on the species to alleviate demand burden on it and ensure that its availability is an opportunity to the regions of its distributions. This has so far, proven unsuccessful (Kyei, 2017). The awareness of the best conditions to regenerate the species through seed is an assurance for their sustainable management (Monteuuis, 2000; Fandohan *et al.*, 2010).

In Nigeria, there is a dearth of information on the techniques that may enhance the germination of this species. Hence, there is a need for further research into the development of suitable mass production protocols. It is against this background that this research was conducted, in order to investigate the effects of pre-sowing treatments and sowing media on the germination of the species.

Materials and methods

Experimental site

This study was carried out in the screen house, Nursery Unit of the Department of Forest Production and Products, University of Ibadan, Nigeria. The nursery is located approximately between latitudes E3°53'899" and E3°53'552" and longitudes N7°26'850" and N7°27'087" with elevation ranging from 205m-227m above sea level in the sub-humid tropics (Oluwasemire *et al.*, 2012).

Ibadan climate is West Africa tropical monsoon which is characterized by wet and dry seasons (Sangotegbe *et al.,* 2015). The area is characterized by bimodal

pattern of rainfall with the peak around June and July and September to October and the mean total annual rainfall is 1420.106mm in about 109 days (Weatherspark.com, 2021). The average relative humidity of Ibadan was 82% between June and September and 60% between December and February, while the annual temperature ranges between 18.07°C and 34.4°C in 2021 (Weatherspark.com, 2021).

Experimental design and layout

A stratified random sampling technique was used. Four vegetation zones (Guineo-Sudanian savanna; Southern Guinea savanna; Derived/Guinea savanna; and Northern/Southern Guinea savanna) in Nigeria were assessed. Four states (Kaduna, Kogi, Oyo and Taraba) were purposely selected each representing one of the four vegetation zones within the species' distribution range (Based on a reconnaissance survey). Each state was stratified into three agro-ecological zones (three local government areas) as follows: P1= Guineo-Sudania savanna (Kaduna State: Igabi, Chikun and Kagarko Local Government Areas) P2= Southern Guinea savanna (Kogi State: Ajaokuta, Ofu and Iddo Local Government Areas) P3= Derived/Guinea savanna (Oyo State: Shaki West, Ibarapa East and Oorelope Local Government Areas) and P4= Northern/Southern Guinea savanna (Taraba State: Sardauna, Kurmi and Donga Local Government Areas).

Ten mother stands were selected randomly from each agro-ecological zone. Hence, thirty mother trees were selected from each state giving a total of 120 mother trees for the four vegetation zones. Five hundred fruits were collected randomly from each mother tree. About 17,200 seeds were obtained from the 60,000 fruits collected from the four ecological zones (some seeds were lost to seed decay, rotting, and damaged seeds during processing. An average of 74.7% viability was recorded across the four vegetation zones using the floating test (Ehiagbonare and Onyibe, 2008; Daneshvar *et al.,* 2017). Sixty-six viable seeds were selected from each mother stand. Hence, a total of 1,980 seeds were randomly selected from each vegetation zone and thoroughly mixed.

This gave a total of 7,920 seeds used in the study. The seeds were subjected to three scarification treatments, including heat, mechanical and acid. For the heat scarification, seeds were soaked in water at three different temperatures viz: 27°C (room temperature), 50°C and 75°C. The soaking in water lasted 8 hours, 16 hours and 24 hours (i.e. T_1= room temperature for 8h; T_2= room temperature for 16h; T_3 = room temperature for 24h; T_4= 50°C for 8h; T_5= 50°C for 16h; T_6= 50°C for; 24h T_7= 75°C for 8h; T_8= 75°C for 16h; and T_9= 75°C for 24h). For mechanical scarification, nicking at micropyle (T_1), 50% seed coat removal (T_2) and 100% seed coat removal (T_3) were done. For acid scarification, seeds were soaked in H_2So_4 at 25%, 50%, and 75% concentrations for 1 minute, 4 minutes and 7 minutes for each level of concentration (i.e. T_1= 25% for 1 min, T_2= 25% for 4 min, T_3= 25% for 7 min, T_4= 50% for 1 min, T_5= 50% for 4 min, T_6= 50% for 7 min, T_7= 75% for 1 min, T_8= 75% for 4 min. and T_9= 75% for 7 min). Seeds that were not pre-treated before sowing were the Control (T_0) experiment.

The seeds were sown on three sowing media are including 100% river sand =S_1, 100% topsoil =S_2 and a mixture of river sand and topsoil at ratio 1:1 =S_3 after exposing them to the pre-sowing treatments described above.

The experiment was a 3x3 factorial and was set out in a Randomized Complete Blocked Design (RCBD). The treatments combinations were randomized among seeds from the four vegetation zones representing four blocks.

The mathematical model for the experimental design is:

$$Y_{ijk} = \mu + B_i + W_j + S_k + (WS)_{jk} + e_{ijk} \quad \text{.....Equation 1.}$$

Where,

Y_{ijk} = Seed germination

μ = Overall mean

B_i= effect of the vegetation zones

W_j = effect of pre-sowing treatments

S_k = effect of sowing media

WS_{jk} = effect of interaction between pre-sowing treatments and sowing media

e_{ijk}= random error term.

Experimental procedures

Experiment A: Effect of heat scarification and sowing media on seed germination

Nine hundred seeds were randomly selected from each vegetation zone. The seeds were grouped into 10 groups of 90 seeds each. One seed group was used for the control experiment and the remaining nine seed groups were used for the heat scarification experiment. Each seed group was further divided into three groups of 30 seeds each and was sown on the three sowing media viz: 100% river sand, 100% topsoil and a mixture of river sand and topsoil in ratio 1:1 in triplicates.

Experiment B: Effect of mechanical scarification and sowing media on seed germination

Three hundred and sixty seeds were randomly selected from each vegetation zone. The seeds from each vegetation zone were divided into four groups of 90 seeds each. One seed group was used for control experiment and the other three seed groups used for mechanical scarification experiment. Each similarly treated seed groups was further divided into three groups of 30 seeds each and was sown on the three sowing media in in triplicates.

Experiment C: Effect of acid scarification and sowing media on seed germination

Nine hundred seeds were randomly selected from each of the four vegetation zones. The seeds from each vegetation zone were put into 10 groups of 90 seeds each. One seed group was used in the control experiment and the nine other seeds groups for the acid scarification experiment. Each seed group was further divided into three groups of 30 seeds each and sown on the three sowing media in triplicates.

Data collection

Germination was monitored to record the seeds number that germinated every day, with time taken for initial and final emergence (days) (Kanmegne *et al.*, 2021). Germination was considered to be completed when no additional germination took place in six days (based on the pilot study). The data was used to calculate germination behaviours viz: germination rate, cumulative germination percentage, number of days to germination and time spread of germination.

Methods of data analysis

Effect of pre-sowing treatments and soil media on seed germination behaviours were analysed using Analysis of Variance (ANOVA). The ANOVA Model is as stated below:

$Y_{ij} = \mu + B_i + T_j + e_{ij}$ ..... Equation 2.

Where,

μ = Overall mean

B_i= effect of ith block

T_j = effect of jth treatment

e_{ij}= random error term (Adesoye, 2004).

Mean values found significant were split up by means of the Duncan Multiple Range Test (DMRT) as shown below:

$R_p = r_p\sqrt{\frac{s^2}{n}}$ .....Equation 3.

Where;

r_p = Least significant studentized range

s^2 = Error mean square

n= Sample size (Bewick *et al.*, 2004).

Also, the effects of pre-sowing treatments, seed sources and soil media, on germination patterns (number of days to germination and time spread of germination) were tested with descriptive statistics.

Results and discussion

Germination behaviours

Cumulative germination percentage

Significant differences ($p<0.05$) were observed in the effects of pre-sowing treatments on cumulative germination percentage of seeds, while the effect of sowing media and the combination of sowing media and pre-sowing treatments were not significant ($p>0.05$) as shown in Table 1.

The Duncan test on the effect of pre-sowing treatments shows that water treatment (T_1: Soaking in water at room temperature for 8 hours) had the highest mean cumulative germination percentage (68.33±5.90%), followed by 65.56±5.81% in (T_3: soaking in water at

room temperature for 24 hours), while mechanical scarification (T_3: 100% removal of seed coat) had the least mean value (18.33±3.88%) (Table 2).

Table 1. ANOVA showing the effect of sowing media (SM), pre-sowing treatments (PT) and their interactions on the cumulative germination percentage of *p. erinaceus* seeds.

Source of Variation	Sum of Square	Degree of Freedom	Mean Square	F	P-Value
SM	136.60	2	68.30	0.24	0.79ns
PT	71996.60	21	3428.40	11.91	0.00**
SM*PT	13858.60	42	330.00	1.15	0.37ns
Error	6911.10	24	288.00		
Total	92,902.90	89			

** = Highly significant at 0.05% levels of probability.

ns = Not significant at 0.05% levels of probability.

***Note: SM= sowing media; PT= pre-sowing treatments; SM*PT= interactions between sowing media and pre-sowing treatments.

Table 2. Effect of pre-sowing treatments (PT) on the cumulative germination percentage of *P. erinaceus* seeds.

	Pre-sowing Treatments		
PTL	WT	MS	AS
T_0	63.43±3.94abc	63.43±3.94abc	63.43±3.94abc
T_1	68.33±5.90a	26.39±4.86d	60.00±8.922abc
T_2	60.00±7.92abc	22.50±5.93d	52.50±9.981abc
T_3	65.56±5.81ab	18.33±3.88d	64.17±16.02abc
T_4	55.56±6.73abc		55.83±4.17abc
T_5	60.83±4.36abc		52.22±7.18abc
T_6	22.50±4.02d		51.11±5.68cd
T_7	30.83±8.14d		56.39±7.65abc
T_8	50.56b±6.51c		54.44±8.46abc
T_9	21.94±4.78d		48.33±9.35c

Duncan 0.05: Means within columns that are followed by the same alphabets are not significantly different.

***Note: PTL= pre-sowing treatments levels; WT= water treatments; MS= mechanical scarification and AS= acid scarification.

Germination rate

ANOVA results in Table 3 revealed that, effect of sowing media (SM), pre-sowing treatments (PT), the combination of sowing media (SM) and pre-sowing treatments (PT) on the germination rate of *P. erinaceus* were significant ($p<0.05$).

The Duncan result revealed that, sowing medium (S_1: 100% river sand) gave the highest mean germination rate (1.41±0.10%/day), while sowing medium (S_2: 100% top soil) had the least mean germination (1.26±0.09% /day) (Table 4).

For the pre-sowing treatments effects, water treatment (T_3: soaking in water at room temperature for 24 hours) recorded the highest mean value (1.79±0.23%/day), followed by acid scarification (T_2: soaking in 75% concentration of H_2SO_4 for 1 minute) with mean value (1.71±0.35%/day), while water treatment (T_9: soaking in water at 75°C for 24hours) gave the least mean value (0.60±0.13%/day).

Table 3. ANOVA showing the effect of sowing media (SM), pre-sowing treatments (PT) and their interactions on the germination rate of *p. erinaceus* seeds.

Source of Variation	Sum of Square	Degree of Freedom	Mean Square	F	P-Value
SM	1.01	2	0.51	3.62	0.04*
PT	55.68	21	2.65	18.96	0.00**
SM*PT	20.82	42	0.50	3.54	0.00**
Error	3.36	24	0.14		
Total	80.87	89			

** = Highly significant at 1% levels of probability.

ns = Not significant at 1% levels of probability.

Table 4. Mean effect of sowing media (SM) and pre-sowing treatments (PT) on the germination rate of *P. erinaceus* seeds.

Sowing Media		Pre-sowing Treatments			
SML	Mean	PTL	WT	MS	AS
S_1	1.41±0.10a	T_0	1.63±0.15bc	1.63±0.15bc	1.63±0.15bc
S_2	1.26±0.09b	T_1	1.62±0.18bc	0.64±0.14d	1.59±0.34bc
S_3	1.39±0.13a	T_2	1.41±0.23c	0.64±0.20d	1.15±0.72a
		T_3	1.79±0.23b	0.74±0.18d	1.48±0.30bc
		T_4	1.37±0.23c		1.64±0.24bc
		T_5	1.57±0.19bc		1.43±0.26bc
		T_6	1.57±0.10d		1.50±0.24bc
		T_7	0.69±0.21d		1.71±0.35bc
		T_8	1.38±0.24c		1.66±0.34bc
		T_9	0.60±0.13d		1.46±0.32bc

Duncan 0.05: Means within columns followed by the same alphabets are not significantly different.

***Note: SML= sowing media levels; PTL= pre-sowing treatments levels; WT= water treatments; MS= mechanical scarification; and AS= acid scarification.

Germination pattern

Effect of pre-sowing treatments and sowing media on number of days to germination

As shown in Table 5, mechanical scarification (T_2: removal of 50% seed coat) recorded least mean

number of days to germination (NDG) value (4.00±1.01days) while water treatment (T_3: soaking in water at room temperature for 24 hours) had the highest (10.50±2.31days).

Fig. 1 shows that, the least mean number of days to germination (NDG) value (5.77±0.29) was recorded by the sowing medium (S_3: mixture of river sand and topsoil in equal proportion), while sowing medium (S_2: 100% top soil) had the highest mean (7.60±0.45days).

Table 5. Effect of pre-sowing treatments on number of days to germination (NDG) of *P. erinaceus* seeds.

PTL	WT	MS	AS
T_0	6.64±0.44	6.64±0.44	6.64±0.44
T_1	7.08±0.87	4.58±0.94	6.58±0.78
T_2	7.25±0.76	4.00±1.07	7.08±0.67
T_3	10.50±2.41	4.08±0.49	7.25±0.82
T_4	6.25±0.69		6.83±0.95
T_5	5.75±0.69		6.58±0.67
T_6	6.83±1.25		7.58±1.59
T_7	6.08±0.68		6.50±0.90
T_8	6.50±0.86		7.00±0.88
T_9	9.08±2.09		5.50±1.10

***Note: PTL= pre-sowing treatments levels; WT= water treatments; MS= mechanical scarification and AS= acid scarification.

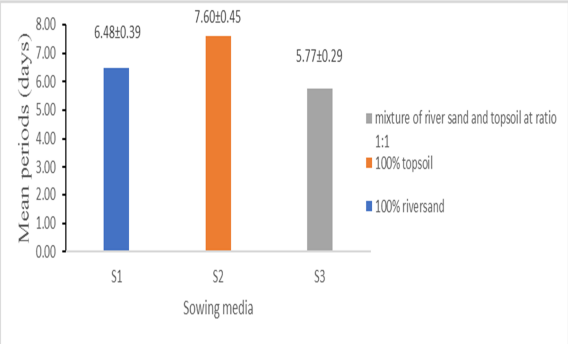

Fig. 1. Effect of sowing media on number of days to germination (NDG) of *P. erinaceus* seeds.

Effect of seed sources, pre-sowing treatment and sowing media on the Time Spread of Germination

Table 6 indicates that the highest mean time spread of germination (TSG) value (12.83±2.01days) was recorded in water treatment (T_5: soaking in water at 50°c for 16 hours) while the lowest mean value (3.25±1.43days) was obtained from mechanical scarification (T_3: 100% removal of seed coat).

Fig. 2 reveals that the highest mean time spread of germination (TSG) value (8.96±0.61days) was recorded by the sowing medium (S_1: 100% river sand). Sowing medium (S_3: mixture of river sand and top soil at equal proportion) had the lowest mean value (7.69±0.56days).

Table 6. The effect of pre-sowing treatments on the time spread of germination of the *P. erinaceus* seeds.

PTL	WT	MS	AS
T_0	11.28±0.976	11.28±0.976	11.28±0.976
T_1	9.75±1.43	5.42±1.32	10.00±1.16
T_2	9.92±1.44	4.17±1.32	9.33±1.60
T_3	8.50±1.94	3.25±1.43	6.67±1.47
T_4	12.00±1.26		10.58±1.36
T_5	12.83±2.01		7.83±1.56
T_6	4.50±1.23		9.42±1.49
T_7	8.75±1.48		7.58±0.83
T_8	9.08±1.51		10.00±1.90
T_9	4.92±1.79		6.33±1.59

***Note: PTL= pre-sowing treatments levels; WT= water treatments; MS= mechanical scarification and AS= acid scarification.

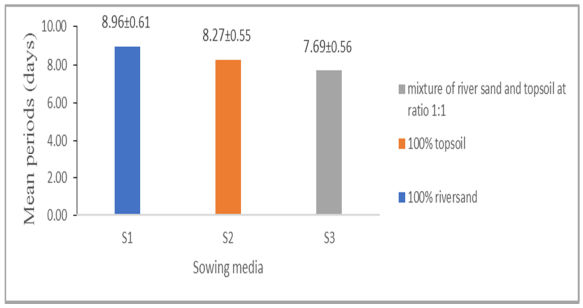

Fig. 2. The effect of the sowing media on the time spread of germination of *P. erinaceus* seeds.

Discussion

Germination behaviours

Cumulative germination percentage

The effect of the pre-sowing treatments (PT) and sowing media (SM) on the cumulative germination percentage

Table 1 show that effects of pre-sowing treatments on the cumulative germination percentage were significant, but effect of sowing was not significant.

Table 2 indicates that the seeds soaked in water at ambient temperature (27°C) for eight hours gave the highest cumulative germination percentage among the pre-sowing treatments applied in this study.

Soaking of seeds in water at room temperature had potentials to dissolve and leach out the chemicals that could cause dormancy (Deghan *et al.*, 2003). The enhanced cumulative germination percentage observed in the treated seeds may be due to the alteration of the physiology of the seed embryos and the activation of enzymes due to the treatments applied (Kattimani *et al.,* 1999, in Kolapo *et al.*, 2017). This result is in line with Kyei. (2017) who recorded a higher germination percentage (70%) in the seeds of *P. erinaceus* pre-treated with water at 25°C for 24 hours. It is also in line with the observation of Kolapo *et al.* (2017) who reported that the seeds of *Monodora myristica* soaked in water at ambient temperature for 24 hours gave the optimum cumulative germination percentage. Thus, soaking of *P. erinaceus* seeds in water at an ambient temperature for eight hours produced the highest cumulative germination percentage.

Germination Rate

The effect of pre-sowing treatments (PT) and sowing media (SM) on the germination rate

The ANOVA results in Table 3 and the follow up test result in Table 4 indicated that the effects which pre-sowing treatments (PT) and sowing media (SM) had on the germination rate of seeds were significant.

Among all the pre-sowing treatments applied in this study, soaking of *P. erinaceus* seeds in water at an ambient temperature for 24 hours gave the highest mean germination rate. Effective pre-sowing treatments like leaching by water had been reported to enhance germination (Anand *et al.*, 2012). Ameri and Daldoum (2017) also reported that soaking of seeds in water before sowing could increase the germination percentage and rate in many plant species. Similarly, Kyei (2017) observed that seeds pre-treated with water at ambient temperature had fastest germination rate than those that received other treatments.

According to Missanjo *et al.* (2014), the mechanism by which seed hydration treatment improved seed germination was probably due to increase in hydrophilic enzyme activities. This might be what was responsible for the fastest mean rate of germination that was witnessed in the seeds which were immersed in water at an ambient temperature for 24 hours.

P. erinaceus seeds sown in 100% river sand recorded the highest mean germination rate (Table 4). As reported by Fry. (2017), river sand possessed light properties and friable particles. Also, Kolapo *et al.* (2017) observed that, it was easier for emerging seedlings to push through sand particles because of its porosity. This probably explains why the seeds of *P. erinaceus* sown in river sand recorded the highest mean rate of germination. This result is however contrary to Yerima *et al.* (2015), who reported lowest germination rate in the seeds of *Helianthus annus* sown in sand. However, it agrees with Kolapo *et al.* (2017), who observed that, seeds of *M. myristica* sown in river sand showed the topmost germination rate amidst the whole sowing media used in their study.

Germination pattern

Number of days to germination

As shown in Table 5, the least mean number of days to germination (NDG) was recorded in the seeds which received mechanical scarification (50% of seed coat removed) before sowing. This result is in tandem with Adeniji *et al.* (2019), who reported that, mechanical scarification performed best in terms of early emergence of seeds among all the pre-treatment methods they investigated on seeds of *Afzelia africana*. It is also in line with Peter *et al.* (2021), who reported the shortest number of days to germination in the seeds of *P. erinaceus* subjected to mechanical scarification.

The result is however contrary to the conclusions of Kyei (2017), who stated that water treatment produced the shortest number of days to germination among all the pre-sowing treatments used on seeds. Mechanical scarification has been reported by Tigabu and Oden (2001) to interrupt physical dormancy which could inhibit exchange of gases and water uptake and improved the germination capacity in seeds. Therefore, removal of 50% seed coat of *P. erinaceus* seeds has made the seeds readily pervious

to water, so that imbibition could occur, which might have occasioned some enzymatic hydrolysis from the seeds and therefore transmuting the embryo into a seedling (Azad *et al.*, 2010). This probably explains reasons for the fewest number of days to germination which were observed in the seeds of *P. erinaceus* that were exposed to mechanical scarification (T2: removal of 50% seed coat). Hence, *P. erinaceus* seeds in which the coat was reduced to 50% took the fewest number of days to germination.

Among the three sowing media used in this study, mixture of river sand and top soil in equal proportion had the least mean number of days to germination (Fig. 1.). This result affirms the observation of Aderounmu *et al.* (2020) that a good blend of topsoil and river sand would result in a medium that possessed varying physical and chemical properties. This finding also supports the discoveries of Patel *et al.* (2020) who recorded a minimum number of days pro the first day of germination (FDG) in seeds of *Pterocarpus santalinus* sown in topsoil and river sand. A combination of topsoil and river sand was suggested to heighten the soil media's biological, chemical and physical properties which could, in turn, result in vibrant plant germination and growth (Carter, 2002; Kanmegne *et al.*, 2021). An evidence of this is the resultant fewest number of days to the first germination that was documented in the seeds of *P. erinaceus* sown in the mixture of river sand and topsoil in equal proportion.

This is an indication that the mixture of river sand and topsoil in equal proportion had suitable physical properties and good water holding capacity that reduced the number of days for germination in the seeds of *P. erinaceus*.

Time spread of germination

Among the three pre-sowing treatment methods used, mechanical scarification (T_3: 100% removal of seed coat) recorded the lowest mean time spread of germination (Table 6). This result is in agreement with Adeniji *et al.* (2019) who noticed that, seeds of *Afzelia africana* subjected to mechanical scarification took shortest time to complete germination. Similarly, it agrees with Peter *et al.* (2021), who observed that seeds of *P. erinaceus* subjected to mechanical scarification, took a shorter time to complete germination. Mechanical scarification is recognised to break down the seeds' physical dormancy and aid metabolic activities in the seeds (Tigabu and Oden, 2001).

As observed by Missanjo *et al.* (2014), mechanical scarification could enhance gases and water uptake, especially in tropical species. Ready water uptake by the dry seeds, could be responsible for the short time spread of germination observed in seeds of *P. erinaceus* in which 100% of the seed coat was removed (Botsheleng *et al.*, 2014). Thus, seeds in which 100% coat was removed attained highest germination in a short time.

Mixture of river sand and topsoil in equal proportion had the lowest mean time spread of germination (Fig. 2.). This result is in conformity with the conclusions of Patel *et al.* (2020) who reported that soil and sand, in equal proportion gave 7.33 days as the minimum time spread of germination in *Pterocarpus santalinus* Linn. F. Soil is an important environmental factor, whose physical and chemical properties play a substantial role in ensuring optimal germination of seed and healthy growth of plants (Ghelot *et al.*, 2014). According to Patel *et al.* (2020), the properties of media derived from a mixture of river sand and topsoil at equal proportion that is; moderately compacting, optimum water holding capacity, more pore space and aeration had been reported to favour the easy root and shoot sprouting.

Hence, the shortest time spread of germination recorded in the seeds of *P. erinaceus* sown in a mixture of river sand and topsoil in equal proportion, might be as a result of favourable properties of the sowing media (more aeration with optimum moisture retention capacity) that had propelled the early and uniform seed germination. Seeds of *P. erinaceus* sown in a mixture of river sand and topsoil at equal proportion completed germination within the shortest time.

Conclusion

It is evident from this study that pre-sowing treatments and sowing media had various effects on the germination behaviour of *Pterocarpus erinaceus* seeds. Effects of Pre-sowing treatments were significant on cumulative germination percentage while soil media was not. The utmost cumulative germination percentage was observed in the seeds of *P. erinaceus* soaked in water at an ambient temperature for eight hours (T_1).

Pre-sowing treatments (PT) and sowing media (SM) also had a significant effect on the germination rate of seeds of *P. erinaceus*. Seeds of *P. erinaceus* that were immersed in water at an ambient temperature for 24 hours (T_3) and the seeds that was sown in the 100% river sand (S_1) gave the fastest germination rate.

The shortest number of days to germination was observed in seeds of *P. erinaceus* that was sown in a mixture of river sand and topsoil in equal proportion (S_3). Similarly, fifty percent seed coat removal (T_2) also gave smallest number of days to germination among the pre-sowing treatments.

Seeds of *P. erinaceus* sown in a mixture of top soil and river sand in equal proportion (S_3) accomplish maximum germination in the shortest time. Also, 100% seed coat removal gave the shortest time to accomplish germination.

Recommendation

To achieve optimal cumulative germination percentage in *P. erinaceus* seeds, soaking of seeds in water at an ambient temperature for eight hours, and sowing of seeds in 100% top soil are recommended. For high rate of germination in *P. erinaceus* seeds, seeds should be soaked in water at room temperature for 24 hours and sown in 100% river sand. To achieve earliest commencement of germination (NDG), the seeds should be subjected to 50% seed coat removal and be sown in a mixture of topsoil and river sand in equal proportion. To ensure completion of germination within the shortest time, seeds should be subjected to 100% seed coat removal and sown in a mixture of top soil and river sand in equal proportion.

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Competing interest

The authors declare that there is no competing interest.

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