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Effects of Desiccation and Post-Harvest Treatments on the Germinability of Threatened Timber Species: *Afzelia africana* SM. and *Chrysophyllum albidum* Linn

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Abstract

Deforestation, biodiversity loss, and increasing demand for timber have intensified interest in cultivating high-value cabinet timber species in the tropics. This study examined the effects of desiccation and post-harvest treatments on the germinability of two rainforest species: *Afzelia africana* Sm. and *Chrysophyllum albidum* Linn. Data collected included seed germinability and electrolyte leakage (conductivity) to assess membrane integrity. A completely randomized design was used, with data collected in triplicate and analyzed using SPSS (version 2.0). In *A. africana*, an initial desiccation period (0–15 days) significantly ($P \leq 0.05$) enhanced germinability, which remained relatively high (60%) even at low moisture content (4.03%). Conversely, over 50% of *C. albidum* seeds lost viability below 34% moisture, with complete loss at 27.63%. Electrolyte leakage decreased significantly in *A. africana* but increased in *C. albidum* with desiccation. Nicking of *A. africana* seeds did not improve germinability initially but was beneficial in later desiccation stages. However, nicking had no effect on the recalcitrant seeds of *C. albidum*. These results indicate that *A. africana* possesses orthodox seed characteristics, while *C. albidum* exhibits recalcitrant seed behaviour. This information is crucial for developing propagation and conservation strategies for these economically and ecologically valuable timber species.

Key words: Desiccation, Germinability, Nicking

1. Introduction

Declining supplies of cabinet timber from natural tropical rainforest stands, coupled with rising demand for timber across various classes, have spurred growing interest in establishing plantations of high-value cabinet timber species in many tropical regions. *Cabinet timber* refers to hardwood of superior quality, often characterized by fine grain, durability, and aesthetic appeal, making it ideal for furniture, interior finishing, and decorative woodwork (Orwa *et al*., 2009). There is increasing need for production of seedlings of hardwood species for use in establishing plantations. Hardwood species are also planted for their non-timber products, including the maintenance of forest abundance for the present generation and generations yet unborn and other aesthetics and recreational services. They are also a source of fruits, nuts, vegetables, medicine, resins and other raw materials. *Afzelia Africana* (African Mahogany or African Oak) and *Chrysophyllum albidum* (African star apple) are two examples of indigenous tropical hardwood species.

Afzelia africana is a large, deciduous leguminous tree belonging to the family Fabaceae and the sub-family Caesalpiniaceae. It naturally occurs in both humid and dry forest ecosystems across tropical Africa (Umedum *et al*., 2014; Orwa *et al*., 2009). The species has been classified as vulnerable due to its limited natural regeneration in the wild, as highlighted by Padonou *et al*. (2013). It is a multipurpose species, with all parts of the plant considered valuable for various uses, including traditional medicine, forage, and construction (Igbadul *et al*., 2014; Louppe *et al*., 2008). *A. africana* is also known for producing high-quality, termite-resistant timber, although it's wood can be somewhat challenging to process. International trade of *Afzelia* species, including *A. africana*, has been documented, with Cameroon identified as a major exporter and average sawn wood prices reaching approximately US$780 per cubic meter (Balima, 2018). However, increasing anthropogenic pressures such as deforestation, urban development, and population growth have led to a significant decline in its natural populations. As a result, the International Union for Conservation of Nature (IUCN) has listed the species as Vulnerable (IUCN, 2004).

Chrysophyllum albidum, commonly referred to as the white star apple, is a fruit-bearing forest tree that belongs to the family Sapotaceae and is widely distributed across tropical Africa (Daziel, 1937; Okigbo, 1977). The fruit is of significant economic importance; Amusa *et al*. (2003) reported that jams produced from its pulp have the potential to rival commercial raspberry jams and jellies. In addition, oil extracted from the seeds has various domestic and industrial applications. The fruit is also recognized for its high antioxidant content, which contributes to its therapeutic potential in combating oxidative stress and related health conditions (Burits & Bucar, 2000; Adisa, 2000). The timber of *C. albidum* is characterized by its brown coloration, high density, moderate strength, and fair durability, making it suitable for local construction and carpentry (Etukudo, 2003; Nwachukwu & Umeh, 2014).

Seeds play a fundamental role in crop production, serving as the primary input for both direct sowing and seedling propagation (Larmaca *et al*., 2016; Bewley *et al*., 2013). Many seed types exhibit remarkable longevity under proper storage conditions, retaining their viability and germination potential for several years. This enables their transport and use across different geographical regions and planting seasons, well beyond their site and time of origin. However, certain seeds, particularly those categorized as recalcitrant, are highly sensitive to desiccation and cannot withstand drying or extended storage. As a result, their viability declines rapidly, posing challenges for their integration into conventional agricultural systems (Hay & Probert, 2013; Berjak & Pammenter, 2008).

This research was undertaken to develop protocols for germinating high value native rainforest timber species *Afzelia africana* (African mahogany or African Oak) and *Chrysophyllum albidum* (African star apple) and investigate desiccation tolerance in both species.

2. Materials and Methods

2.1 Study Area/ Experimental Site

The research was conducted in Calabar, the capital of Cross River State in southeastern Nigeria. Geographically, Calabar is situated between latitudes 5°45′ and 5°75′ North of the Equator and longitudes 8°30′ and 8°42′ East of the Greenwich Meridian. The experiment took place in a screen house located within the Department of Plant and Ecological Studies, Faculty of Biological Sciences, University of Calabar. All activities were carried out under natural ambient environmental conditions.

2.3 Growth Medium Collection and Preparation

A growth medium composed of equal parts fine sawdust and smooth sea sand (1:1 ratio) was used for the experiment, following the method described by Ngele *et al*. (2024). Two kilograms (2 kg) of this medium were measured into each germination tray and thoroughly drenched with deionized water to eliminate potential contaminants.

2.4 Seed Collection and Preparation

Mature seeds of *Afzelia africana* and *Chrysophyllum albidum* were obtained by harvesting mature fruits from their tree stands; fruits were de-pulped to obtain the seeds. Dead and non-viable seeds were screened out of the seed lot by visual inspection and by floatation in water.

2.5 Experimental Design and Layout

The experimental setup followed a Completely Randomized Design (CRD) with three replicates for each treatment.

2.6 Seed Desiccation

Seeds were subjected to desiccation at ambient room temperature over a series of time intervals: 0, 3, 7, 10, 13, 15, 22, and 35 days. At each time point, twenty seeds from each species were randomly selected and their fresh weights recorded. These seeds were then oven-dried at 100 °C until a constant weight was achieved, after which their dry weights were measured. The moisture content (MC) of the seeds was calculated using the formula:

$$\textbf{MC}\ (\%) = \frac{\text{fresh weight} - \text{dry weight}}{\text{Fresh weight}} \times 100$$

2.7 Desiccation and Germination Tests

After the desiccation period, seeds were sown in germination trays to assess their germination potential. Prior to sowing, all seeds were soaked in water for 12 hours. Post-harvest treatments were also applied: *Afzelia africana* seeds underwent nicking and de-capping, while *Chrysophyllum albidum* seeds were treated by nicking only. The sown seeds were monitored daily, and germination was recorded based on the visible emergence of the radicle through the seed coat. Daily germination data were collected and used to calculate the Percentage Maximum Germination (Gmax) and Germination Rate (GR), following the method described by Ngele *et al*. (2024) as:

$$\textbf{Gmax}.\ (\%) = \frac{\text{number of germinated seed}}{\text{Total number of sown seeds}} \times 100$$

$$\textbf{GR} = t^{-1} \text{ to } G = 0.5$$

Where:

t = time to germination in days

$G = 0.5$ (50 % germination)

2.8 Desiccation on Conductivity

The conductivity of the bath solution, after seeds were steeped in water, was checked using a conductivity meter (B. Bran Scientific & Instrument Company England; Model DDS-307). The conductivity readings were obtained, calculated and expressed in $\mu s/cm^{-1}$ as described by Nkang (1990).

3. Results

3.1 Moisture Content in Seeds of Test Plants and Conductivity of Bath Solution Following Desiccation

Seed moisture content in *Afzelia africana* and *chrysophyllum albidum* declined significantly ($P \leq 0.05$) following desiccation (Table 1). Conductivity of the bath solution of *A. africana* on collection was significantly higher ($P \leq 0.05$), but conductivity decreased gradually following desiccation. However in *C. albidum*, conductivity increased following desiccation, with a significantly ($P \leq 0.05$) higher conductivity obtained at 35 days desiccation.

Table 1: Influence of desiccation on moisture content (%) and conductivity (µscm^{-1}) in *Afzelia africana* and *Chrysophyllum albidum*

	Afzelia africana		*Chrysophyllum albidum*	
Desiccation Period (Days)	**Moisture Content (%)**	**Conductivity (µScm^{-1})**	**Moisture Content (%)**	**Conductivity (µScm^{-1})**
0	*13.81^{a}±0.62	21170.00^{a} ±26.46	*40.04^{a}±0.34	15800.00^{e}±242.69
3	8.36^{b} ±0.24	18830.00^{b} ±43.49	37.23^{b} ±0.18	18360.00^{d}±1053.99
7	6.76^{c} ±0.08	13580.00^{c} ±10.00	34.77^{c} ±0.12	18570.00^{d}±609.18
10	6.36^{c}±0.13	12860.00^{cd} ±26.46	32.11^{d}±0.19	18690.00^{d} ±330.45
13	5.34^{d}±0.15	12440.00^{d} ±874.70	27.63^{e}±0.14	18840.00^{bc} ±133.58
15	4.86^{de}±0.06	11030.00^{de} ±1184.70	25.56^{f}±0.30	20390.00^{bc} ±782.56
22	4.23^{e}±0.05	10680.00^{e}±20.00	10.31^{g}±0.30	21220.00^{b}±187.35
35	4.03^{e}±0.37	10146.67^{e}±0.02	9.02^{h}±0.07	24833.33^{a}±152.46

* Means of three replicates ± standard error of mean. Means within each column followed by different letters are significantly different at P ≤ 0.05.

3.2 Desiccation on Germinability of *Afzelia Africana* and *Chrysophyllum Albidum*

The results obtained on the influence of desiccation on germinability of the test plants are presented in Table 2. Germination rate in *A. africana* declined significantly (P≤0.05) following desiccation; while maximum germination increased gradually following desiccation, with the highest maximum germination obtained at 15 days of desiccation with 4.86 % moisture content. There was however a significant reduction (P≤0.05) in maximum germination at 22- and 35-days desiccation, though comparable with values obtained at 0 and 3 days of desiccation.

In *c.albidum*, germination rate was significantly (P≤0.05) higher in seeds on collection, while seeds desiccated for three days had a significantly (P≤0.05) lower germination. Maximum germination was significantly (P≤0.05) higher in seeds on collection, but declined significantly (P≤0.05) following desiccation. There was no seed germination at 13 days desiccation and above.

Table 2: Effect of desiccation on germinability of *Afzelia africana* and *Chrysophyllum albidum*

	Afzelia africana		*Chrysophyllum albidum*	
Desiccation Period (Days)	**Germination Rate**	**Maximum Germination (%)**	**Germination Rate**	**Maximum Germination (%)**
0	*0.09^{a} ±0.01	66.28^{bcd}±0.23	0.09^{a} ±0.00	76.67^{a}±3.33
3	0.08^{a} ±0.01	71.67^{abcd}±4.41	0.04^{b} ±0.00	56.67^{b}±3.33
7	0.08^{a} ±0.01	79.67^{ab}±5.78	0.00^{c} ±0.00	15.00^{c}±2.89
10	0.05^{b}±0.01	77.67^{abc}±8.88	0.00^{c} ±0.00	11.67^{c}±3.33
13	0.04^{c}±0.01	85.00^{ab}±2.89	0.00^{c} ±0.00	0.00^{d} ±0.00
15	0.04^{c}±0.00	90.00^{a}±5.77	0.00^{c} ±0.00	0.00^{d} ±0.00
22	0.03^{cd}±0.00	55.00^{d}±8.66	0.00^{c} ±0.00	0.00^{d} ±0.00
35	0.02^{d}±0.01	60.00^{cd}±5.77	0.00^{c} ±0.00	0.00^{d} ±0.00

* Means of three replicates ± standard error of mean. Means within each column followed by different letters are significantly different at P ≤ 0.05.

3.3 Post Harvest Treatments on Germinability of *Afzelia africana* and *Chrysophyllum albidum*

Scarification did not significantly improve germinability in *A. africana* during initial desiccation periods (Table 3). Maximum germination was however significantly higher (P≤0.05) in scarified seeds at the 22nd and 35th day of desiccation. However in *C. albidum*, germinability was not improved in scarified seeds (Table 4) and there was no germination after the 10th day following desiccation.

Table 3: Effect of desiccation and post-harvest treatments on germination in *Afzelia Africana*

Desiccation Period (Days)	Post-harvest Treatment	Germination Rate	Maximum Germination (%)
0	Intact	$0.09^{a}\pm0.00$	$96.67^{a}\pm1.67$
	Decapped	$0.05^{b}\pm0.00$	$51.67^{b}\pm1.67$
	Nicked	NA	$18.33^{c}\pm0.88$
3	Intact	$0.07^{a}\pm0.00$	$60.00^{a}\pm0.00$
	Decapped	$0.10^{a}\pm0.00$	$90.00^{a}\pm0.00$
	Nicked	NA	$40.00^{b}\pm0.00$
7	Intact	$0.07^{a}\pm0.00$	$90.00^{a}\pm0.00$
	Decapped	$0.06^{a}\pm0.00$	$90.00^{a}\pm0.00$
	Nicked	NA	$30.00^{b}\pm1.53$
10	Intact	$0.05^{a}\pm0.00$	$80.00^{a}\pm0.00$
	Decapped	NA	$20.00^{b}\pm0.00$
	Nicked	NA	$30.00^{b}\pm0.00$
15	Intact	$0.04^{a}\pm0.00$	$71.67^{a}\pm6.01$
	Decapped	$0.01^{a}\pm0.01$	$40.00^{b}\pm5.77$
	Nicked	$0.01^{a}\pm0.01$	$45.00^{b}\pm2.89$
22	Intact	$0.04^{a}\pm0.00$	$90.00^{a}\pm5.77$
	Decapped	$0.04^{a}\pm0.00$	$70.00^{b}\pm5.77$
	Nicked	$0.05^{a}\pm0.00$	$80.00^{ab}\pm0.00$
35	Intact	$0.04^{a}\pm0.00$	$65.00^{b}\pm8.66$
	Decapped	$0.04^{a}\pm0.00$	$65.00^{b}\pm2.89$
	Nicked	$0.04^{a}\pm0.00$	$90.00^{a}\pm5.77$

* Means of three replicates ± standard error of mean. Means within each column followed by different letters are significantly different at $P\leq0.05$. NA: Not Applicable.

Table 4: Effect of desiccation and post-harvest treatments on germination in *Chrysophyllum albidum*

Desiccation Period (Days)	Post-harvest Treatment	Germination Rate	Maximum Germination (%)
0	Intact	$0.09^{a}\pm0.00$	$66.67^{a}\pm3.33$
	Nicked	$0.02^{b}\pm0.02$	$43.33^{b}\pm8.82$
3	Intact	$0.05^{a}\pm0.00$	$63.33^{a}\pm15.28$
	Nicked	$0.01^{b}\pm001$	$46.66^{b}\pm6.67$
7	Intact	NA	$18.33^{a}\pm4.41$
	Nicked	NA	$11.67^{b}\pm3.33$
10	Intact	NA	$10.65^{a}\pm3.33$
	Nicked	NA	$6.27^{b}\pm3.33$
22	Intact	NA	0.00 ± 0.00
	Nicked	NA	0.00 ± 0.00
35	Intact	NA	0.00 ± 0.00
	Nicked	NA	0.00 ± 0.00

* Means of three replicates ± standard error of mean. Means within each column followed by different letters are significantly different at $P\leq0.05$. NA: Not Applicable.

4. Discussion

Seeds of *Afzelia africana* had low moisture content on collection (13.81 %) in comparison to seeds of *Chrysophyllum albidum,* which had relatively higher moisture content on collection (40.04 %). Seeds of *A. africana* remained viable following desiccation even at moisture contents as low as 4.03 %.

However seeds of *C. albidum* lost viability at moisture level of 27.63 %. Orthodox seeds have been reported to acquire desiccation tolerance during development through maturation drying (Maia *et al*., 2011; Berjak and Pammenter, 2013); while recalcitrant seeds retain a high moisture content at maturity. Results suggest that seeds of *A. africana* showed orthodox characteristics, having germination potential even at low moisture levels. Seeds of *C. albidum* on the other hand exhibited recalcitrant seed viability characteristics as seed viability was lost with declining moisture level. Recalcitrant seeds exhibit high sensitivity to drying and, as a result, can only be stored for very limited durations while remaining hydrated (Hay & Probert, 2013). Knowledge of the moisture content and germinability among seeds of hardwood tree species are of immense importance in seed collection missions, by providing useful information to foresters, agronomists and agriculturists working on seeds of such species. Knowledge of the relationship between moisture content and dehydration period in seed germination is advantageous for it can influence the collection, processing for storage and treatments of the seeds (Gupta and Aneja, 2004). Results from this study also show a relationship between seed moisture content, germinability and electrical conductivity. Conductivity in *A. africana* seeds decreased following desiccation while increasing in seeds of *C. albidum*. Increase in conductivity was associated with loss of viability in seeds of *C. albidum*. Research findings of Alpert and Oliver (2002), Verma *et al*. (2003), Wood and Alpert (2006) and Seiler (2010) indicate that conductivity has a role to play in germination as it is strongly related to storage and moisture content. The longer the dehydration period of seeds the more porous the investing structures and membranes, hence, the more the electrolyte leakage. Increased conductivity following prolonged desiccation may be associated with the leaching of mineral nutrients into the steeping solution. Nkang (1990) and Nkang & Chandler (1989) also reported that viability loss in recalcitrant seeds of *Guilfoylia monostylis* was associated with loss in germinability and increased electrical conductivity.

Seed scarification of *A. africana* did not enhance germinability on collection and following initial desiccation but, scarification enhanced germination at the latter desiccation period. In orthodox seeds, desiccation leads to the formation of a highly viscous intracellular environment, a process known as vitrification, which restricts residual metabolic activity and limits the movement of free radicals and reactive oxygen species (ROS). The ability to maintain this vitrified state is essential for seed survival during prolonged dry conditions. Additionally, scarification plays a critical role by increasing seed coat permeability, thereby facilitating the leaching of ROS and enhancing germination potential (Berjak & Pammenter, 2008). Scarification however did not improve germinability in the recalcitrant *C. albidum*. Results from this research have shown that germinability in dried orthodox seeds can be enhanced by scarification.

5. Conclusion

Seeds of *Afzelia africana* are desiccation tolerant and can be stored for long-term use; while seeds of *Chrysophyllum albidum* rapidly lost viability following desiccation, suggesting that seeds with recalcitrant viability characteristics cannot be stored and dried. Information generated from this study is useful in the development of seed bank protocols for these and similar species (*Ex-situ* conservation).

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Author Contributions

Ngele, Blessing Alfred: Designed the experiment and carried out the investigation, collected data and wrote the original draft.

Effa, Effa Anobeja: carried out the statistical analysis.

Nkang, Ani Essien: Conceptualization, laboratory analysis, review, and editing of draft.

Conflict of Interest Statement

The authors declare no conflict of interest.

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