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Effects of Desiccants on the Quality and Conservation of Seeds of Tree Species in a Ghanaian Forest

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Authors' contributions

This work was carried out in collaboration between all authors. Author PKT designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. Authors HMB and SEO managed the analyses of the study. Author BA managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

A study was carried out to determine the effects of seed desiccants on seed quality of three very important indigenous forest tree species. The experimental period was December, 2015 to February, 2016. Seeds were collected from the Bobiri Forest Reserve. This Forest Reserve is located in the south-east sub-type of moist semi-deciduous (MSSE) forest in Ghana, covering an area of about 5,445 ha. It is located on the main Accra - Kumasi Highway at the village of Kubease, about 30 kilometres (19 miles) from Kumasi. Seed desiccation experiment was set up in a Complete Randomized Design (CRD) with three (3) replications. Germination percentage, seed vigour, 1000 seed weight, moisture content, seed health analysis, carbohydrate, protein and oil contents were determined before and after seed desiccation. The study revealed that the Zeolite beads® dried the seeds of *Pericopsis elata* within 2 days and 3 days for *Sterculia rhinopetala* but *Guarea cedrata* seeds were dried within 12 days. This rate of drying was much faster than the rest

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of the desiccants without any deleterious effect on the physical and chemical properties of seeds. *P. elata* and *S. rhinopetala* showed orthodox seed storage behavior by surviving drying to a lower moisture content which can enhance their long term storability. *G. cedrata* seeds however, exhibited recalcitrant seed behaviour and lost viability significantly after desiccation. *G. cedrata* seeds unlike *P. elata* and *S. rhinopetala* cannot be dried to lower moisture contents and stored for longer period under ambient conditions.

Keywords: Storage; orthodox; germination; conservation; recalcitrant; vegetation.

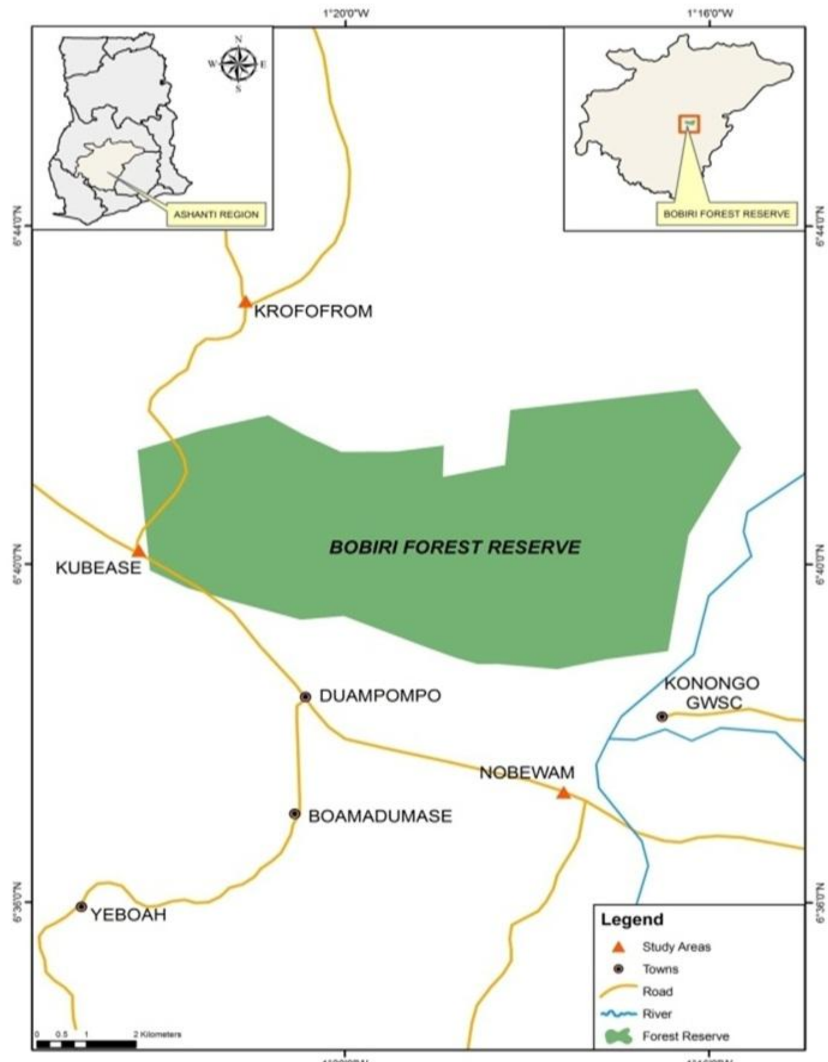
1. INTRODUCTION

Tree planting is undoubtedly known to be an effective measure to protect the climate and mitigate the effects of climate change. This is possible due to the role trees play in greenhouse gas carbon dioxide sequestration, counteracting soil erosion and desertification among others [1]. There is a growing concern about the uncontrolled exploitation and depletion of trees especially indigenous species in the tropics that are threatened with extinction. Studies have shown that many plant species are in danger of extinction, while some have already become extinct [2]. On a global basis, the IUCN has estimated that about 12.5% of the world's vascular plants, totaling about 34,000 species, are under varying degrees of threat. In Ghana, three indigenous trees of economic importance included *Peripcopsis elata* "Kokrodua" is classified as endangered species [3], *Sterculia rhinopetala* "Wawabima" and *Guarea cedrata* "Kwabohoro" have been described as vulnerable, according to the IUCN Red List of Threatened Species [4]. These species provide quality timber for export and other non-timber products which generate high revenue for the country. There is therefore an urgent need to conserve these species in any way practicable. This can be achieved by in situ or by ex-situ conservation technologies. One of the ex situ conservation of plant germplasm that is safe, effective and inexpensive is conventional seed storage. This method does not only maintain its viability but also its vigour without hampering the genetic makeup [2] In storage, the seed longevity is influenced by the seed moisture content, temperature and type of container used. Among these factors, the seed moisture content plays a significant role in determining seed longevity. There are various forms of drying methods that have been used for drying seeds of all kinds to reduce seed moisture content. Methods such as sun drying, forced air drying, modified solar drying [5] and desiccant drying [6,7]. Since seed is a material used for regeneration purposes, it must be dried in a manner that does not affect its germination and vigour during storage. To effectively conserve these tropical tree seeds, it is essential that we have basic knowledge about their seed drying sensitivity, seed physiology, responses to desiccation and their storage potential. Desiccant drying in a closed container is often suggested as a low-technology method to reduce the moisture content of seed germplasm. Suitable desiccants include silica gel (sodium silicate), lithium chloride, calcium chloride, molecular sieve, charcoal and rice which have been widely used on agricultural seeds with quite an appreciable success[7,8,6]. However, there is little information known on how the desiccants perform on tree seed species, particularly the tropical species. This study was aimed at drying the seeds of these tropical tree species to lower moisture using different desiccants for subsequent storage.

2. MATERIALS AND METHODS

2.1 Seed Collection and Seed Desiccation Experiment

The seed samples were collected from the Bobiri Forest Reserve in December, 2015. This Forest Reserve is located in the south-east sub-type of moist semi-deciduous (MSSE) forest in Ghana, covering an area of about 5,445 ha [9]. It is located on the main Accra - Kumasi Highway at the village of Kubease, about 30 kilometres (19 miles) from Kumasi. It is about 25 minutes' drive from the Kwame Nkrumah University of Science and Technology (KNUST). The Reserve was created in 1931 and has an area of 54.65 km^2. After seeds were collected, they were put in plastic seed bags, tightly sealed and sent to the experimental station of the Department of Horticulture, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana. The seed desiccation and other laboratory experiments were conducted at the Department of Horticulture, KNUST.



Source: G I S Remote Sensing and Cartography Unit, Department of Geography and Regional Planning

Plate 1. Map of the study area-Bobiri Forest reserve (Ghana)

2.2 Experimental Procedure

The seed to desiccant ratio used was 1:1. 100 g each of the seeds of the three species were weighed using an electronic scale and put in an airtight transparent plastic container. 100 g each of the desiccants were weighed, put in gauze and held above the seeds in the container to prevent the desiccants from having direct contact with the seeds. The study design was 3X5 Factorial arranged in a completely randomized design and replicated three times. The desiccants used were Zeolite Bead®, Charcoal, Biochar, Paddy rice and no desiccant (as control).

2.3 Data Collected

Data collected include time taken (days) for seeds to be completely dried,1000 seed weight (g), seed germination percentage (SGP), seed vigour (relating to total leachates) and seed moisture content (%) determined according to ISTA Rules, 2007[10]. The chemical seed composition; percentage oil, moisture content, protein and carbohydrate were determine using the rules as set out in AOAC, 2007 [11]. The Seed Vigour Index (SVI) was determined according to the formula proposed by Abdul-Baki and Alderson (1973) as: Seed Vigour Index = (Shoot length + Root length) X Germination Percentage [12]. Data collected from the laboratory experiments were subjected to analysis of variance using Statistix Student Version 9.0. Tukey's HSD (Honest Significant Difference) was used for mean separation at probability level 0.01.

3. RESULTS

3.1 Seed Initial Quality Characteristics

There were significant differences among the treatments for seed moisture content, seed vigour, seed vigour index, thousand seed weight and germination percentage (Table 1). *Guarea cedrata* had the highest moisture content (27%) and thousand seed weight (1089.7 g). On the other hand, *Pericopsis elata* recorded significantly the highest vigour index (2689.7) but the least moisture content (7.5%) and thousand seed weight (254.67g). There were significant differences ($p \leq 0.01$) between the treatments for germination percentage. *P. elata* recorded significantly the highest germination (96%) percentage followed by *S. rhinopetala* (95%). There were however, no significant differences ($p \leq 0.01$) between the treatments for seed vigour (Table 1).

3.2 Seed Initial Proximate Composition

There were significant differences between the treatment for P. elata, S. rhinopetala *and* G. cedrata. P. elata *recorded the* highest seed oil (31.25%) and protein (37.41%) contents but the least carbohydrate (1.93%) content. The least oil (23%) and protein (9.1%) contents were recorded by G. cedrata but recorded the highest carbohydrate (19.43%) content.

3.3 Number of Days Taken For Seeds to Attain Dryness

There were significant differences between the treatments for the number of days taken for each of the seeds species to attain dryness at a moisture content of 3.5% for all the species (Fig. 1). It took 2 and 3 days for the Zeolite Bead® to dry *P. elata* and *S. rhinopetala* significantly less in time than the other desiccant treatments. The number of days to dry the same species using charcoal or Biochar was not significantly different. The longest time for the attainment of dryness was experienced under the control treatment (no desiccant) and use of Rice (paddy) (13 to 82 days). The rice desiccant treatment took 6.5 times more days than the Zeolite beads to dry *P. elata* (Table 3). It took 12.3 days for the Zeolite Bead® to dry *G. cedrata* to steady moisture content, significantly less in time than the other desiccant treatments. It however, took 37 and 39 days respectively using charcoal and biochar to dry the same species under the same conditions. The number of days increased further to 82 when rice was used as a desiccant or no desiccant was applied.

3.4 Proximate Composition of Dried Seeds

3.4.1 Carbohydrate content

There were no significant desiccant and species interactions for the carbohydrate content in the seed after desiccation (Table 3). Among the species, there was significant differences in the amount of seed carbohydrate, where the highest was recorded by *S. rhinopetala* seeds and the least was recorded by *P. elata* seeds. Among the desiccants, there were no significant differences between the means.

3.4.2 Protein content

There were significant desiccant and species interaction for the protein content of the species (Table 4). Significantly highest protein was recorded by *P.elata* seeds dried with Biochar which was similar to seeds dried with the other desiccants. The least protein was recorded by *G. cedrata* seeds dried with Rice desiccant which was similar to the other desiccants. Among the desiccants, there were no differences in the protein contents. However among the species, there were significant differences among the proteins, where the highest protein as recorded by *P.elata* and the least by *G. cedrata*

Table 1. Initial seed quality characteristics of *G. cedrata, S. rhinopetala* and *P. elata*

Species	Moisture content %	Vigour ($\mu S\ cm^{-1} g^{-1}$)	Vigour index	1000 SW (g)	Germination (%)
P. elata	7.5a	23.0a	2689.7a	254.7a	96.3a
S. rhinopetala	10b	22.5a	2376.7b	779.7b	95.4a
G. cedrata	27b	25.4a	2251.7c	1089.7c	90.7b
HSD (0.01)	3.7	4.36	27.96	5.59	3.66

Table 2. The initial proximate composition of the three tree species

Species	Oil (%)	Protein (%)	Carbohydrate (%)
P. elata	31.3a	37.4a	1.9b
S. rhinopetala	23.0ab	19.2b	17.4a
G. cedrata	13.5b	9.1c	19.4a
HSD (1%)	10.85	3.23	3.81

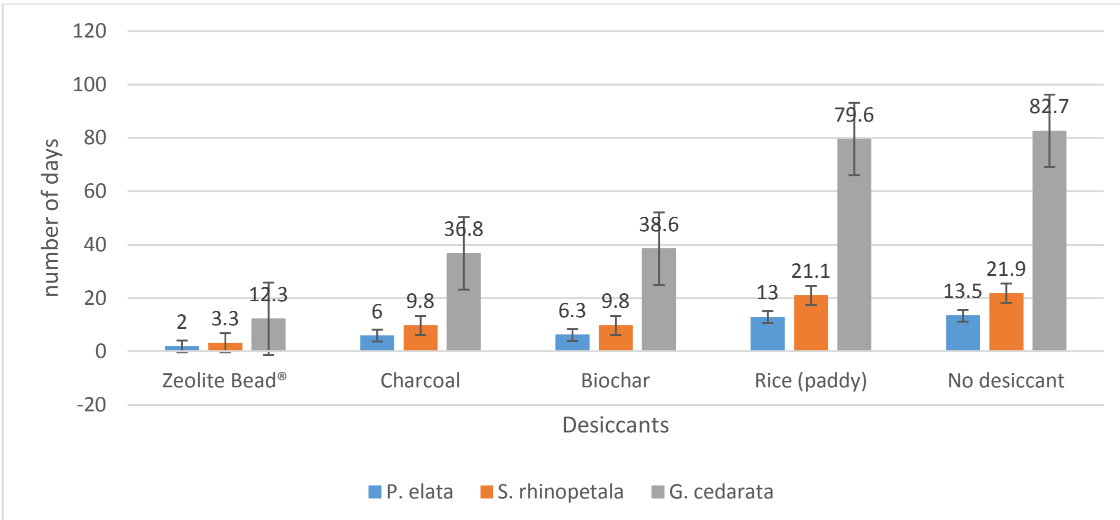


Fig. 1. Effect of desiccants on the number of days taken for seeds to dry

Table 3. Effects of desiccants on carbohydrate content (%) of the three tree species

Desiccants	Species			Mean
	P. elata	***S. rhinopetala***	***G. cedrata***	
Zeolite Bead®	1.42a	16.62a	13.16a	10.40a
Charcoal	1.39a	16.61a	12.81a	10.26a
Biochar	1.39a	16.50a	12.88	10.26a
Rice (Paddy)	1.41a	16.30a	16.30	10.24a
No desiccant	1.27a	16.40a	13.10a	10.26a
mean	1.36b	16.47a	12.92a	
HSD (0.01)	Desiccants=9.98 Species=6.84 Desiccants*Species=21.06			

Table 4. Effects of desiccants on protein content (%) of the three tree species

Desiccants	Species			Mean
	P. elata	***S. rhinopetala***	***G. cedrata***	
Zeolite Bead®	38.07a	20.56b	11.07c	23.24a
Charcoal	38.06a	20.55b	11.06c	23.23a
Biochar	38.08a	20.57b	11.08c	23.25a
Rice (Paddy)	38.06a	20.55	11.06c	23.22a
No desiccant	38.03a	20.57b	11.08c	23.25a
mean	38.07a	20.56b	11.07c	
HSD (0.01)	Desiccants=2.56 Species=1.76 Desiccants*Species=5.41			

3.4.3 Fat content

There were no significant desiccant and species interaction on the fat percentage of the seeds after desiccation. Significant differences were observed among the species, where the highest fat was recorded by *P. elata* and the least was recorded by *G. cedrata* (Fig. 2).

3.5 Vigour of Seeds

There were significant desiccant and species interaction for the vigour of the three species (Table 5). Significantly highest vigour was obtained by *G. cedrata* seeds dried with zeolite beads and the least was obtained by *P. elata* seeds dried with the beads, which was similar to both *P. elata* and *S. rhinopetala* seeds dried with all the different desiccants. Among the desiccants, the highest vigour was recorded by the beads and the least was obtained by the seeds which no desiccant was used for drying. Among the species, significantly highest vigour was recorded by *G. cedrata* and the least was *P. elata*.

3.6 Effects of Desiccants on 1000 Seed Weight (g) for the Tree Species

There were significant desiccant and species interaction for the 1000 seed weight of the three species (Table 6). The highest 1000 seed weight was obtained by *G. cedrata* seeds dried with no desiccant, rice and biochar whilst the least was recorded by *P. elata* seeds dried with zeolite beads. Among the desiccants, the highest 1000 seed weight was obtained by seeds dried with no desiccants and the least was those dried with the zeolite beads. Among the species, the highest 1000 seed weight was *G. cedrata* and the least was *P. elata*

3.7 Effects of Desiccants on Germination (viability) of Seeds after Desiccation

There were significant desiccant and species interaction for the germination percentage of the three species (Table 7). Highest and least germination percentage were recorded by *P. elata* and G. cedrata seeds dreied with zeolite beads respectively. Among the desiccants, there were no differences between the means. Among the species, the highest germination was *P. elata* and thee least was *G. cedrata.*

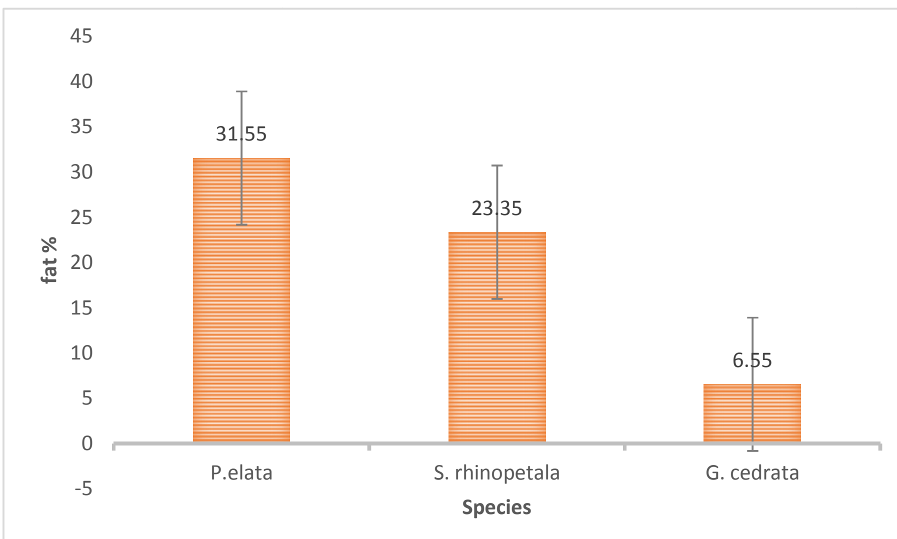


Fig. 2. Effects of desiccants on the fat content (%) of the three species

Table 5. Effects of desiccants on vigour (µS $cm^{-1}g^{-1}$) of the three tree species

Desiccants	**Species**			**mean**
	P. elata	***S. rhinopetala***	***G. cedrata***	
Zeolite Bead®	24.53d	26.083d	32.43a	27.70a
Charcoal	24.64d	26.14d	30.63ab	27.14ab
Biochar	24.59d	26.09d	29.33abc	26.77ab
Rice (Paddy)	24.60d	26.19d	27.53bcd	26.08b
No desiccant	24.64d	26.14d	27.23cd	26.00b
mean	24.61c	26.11b	29.49a	
HSD (0.01)	Desiccants=1.48 Species=1.02 Desiccants*Species=3.13			

Table 6. Effects of desiccants on 1000 seed weight (g) content of the three tree species

Desiccants	Species			mean
	P. elata	***S. rhinopetala***	***G. cedrata***	
Zeolite Bead®	254.3e	781.0c	1094.4b	709.92c
Charcoal	257.0de	781.4c	1097.1ab	711.84b
Biochar	258.0d	781.7c	1098.1a	712.60ab
Rice (Paddy)	258.8d	782.0c	1098.9a	713.23ab
No desiccant	258.9d	782.1c	1099.0a	713.33a
mean	257.40c	789.60b	1097.50a	
HSD (0.01)	Desiccants=1.40 Species=0.95 Desiccants*Species=2.95			

Table 7. Effects of desiccants on germination percentage/viability (%) of the three species after desiccation

Desiccants	Species			mean
	P. elata	***S. rhinopetala***	***G. cedrata***	
Zeolite Bead®	95.667a	88.967abcd	8.987e	64.540a
Charcoal	94.667ab	88.767abcd	10.977e	64.803a
Biochar	93.667abc	87.997bcd	12.087e	64.583a
Rice (Paddy)	93.667abc	85.997d	12.997e	64.220a
No desiccant	92.667abcd	86.867cd	9.867e	63.133a
mean	94.067a	87.719b	10.983c	
HSD (0.01)	Desiccants=3.49 Species=2.39 Desiccants*Species=7.37			

4. DISCUSSION

The differences observed in the initial seed quality could be attributed to the high genetic variations that existed between the species. Seeds of *P. elata* and *S. rhinopetala* were shed with relatively lower moisture contents of 7.5% and 10%, respectively, which is characteristic of orthodox seeds. According to Berjak and Pammenter (2004), viability of orthodox seeds can be maintained even when the moisture content is reduced and can also be dried further to enhance their longevity [13]. The results of the present study showed that *P. elata* and *S. rhinopetala* seeds could remain viable for a long period of time when moisture was reduced. *G. cedrata* seeds, however were shed at very high moisture content (27%) and the seeds were metabolically active and also recorded high germination which is characteristic of recalcitrant seeds. Hay (2003) reported that recalcitrant seeds are metabolically active and would have high germination capacity when planted immediately after seed collection [14]. The results of the present study clearly confirm that *G. cedrata* had an initial high seed moisture but with a high initial germination probably showing recalcitrant seed storage behaviour.

The initial vigour index was highest (2689.7) whilst the initial vigour (in terms of solute leakage) were low and within the recommended leakage levels as reported by Milosevic et al. (2010) that seeds with leakage below 25 µS $cm^{-1}g^{-1}$ were of high vigour whilst those with vigour more than 35 µS $cm^{-1}g^{-1}$ were of low vigour [15].

The Zeolite Bead® were significantly able to dry the seeds at a faster rate as compared to charcoal, biochar, rice and the control. This could be attributed to the presence of aluminum silicates that fill the micropores which have high affinity to hold water in these micro molecular pores for a longer duration. The results of the current study confirms the findings of Nassari et al. (2014) who investigated the drying ability of beads on the quality of tomato seeds and reported that the beads were significantly effective to reduce absorb seed moisture at the fastest rate [16]. Hay et al. (2012) also reported on the advantages of using the beads as desiccant including their greater affinity for water, especially at low humidity; more rapid drying; and no hysteresis effect, which lowered the amount of water that could be adsorbed after regeneration [6]. Buady (2002) reported that charcoal was a good drying agent and was found to keep stored seeds viable quite better as compared to dried rice used as a desiccant [17]. Moreover, Nyarko (2006), indicated that rice was a poor desiccant as compared to charcoal just as was found in the present study [18]. Additionally, for *P. elata* and *S. rhinopetala*, the desiccants did not have any deleterious effect on the vigour (solutes leakage), vigour index, germination percentage, seed protein, oil content and carbohydrate. This could be due to the fact that the two species are orthodox seeds and that desiccation to a lower moisture content rather improved viability thereby confirming Harrington's principle that for every 1% reduction in seed moisture there was a doubling of the viability of the seed [19]. McDonald, (2004) also reported that desiccation-sensitive seeds cannot be dried to lower moisture content without deleterious effect on viability as compared to desiccation-insensitive seeds [20].

The deleterious effects of desiccation on *G. cedrata* seeds which was evident in the significantly reduced germination percentage, confirmed their high sensitivity to drying. According to Pritchard (1991), seeds that are desiccation-sensitive lose their viability considerably after dehydration [21]. Hoekstra et al. (2001) also indicated that desiccation results in reduced cellular volumes and causes the compaction of cytoplasmic components [22]. This compaction increases molecular interactions leading to protein denaturation and membrane fusion. Furthermore, Chin (1988) opined that death of recalcitrant seeds was due to reduction in moisture and was basically due to the loss of membrane integrity and nuclear disintegration [23]. The results of the present study for *G. cedrata* confirm these findings.

5. CONCLUSION

Results obtained from this study has shown that among the four desiccants used in drying *P. elata, S. rhinopetala* and *G. cedrata,* beads had the fastest drying time without any deleterious effect on the physical and chemical properties of seeds. *G. cedrata* seeds lost viability considerably after desiccation and therefore could not be stored.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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