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Improving storability of *Bambusa arundinacea* (Retz.) Willd. seeds

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Abstract—The viability of *Bambusa arundinacea* seeds in relation to collection, drying methods and storage temperatures was studied. Bamboo seeds need to be collected immediately before rains set in as seeds lose viability rapidly on exposure to excess moisture. Storage of wet seeds also poses problems. Desiccator drying of seeds was found to retain viability while sun drying proved detrimental. Moisture content of seeds could be reduced to as low as 1.90% for effective storage. Seeds with initial moisture content of 9.6% were stored in plastic containers at five different temperatures: −15°C, −5°C, 5°C, 10°C and ambient (28–30°C). Rapid loss in viability of the seeds stored under ambient conditions occurred within 6 months, while in other storage conditions deterioration was gradual, reaching 6% germination after 18 months.

Key words: *Bambusa arundinacea*; bamboo; seeds; viability; storage.

INTRODUCTION

Bamboo is one of the most used plant commodities, as it provides food, raw material, shelter and employment opportunities. It was over exploited as raw material for pulp and paper industry and continuous demand from industry still exists. India is one of the leading countries of the world, second only to China in bamboo production, and shelters as many as 125 indigenous and exotic species of bamboo [1] over an area of 89 600 ha with an annual production of 4.5 million ton. *Bambusa arundinacea* is one of the principal bamboos of India with an overall annual production of 5 million ton, occupying 13% of the total bamboos in India [2]. It is the fastest growing wood species, attaining maturity in less than 5 years. Currently the entire requirement of 1.46 million tons per annum of bamboo

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for pulp and paper industries is being met from forest-based natural resources. The widespread use of bamboos has resulted in a serious resource shortage and escalating price. Due to its peculiar flowering behaviour, very little work has been done on bamboo breeding and genetic improvement. The best alternative to increase the yield per hectare is the use of quality-planting stock in plantation programmes. In the national afforestation programmes bamboo is propagated through seeds, rhizomes, or offsets. The availability of bamboo offsets is limited. Planting stock can be produced by vegetative propagation, but the synchronous flowering of the vegetatively propagated clumps and parent clumps leads to the death of the entire plantation. Propagation of bamboos through seed is the easiest and cheapest method.

Bamboos are known for their irregular flowering cycle, with most of the economically important bamboos flowering only once in every 20–60 years. The sporadic flowering that takes place annually in isolated clumps of some species yields only a few viable seeds, when compared to seed from gregarious flowering. Continuous availability of seeds is therefore uncertain and irregular. The unique flowering nature of bamboo is the major limiting factor in improvement programmes. Large tracts of bamboos flower simultaneously during gregarious flowering with production of large quantities of seed. Death of the flowering clumps following seed set limits further seed production in the following years.

Bamboo seeds have a short viability, which lasts only for l–2 months [3]. The viability of bamboo seeds in relation to storability needs investigation. Research is needed to address the often-observed problem of low quality seed being available for propagation and poor vigour of many seedlings. Even if good quality seeds are produced, they have to be harvested and stored appropriately to maintain their vigour. Further, under optimum storage conditions, good quality seeds will maintain viability and vigour for a longer period of time. There is also a need to prolong the viability of bamboo seeds in order to make the seeds available during non-seeding years for propagation. Therefore, investigations were focused on prolonging the viability of bamboo seeds by storing under different temperatures. Seed storage studies were carried out to study the effect of collection methods, desiccation and temperature tolerance.

METHODOLOGY

Seeds of *Bambusa arundinacea*, collected from Attapady (11°5′N; 76°37′E), Kerala, India during flowering season, were used for the studies. The area under the flowering clumps was cleared of litter and vegetation. Seeds were collected by manually shaking the fruiting culms after spreading a canvas sheet on the ground. Care was taken to collect only freshly fallen seeds as old seeds have been reported to have poor viability. The seeds were packed in jute bags and transported to the laboratory. The seeds were thoroughly cleaned by winnowing in a tray to remove non-seed (inert) materials. The seeds were then stored in cloth bags at 20°C until the start of the experiments. The seeds were tested for their initial germination and moisture content under laboratory conditions.

Tests for germination and moisture content

The germination test was carried out in Petri plates on moistened germination paper. The test was carried out in 4 replicates of 50 seeds each. The number of seeds germinated was counted and recorded daily. The first germination was observed on day 3 and the final count was done on day 21. The seed moisture content was determined by drying the seeds in an oven at 103 ± 1°C for 17 h [4]. Four replications, each with 5 g seeds, were used for determination of initial moisture content. The moisture content was calculated on fresh weight basis.

Viability of wet seeds

In bamboos, the flowering season always coincides with rains. It has been observed that the storability of the seeds collected after rains is poor. Systematic study was conducted to elucidate the storability of wet seeds. 100 g of seeds soaked in rain was collected. The seeds were spread on a blotting paper and shade dried for 24 h. After ensuring seeds were properly surface dried, they were stored in airtight plastic containers at ambient condition. 100 g of seeds collected before rains from the same clumps and stored in airtight plastic containers under ambient conditions served as control. The seeds were stored for 10 weeks and then tested for their germination at weekly intervals. Germination tests were conducted as mentioned earlier.

Desiccation tolerance and drying methods

Eight samples were taken at random from freshly collected seeds. The fresh weight of the samples was determined. Following determination of moisture content of the fresh seeds, the eight seed samples were subjected to two types of drying namely (i) sun drying (approximate temperature 32 ± 1°C, RH 52.81% and average wind velocity 5.35 km/h) and (ii) drying in desiccators (non-evacuated) at room temperatures (28 ± 2°C) using silica gel until the fixed target moisture levels were attained. Duration for drying to the lowest target moisture was 24 days. The target moisture contents fixed were 8%, 6%, 4% and 2% in both drying methods. The target weight for drying the seeds was determined using the standard methods [5]. The seeds at different moisture levels were subjected to germination test.

Storage temperature

This experiment was carried out to study the effect of low temperature on seed viability. The fresh seeds were stored in air-tight plastic containers for 18 months at 5 different storage temperatures namely, −15°C, −5°C, 5°C, 10°C and ambient (28–30°C). The seeds were tested for their viability at 2-month intervals for a period of 18 months.

Statistical analysis

The experiments were carried out in completely randomised design and analysed for statistical significance [6]. Transformed data were used wherever necessary.

RESULTS

Seeds were tested for initial moisture content and germination immediately after collection. The initial moisture content was found to be 9.6% with an initial germination of 80%.

Viability of wet seeds

The germination percentage of seeds soaked in rain and control seeds are given in Fig. 1. Although the wet seeds expressed the same germination after one week of storage, the viability of wet seeds drastically reduced to 1.5% after 10 weeks.

Effect of desiccation tolerance and drying methods on seed germination

The germination percentage obtained at different moisture contents and the time taken for attaining the target moisture contents in both desiccator drying and sun drying are shown in Table 1. The desiccator-dried seeds took 6 days to attain 4% moisture content and 24 days to reach 2% moisture content from the initial moisture content of 9.6%, whereas the sun-dried seeds took 3 h to reach 4% moisture content and 44 h to attain 2% moisture content. The desiccator-dried seeds reduced the moisture content up to 1.9% without any drastic effect on the viability of seeds. On the other hand, there was a rapid loss of moisture content and viability in sun-dried

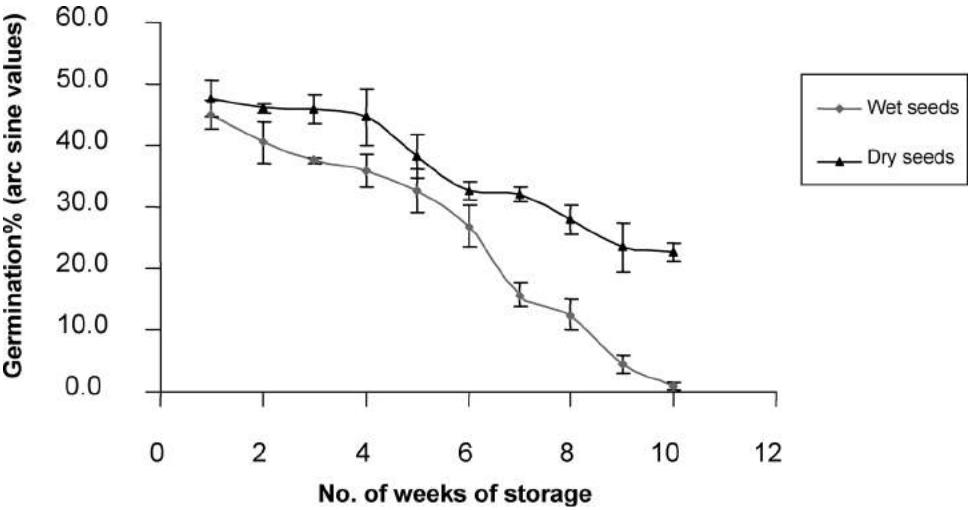

Figure 1. Effect of storing wet bamboo seeds (8% MC, at 20°C) on germination.

Table 1.
Effect of desiccation tolerance and drying methods on seed germination

Time taken for drying	Target moisture content (%)	Actual moisture content (%)	Germination percentage (%)
Desiccator drying			
24 h	8	7.8	72
48 h	6	5.7	67
144 h (6 days)	4	3.7	64
576 h (24 days)	2	1.9	66
SED			3.92
CD			NS
Sun drying			
30 min	8	6.6	0
2 h	6	5.6	0
3 h	4	3.5	0
44 h	2	1.8	0

SED is standard error of deviation, CD is critical difference.

Table 2.
Effect of storage temperature on seed germination (MC of seed is 9.6%)

Storage temperature (°C)	Germination percentage							
	4 months	6 months	8 months	10 months	12 months	14 months	16 months	18 months
−15	58	57	57	64	35	0	0	0
−5	62	62	62	65	13	5	2	2
5	53	51	51	61	7	0	0	0
10	71	67	67	67	36	10	9	6
Ambient (28–30)	43	8	0	0	0	0	0	0

seeds. Drying of seeds in the sun was found to adversely affect the seeds. The seeds could retain viability even when dried to 2% moisture content in a desiccator, while the sun-dried seeds could not retain the viability even at 8% moisture content.

Storage temperature

The results on germination percentage of *Bambusa arundinacea* seeds stored at five different temperatures, −15°C, −5°C, 5°C, 10°C and ambient (28–30°C), at 2-month intervals are given in Table 2 and the results of the statistical analysis of the correlation between the parameters are shown in Table 3. Seeds with initial germination of 80% when stored under ambient conditions showed reduction in germination after 4 months (43%). Storing beyond this period was detrimental to the seeds. All other storage temperatures were found to be conducive (germination of above 60%) for effective storage of bamboo seeds up to 10 months.

Table 3.
Statistical analysis of the correlation between the parameters

	SED	CD
Storage period	0.951	1.883
Storage temperature	0.752	1.488
Storage period × Storage temperature	2.126	4.210

SED is standard error of deviation, CD is critical difference.

DISCUSSION

Hydration and dehydration treatments reduce viability in bamboo seeds. Once seeds are sodden, they lose viability rapidly. Therefore, it is recommended that separation of filled seeds from unfilled ones by floating method be avoided. Further, increased chances of fungal infections are observed. Seeds should be collected before rains, as the seeds exposed to rain quickly lose their viability. However, few studies report soaking–drying treatment with low concentration of disodium hydrogen phosphate (10^{-4} M) maintaining the vigour and viability of seeds of *D. strictus* [7].

Bamboo seeds germinate at higher percentage under shade than under direct sunlight. Thus, bamboo seeds can be considered as negatively photoblastic [8]. Seeds start germinating within 3–7 days of sowing and continue up to 15–25 days. Observations that the fresh seeds of *B. arundinacea var. spinosa, B. tulda* and *B. longispathus* germinated better than stored ones have been reported. The seeds showed a viability of only 1–2 months under room conditions (temperature 24–30°C and RH 26.6–66.4%) [9].

In the present study, the sudden reduction in moisture content during sun drying when compared to desiccator drying, would have adversely affected the viability of the seeds. Further, sun drying method produces high temperature with no mechanisms for controlling the rise, which could prove harmful for small scale harvested seeds. Drying with seed moisture absorbent was the best result and sun drying was the poorest method for Papaya seeds [10]. The study suggests that bamboo seeds could be dried to 1.9% moisture content for long-term storage. The study indicates that the seeds need to be collected immediately after seed fall with minimal exposure to sun light. If seed collection takes place for more than a day, then seeds need to be stored in ventilated atmosphere.

Seed viability being very low in bamboos, different techniques of storage have been developed [11] to increase the viability [12]. The longevity of bamboo seeds varied from species to species. It was reported to be 30–35 days for *Bambusa tulda*, 55 days for *Dendrocalamus longispathus* and 65 days for *B. arundinacea* var. *spinosa* [13]. It has been suggested that bamboo seeds could possibly be stored for longer durations with proper handling and drying techniques [14]. By storage of seeds under suitable temperature (3–5°C) and moisture (8%), the longevity of *D. strictus* seeds could be extended up to 34 months [15, 16]. Seeds of *D. strictus* stored between 0 and 5°C showed the highest percentage of viability after 9 months [17].

Desiccated seeds of *D. strictus* (8%) could be stored at low temperatures (3–5°C) for over 34 months with 51–59% germination [18]. Attenuation of growth substances like auxins and gibberellins appear to be responsible for the loss of viability of bamboo seeds [19].

Under normal storage conditions, *B. arundinacea* seeds lose their viability rapidly within 6–8 months. *B. arundinacea* seeds, having an initial moisture content of 11%, retained viability up to 413 days on storage at low temperatures(−3 to 0°C) [20]. The seeds gave a germination of 65% following storage at −70°C [21].

In the present study, *B. arundinacea* seeds with an initial moisture content of 9.6% could be stored for a period of 12 months at low temperature. Seeds stored at 10°C could maintain their viability up to 18 months although germination was low (6%). This suggests that bamboo seeds could be stored for longer periods under controlled conditions. Low-temperature storage facilitates prolonging of seed longevity. −5 to 10°C could be the optimum storage temperature range for the seeds. Low temperatures can reduce the rates of both seed deterioration and germination provided that they remain above the value which results in chilling damage (if applicable) or the lower value at which ice crystallization occurs [22]. The seeds, therefore, may be stored at or below 10°C, but care should be taken to gradually reduce the temperature while going for storage at freezing temperatures.

CONCLUSIONS

Bambusa arundinacea seeds can be stored safely for 12 months under controlled conditions. Reducing the initial moisture content before storing helps maintaining the viability beyond 1 year. Seeds can be dried up to 1.9% moisture content for effective storage. The seeds could be safely stored at low temperatures (−15°C) for a longer period. The seeds need to be collected immediately after fall, and exposure to direct sunlight or to dampness/rains reduces viability and storability of the seeds. Further studies are required to ascertain the effect of moisture content on the longevity of seed at different temperatures. Conditions and performance of seeds after storing them at freezing temperatures also need to be determined.

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