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Storage practices in recalcitrant tropical forest seeds of Western Ghats

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Contents

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Recalcitrant seeds are short lived, commonly surviving only for a few days or weeks after maturity. Usually they shed in the hydrated state with high moisture content (>40%) and desiccation sensitive; hence, inability to survive drying below 30% moisture content. Knowledge of handling recalcitrant seeds is meager and not available for practice. In this context, the study was conducted on seed handling of selected tropical tree species, *Artocarpus hirsutus*, *Calophyllum inophyllum*, *Dysoxylum malabaricum*, *Gluta travancorica*, *Syzygium cumini* and *Syzygium travancoricum*.

Maturity index is important for effective seed collection and different in each species. Maturity index is the change of fruit colour from green to yellow for *A. hirsutus*, attaining greenish-yellow fruit colour is for *C. inophyllum* and having bright yellow fruits with longitudinal furrows for *D. malabaricum*. Time of seed collection is also different in each species. Seed collection was during April-May for *A. hirsutus*, December for *C. inophyllum*, June-August for *D. malabaricum*, May- July for *G. travancorica*, May-June for *S. cumini* and *S. travancoricum*. Seed processing is different in each species and itself is act as part of pre-sowing treatment for enhancing seed germination. De-pulping improved germination potential of the seeds of *A. hirsutus*, *S. cumini* and *S. travancoricum*. Similarly, de-coating of seeds also helped to enhance germination potential of the seeds of *C. inophyllum* and *D. malabaricum*.

Fresh seeds of *A. hirsutus* had 49.99% moisture content and its critical moisture level was 40 per cent. Similarly, moisture content of the fresh seeds of *C. inophyllum, D. malabaricum, G. travancorica, S. cumini* and *S. travancoricum* were 56.34, 55.46, 47, 55.35 and 45 per cent respectively. The respective critical moisture levels were 44, 45, 38, 40 and 38 per cent. Germination of the fresh seeds in each species was 88, 94, 97, 99.7, 98, and 58 per cent respectively. However, desiccated seeds of *A. hirsutus* showed higher germination (97%) than that of fresh seeds.

Seeds in earthen pot kept inside wet vermiculite/saw-dust at 16^{o}C and 45% relative humidity (RH) was the optimum storage condition for *A. hirsutus* (32% germination during 8th month and decreased to 11% at the end of 10th month), *C. inophyllum* (20% germination at 14th month), *S. cumini* (24% germination during 3rd month and gradually decreased to 10% at 6th month). Same type of container and medium at 20°C and 45% RH was the best storage condition for *D. malabaricum* (37% germination at 12th week) and room temperature (32 ^{o}C) for *S. travancoricum* (46% germination during 1st month and gradually reduced to 13% at 5th month). Seeds of *G. travancorica* maintained viability with 23% germination during 18th month and reduced to 6% during 20th month when stored in cotton bag inside sawdust at 16^{o}C. The study revealed that longevity of recalcitrant seeds shall be extended for 5 to 20 months under suitable storage conditions after desiccation to a lowest safe moisture level.

സംഗ്രഹം

റീകാൽസിട്രന്റ് ഇനത്തിലുള്ള വിത്തുകൾ വളരെ കുറച്ചുകാലം മാത്രമെ ജീവന ക്ഷമതയോടെ സൂക്ഷിക്കുവാൻ സാധിക്കുകയുള്ളൂ. പാകമായി കുറച്ചു ദിവസങ്ങൾക്കുള്ളിൽ അവയുടെ അങ്കുരണശേഷി നഷ്ടമാകും. സാധാരണ ഇത്തരം വിത്തുകളിൽ ഉയർന്ന ജലാംശം ഉണ്ടായിരിക്കും (>40%). ജലാംശം 30 ശതമാനത്തിൽ താഴെയാക്കി ഉണക്കിയാൽ ജീവനക്ഷമത നഷ്ടമാകുന്നതാണ്. ഇത്തരത്തിലുള്ള വന വിത്തുകളുടെ ശാസ്ത്രീയമായ പരിപാലനത്തെ കുറിച്ചുള്ള അറിവുകൾ വിരളമാണ്. ഇത്തരം വിത്തുകളിൽ ഉൾപ്പെട്ട ആഞ്ഞിലി, പുന്ന, വെള്ളകിൽ, ചെങ്കുറിഞ്ഞി, ഞാവൽ, പൊരിയൽ മുതലയവയെകുറിച്ചുള്ള പഠനമാണ് ഇതിൽ ഉൾപ്പെടുത്തിയിരിക്കുന്നത്.

ഓരോന്നിന്റെയും ഫലങ്ങൾ പാകമാകുന്നതിന്റെ സൂചന വ്യത്യസ്തമായിരിക്കും. ആഞ്ഞിലിയിൽ പച്ചനിറമുള്ള ഫലങ്ങൾ പാകമാകുമ്പോൾ മഞ്ഞനിറമാകുന്നു. പുന്നമരത്തിന്റെ ഫലങ്ങൾ പച്ചകലർന്ന മഞ്ഞനിറമാണ് സൂചകം. മഞ്ഞ നിറത്തോടുകൂടിയ പൊട്ടിയ പഴങ്ങളാണ് വെള്ളകിലിന്റെ സൂചകം. ആഞ്ഞലിയുടെ വിത്തുശേഖരണം ഏപ്രിൽ-മെയ് മാസങ്ങളിലാണ് ചെയ്യേണ്ടത്. പുന്നയുടെ വിത്തുകൾ ഡിസംബറിലും വെള്ളകിലിന്റെ ജൂൺ-ആഗസ്റ്റ് മാസങ്ങളിലും, ചെങ്കുറിഞ്ഞി മെയ്-ജൂലൈ മാസങ്ങളിലും ഞാവൽ, പൊരിയൽ എന്നിവയുടെ വിത്തുകൾ മെയ്-ജൂൺ മാസങ്ങളിലുമാണ് ശേഖരിക്കേണ്ടത്. ഓരോ ഇനത്തിന്റെയും വിത്തു സംസ്കരണം വ്യത്യസ്തമാണ് മാത്രവുമല്ല ഇത് ഒരു വിത്തുപചാരവും കൂടിയാണ്. ആഞ്ഞിലി, ഞാവൽ, പൊരിയൽ എന്നിവയിൽ മാംസള ഫലത്തിൽ നിന്ന് വിത്ത് പുറത്തെടുത്തു നടുന്നത് അങ്കുരണശേഷി വർദ്ധിപ്പിക്കും. പുന്നയിലും, വെള്ളകിലിലും വിത്തിന്റെ തൊലി കളഞ്ഞ് മുളപ്പിച്ചാൽ അങ്കുരണശേഷി വർദ്ധിക്കുന്നതാണ്.

വിളഞ്ഞ് പാകമായ ആഞ്ഞിലി വിത്തിൽ ഏകദേശം 49.99 % ജലാംശം ഉണ്ടായിരിക്കും. അതിന്റെ നിർണ്ണായക അളവ് 40 % ആണ്. അതുപോലെ തന്നെ പുന്ന, വെള്ളകിൽ, ചെങ്കുറുഞ്ഞി, ഞാവൽ, പൊരിയൽ എന്നിവയുടെ ജലാംശത്തിന്റെ ശതമാനം 56.34, 55.46, 47, 55.35, 45 എന്നീ തോതിലാണ്. അവയുടെ നിർണ്ണായക അളവ് യഥാക്രമം 44, 45, 38, 40, 38 ശതമാനമാണ്. ഇവയുടെ അങ്കുരണശേഷി യഥാക്രമം 88, 94, 97, 99.7 98, 58 ശതമാനമാണ്. എന്നാൽ ജലാംശം നിർണ്ണായക അളവിലാക്കിയ ആഞ്ഞലിയ്ക്ക് കൂടിയ അങ്കുരണശേഷി (97 %) നേടാൻ സാധിച്ചിട്ടുണ്ട്.

ആഞ്ഞിലി, പുന്ന, ഞാവൽ എന്നിവയുടെ വിത്തുകൾ 16 ^{o}c ഊഷ്മാവും 45 % ആപേക്ഷിക ആർദ്രതയും ഉള്ള മുറിയിൽ മൺകുടത്തിലിട്ട് അതിനെ നനവുള്ള വെർമിക്കുലൈറ്റ് / മരപ്പൊടി നിറച്ച പാത്രത്തിൽ ഇറക്കി വച്ച് സൂക്ഷിച്ചാൽ അവയുടെ ജീവനക്ഷമത ദീർഘിപ്പിക്കുവാൻ സാധിക്കും. മേൽപ്പറഞ്ഞ രീതിയിലുള്ള സംഭരണിയിൽ 20 ^{o}c ഊഷ്മാവിലും 45 % ആപേക്ഷിക ആർദ്രതയിലും ഉള്ള മുറിയിൽ വെള്ളകിലിന്റെ വിത്തുകളും സാധാരണ ഊഷ്മാവിൽ പൊരിയലിന്റെ വിത്തുകളും സൂക്ഷിച്ചാൽ അവയുടെ ജീവനക്ഷമത ദീർഘിപ്പിക്കുവാൻ കഴിയും. ചെങ്കുറിഞ്ഞിയുടെ വിത്തുകൾ 16 ^{o}c ഊഷ്മാവിലും 45 % ആപേക്ഷിക ആർദ്രത ഉള്ള മുറിയിൽ തുണിസഞ്ചിയിൽ സംഭരിച്ചാൽ അവയുടെ ജീവനക്ഷമത നഷ്ടപ്പെടാതെ ഏകദേശം 20 മാസങ്ങളോളം സൂക്ഷിക്കുവാൻ കഴിയും.

അനുയോജ്യമായ രീതിയിൽ ഇത്തരം റീകാൽസിട്രന്റ് വിത്തുകൾ സൂക്ഷിച്ചാൽ അവയുടെ അങ്കുരണശേഷി അധികം നഷ്ടപ്പെടാതെ ദീർഘക്കാലം സംഭരിക്കുവാൻ സാധിക്കും എന്നതാണ് ഈ പഠനം കൊണ്ട് വ്യക്തമാക്കുന്നത്.

1. INTRODUCTION

Research on tree seeds and tree improvement is one of the most important fields in which investigations are being conducted today. In fact, this thrust area is very vital for improving the productivity of forest. Production of planting stock through seed is much more resistant to environmental stress than other modes like vegetative cloning, since seeds constitute a unique genetic composition resulting from the mixing up of parental genetic materials. Quality of seeds can be ensured through collection of seeds from genetically superior stands/trees and scientific handling practices (Chacko, 2009). Right stage for seed collection, processing, pretreatment and storage are vital for efficient utilization of tree seeds. Thorough knowledge on various stages of seed handling procedure will be beneficial for production of superior planting stock (Chacko *et al*., 2002). Profuse seed production in some species is intermittent or at longer intervals. Seeds are to be collected in large quantity during high seeding years and stored under suitable storage conditions without losing viability. Similarly, seed storage is an alternate solution for conserving the diminishing forest flora and plays a complementary role in germplasm conservation. It is one of the means to preserve plant genetic resources for future forestry crops (Bewley & Black, 1994). Basic understanding of the factors that influence seed longevity and storage requirement is fundamental to successful seed banking.

Seeds can be broadly grouped as orthodox and recalcitrant according to their storage behaviour. Orthodox seeds are most common and they belong to the deciduous species mostly. It usually contains lower moisture content at maturity and survives even drying up to 5-8% MC. This enables them to be stored without any harm for a long period. However, recalcitrant seeds are short lived, commonly surviving only for a few days or weeks after maturity. Most of the seeds of evergreen species are recalcitrant and do not undergo a drying phase during maturation but continue to develop towards germination throughout their short life. Seeds are shed in the hydrated state with high moisture content (> 40%) and desiccation sensitive; hence, difficult to survive drying below 30% moisture content. Consequently, they require special attention during collection, transport and storage. Fungal contamination is ubiquitous in recalcitrant seeds, and is a major cause of deterioration; thus surface sterilization of the seeds immediately on removal from the fruit is critical. Seeds are to be stored at the lowest temperature commensurate with their chilling tolerance. Knowledge of handling recalcitrant seeds is meager and not available for practice. Thus the project was envisaged for standardization of seed handling procedures, specifically seed storage for important recalcitrant forest species such as *Artocarpus hirsutus* Lam., *Calophyllum inophyllum* L., *Dysoxylum malabaricum* Bedd. ex Hiern, *Gluta travancorica* Bedd., *Syzygium cumini* (L.) Skeels and *Syzygium travancoricum* Gamble.

Artocarpus hirsutus belonging to the family Moraceae is a large evergreen canopy tree commonly known as Aini, Anjili and Jungle Jack. The species is endemic to the Western Ghats and disturbed in evergreen forests in varied altitudes ranging from sea level to an elevation of 1000 m with annual rainfall of 1500 mm or more. Tree grows up to 35 m height and about 4.5 m girth. Wood is durable and used in construction; similarly, fruits and seeds are edible (Kader *et al*., 1999).

C. inophyllum, an Indian laurel commonly known as 'Punna', a moderate sized evergreen riparian tree, belonging to the family Clusiaceae. It is distributed as paleotropics, and native from East Africa, southern coastal India to Malaysia and Australia (Mabberley, 1997). In Kerala, it found along backwaters and river banks. The tree is slow growing and grows to 8-15 m height and attains maximum girth of 45 cm. Generally, it flowers during July-August and fruits are matured during November-January. Wood is used for beams, railway carriages, yoke and cabinet works. Seed oil (Tamanu Oil) is used in soap manufacture, illuminant, lubricant, and decoction of flower is given to cure venereal diseases (Nair, 2000). The oil is a significant healing agent and also has anti-neuralgic and antibiotic properties (Dweck, 2002). *D. malabaricum*, an endangered species endemic to Western Ghats belonging to the family Meliaceae is commonly known as white cedar (Nair *et al*., 2004). They are distributed in the evergreen forests of Western Ghats from north Kanara southwards to Kerala and attaining 35 m height and 2.5 m girth (FRI, 1981; Troup, 1921). Wood is very durable and used in construction work, decorative paneling and as air craft plywood (Nair *et al*., 2004).

Gluta travancorica of Anacardiaceae family commonly known as Indian Red Wood is a canopy tree grows up to 35-40 m height with 4.5-5 m girth and endemic to Southern Kerala in wet evergreen forests (600-1400 m). The Wild Life Sanctuary, Shenduruni, in Kollam District is named after the tree. As per IUCN (2014), it is a threatened species. Timber is highly merchantable and used in ship building, furniture and turnery in carving industries (Trivedi Babu, 1991; Jose, 2001; Jose & Pandurangan, 2013). *S. cumini* is a large evergreen tree of Myrtaceae and grows to 30 m height. They are rich in volatile oils and used as medicinal. Fruits used as edible and traditional medicines in divergent ethno-botanical practices (Mahmoud *et al*., 2001; Reynertson *et al*., 2005). Wood is durable and water resistant hence used in railway sleepers. Different parts of the tree are reported for its antioxidant and anti-microbial activities (Chandrasekaran &Venkatesalu, 2004; Reynertson *et al*., 2005; Sagrawat *et al*., 2006; Veigas *et al*., 2007). *S. travancoricum* of Myrtaceae is a critically endangered evergreen tree endemic to Southern Western Ghats (IUCN, 2014). It is a dominant tree species of the unique wetland ecosystems like Myristica swamps grows up to 25 m height and plays a critical role in water storing and maintaining ground water level (Roby and Joyce Jose, 2007). The species is found in a few sacred grove in Thiruvananthapuram, Kollam, Pathanamthitta, Alappuzha, Ernakulam and Thrissur districts of Kerala (Sasidharan, 2006). The tree population has declined considerably because of over-exploitation (logging and wood harvesting) and habitat degradation (Nair *et al*., 2007). Similarly, regeneration appears to be very poor (Roby *et al*., 2013).

The project has the following specific objectives.

- To classify seeds of selected evergreen species into various storage physiology categories.
- To develop protocols for seed handling.
- To study the shelf life of selected species under ambient and artificial storage environments.
- To collate information on silviculture and management of the species and prepare leaflets.

2. MATERIALS AND METHODS

The study included various aspects of seed handling of recalcitrant seeds in addition to their storage practices. The study was limited to aspects for which information was not fully available. List of the six species and their aspects studied are given in Table 1.

Table 1. Species and aspects studied for developing storage practices

Sl. No.	Species	Aspect studied				
		Collection method	**Processing technique**	**Pre-sowing treatment**	**Viability testing**	**Storage**
1	*Artocarpus hirsutus*	*	*	*	*	*
2	*Calophyllum inophyllum*	*	*	*	*	*
3	*Dysoxylum malabaricum*	*	*	*	*	*
4	*Gluta travancorica*	*	*	*	*	*
5	*Syzygium cumini*	*	*	*	*	*
6	*Syzygium travancoricum*	*	*	*	*	*

Various seed handling procedures were tested for selected species with reference to earlier studies (Chacko, 1981; Schmidt, 2000; Chacko *et al*., 2001; Chacko & Mohanan, 2002; Chacko *et al*., 2002; Nair *et al.*, 2002; ISTA, 2004). Methodology for the six species was dealt with in detail under sub-headings 2.1 to 2.4.

***2.1. Seed collection*:** Seed collection was done by plucking mature fruits directly from vigorously growing trees using pole (*A. hirsutus*, *C. inophyllum* and *D. malabaricum*) and shaking branches (*S. cumini* and *S. travancoricum*) with the help of a tree climber. In the case of *G. travancorica*, freshly fallen mature fruits were collected from the ground in cloth bags. Seeds of *A. hirsutus* were collected during May, 2011 and April, 2012 from Peechi in Thrissur District. Similarly, *C. inophyllum* from Palakkad during December 2011, *D. malabaricum* from Kummatti and Sholayar in Thrissur Dt., Kulathupuzha, Arippa and Rosemala in Kollam District during June-August 2010, 2011and 2012. Seeds of *G. travancorica* were collected from Rosemala and Rockwood in Shenduruney Wild Life Sanctuary during May- July 2010, 2011 and 2012, *S. cumini* from Peechi and Mulamkunnathukavu in Thrissur District during May 2010, 2011 and 2012. Seeds of *S. travancoricum* were from Chovannur in Thrissur District during May 2012. The fruits/seeds were transported to the processing centre immediately after collection.

2.2. Seed processing: Seed processing was done to get clean, pure seeds of high physiological quality which can be stored and easily handled during succeeding process. Following processing were carried out: i) Pre-cleaning: removed all non-seed material, ii) Seed extraction –soaked in water for a while, and then macerated and washed (*S. cumini* & *S. travancoricum*). Similarly, seed extraction was done for *D. malabaricum* by split open the fruits using a sharp knife. iii) De-pulping: removed pulp from seeds (*A. hirsutus*, *S. cumini* & *S. travancoricum*), iv) De-coating:

seed coat of *D. malabaricum* and *C. inophyllum* were carefully removed using knife, v) Cleaning – removed remaining inert material to make sure viable seed lot, vi) Grading – removed low quality seeds to improve the average physiological quality, and vii) Determined seed moisture content (MC %) by oven-dry method as per the ISTA rules using the following formula:

$$MC\ \% = \frac{\text{Fresh weight} - \text{Oven dry weight}}{\text{Fresh weight}} \times 100$$

Seed drying: High moisture content of seeds creates ideal environment for infestation of mycoflora (fungi & bacteria). Recalcitrant seeds pose a problem as they are intolerant to desiccation. Seeds with high MC are more prone to heat damage; hence, direct sun-drying was avoided. Seeds were dried to the lowest possible MC % level (lowest safe moisture content, below which desiccation damage occurs) under open desiccation (spreading out seeds on concrete floor and dried by air circulation using fan) for safe storage and maintenance of viability. The seeds were treated with systemic fungicide (Captan 50% WP @ 4 g/kg) to prevent fungal infection (Chacko, 2009).

2.3. Viability: Seed viability indicates the potential germinability of seeds which, with proper handling should reflect expected germination in the nursery (ISTA, 1993). Germination test was conducted for assessing seed quality: ability of seeds to germinate under optimal germination condition - temperature, moisture and light. Fresh seeds were tested for viability through germination trials in the laboratory. Sterilized vermiculite was used as germination medium. Daily observations were recorded up to the culmination of seed germination.

2.4. Seed storage: Open desiccated seeds of each species were kept under different storage conditions to evaluate seed longevity and standardize the best for extending their shelf life. Optimal storage environment (temperature & humidity) is important for maintaining seed viability over a prolonged period. Open desiccated seeds of each species were stored under following conditions:

Artocarpus hirsutus: i) Ambient temperature (room temperature - about 32 ^{o}C) in polythene bag (T0 – control), ii) earthen pot kept inside wet vermiculite at 16 ^{o}C (T1), and iii) same container and medium as T1 at ambient temperature (T2).

Calophyllum inophyllum: i) Ambient temperature in polythene bag (T0), and ii) seeds in earthen pot kept in wet vermiculite at 20 ^{o}C (T1).

Dysoxylum malabaricum: i) Seeds with seed coat in open tray at ambient (T0), ii) de-coated seeds in open tray at ambient (T1), iii) de-coated seeds in cotton bag (Cora cloth) at ambient (T2), iv) seeds with seed coat in same container as T2 at 4 ^{o}C cold storage (T3), v) de-coated seeds in same container as T2 at 4 ^{o}C cold storage (T4), vi) wax (Paraffin wax) coated seeds in cotton bag (Cora cloth) in saw-dust at 4 ^{o}C (T5), vii) tied fruits (fruit tied with GI wire) in saw-dust at 4 ^{o}C cold storage (T6), viii) tied fruits in cotton bag at 4 ^{o}C cold storage (T7), ix) wax coated seeds in cotton bag in saw-dust at ambient (T8), x) de-coated seeds in earthen pot kept inside wet vermiculite at 20 ^{o}C (T9), and xi) de-coated seeds in similar container of T9 at ambient temperature (T10). Cotton

bag was made of Cora cloth; wax coating was done by seeds dipped in melted paraffin wax; tied fruits were prepared for the trial by tying the fruits with GI wire to prevent split open the fruit and seed moisture loss.

Gluta travancorica: i) Polythene bag at ambient temperature (T0), ii) polythene bag at 16 ^{o}C (T1), iii) cotton bag inside sawdust at 16 ^{o}C (T2), vi) wax coated seeds in polythene bag inside sawdust at ambient (T3). Fruit as such used as disseminating unit; hence it called as seed.

Syzygium cumini: i) Single polythene bag at ambient (T0), ii) single polythene bag at 4 ^{o}C (T1), iii) double polythene bag at 4 ^{o}C (T2), iv) cotton bags at 4 ^{o}C (T3), v) single polythene bag inside sawdust saw dust at 16 ^{o}C (T4), vi) single polythene bag inside sawdust at ambient (T5), vii) earthen pot at 16 ^{o}C (T6), and viii) earthen pot at ambient (T7).

Syzygium travancoricum: i) single polythene bag at ambient (T0), ii) earthen pot kept in bucket filled with wet vermiculite at 20 ^{o}C (T1), and iii) earthen pot kept in bucket filled with wet vermiculite at ambient (T2).

Relative humidity (RH) of the cold rooms were maintained as 45 per cent using dehumidifier. Earthen pots were closed with cotton cloths. Representative seed samples were drawn periodically from each treatment and subjected for viability test. Seed longevity was assessed in terms of germination test. This process was continued up to the seeds became fully non-viable (zero per cent germination).

3. RESULT AND DISCUSSION

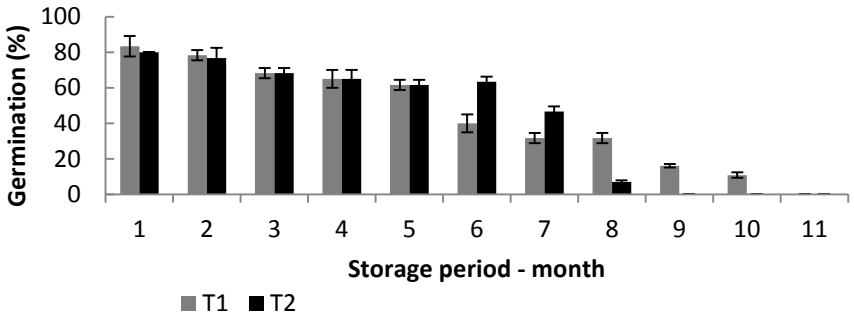
3.1. Artocarpus hirsutus

Study indicated that the optimum time for seed collection is when the fruit attains greenish-yellow (maturity index). Trees in open with fully exposed crown bear more fruits and mature fruits are available during May-June. Moisture content (MC) of the fresh seed was 49.99 per cent and the lowest safe moisture content could be brought down to 40 per cent, which helped to maintain viability under lower temperature (16 ^{o}C). Earlier study reported that seeds of *A. hirsutus* lose their viability if MC drops below 33 per cent due to its recalcitrant nature (Chacko, 2009). Weight of the de-pulped seeds was within the range of 2200-2300 seeds per kg.

3.1.1. Seed viability: The fresh de-pulped seeds commenced its germination 11 days after sowing (DAS) and continued up to 18 days with an average of 88 per cent cumulative germination. In an earlier study by Chacko (2009) reported that de-pulped seeds of *A. hirsutus* starts germination 12 DAS and ends in 60 days with 92 per cent cumulative germination. Previous studies reported 71-80 per cent seed germination for the species (Gopikumar & Mahato, 1993; Kader *et al*., 1999). In the present study, seeds desiccated to the critical moisture content (CMC – 40 %) had 97 per cent germination. Hence, reducing moisture level of the seeds of *A. hirsutus* up to 40 per cent is suggested for higher germination.

3.1.2. Seed storage and longevity: Germination pattern of seeds under different storage conditions is depicted in Figure 1. Seeds maintained their viability only up to three weeks under normal

condition. Earlier study shows that under normal condition seed viability loses within 2-3 weeks (Chacko, 2009). Seeds stored in earthen pot that kept inside wet vermiculite at 16 ^{o}C (T1) could maintained their viability up to 10 months. In such a condition, seed viability was 32 per cent during 8 months of storage. Thereafter, it decreased to 11 % at the end of 10th month. Whereas, seeds under T2 condition (seeds in earthen pot inside wet vermiculite at ambient temperature), maintained their viability up to 8 months. Study showed that the best storage condition for maximizing seed longevity of *A. hirsutus* is the earthen pot inside wet vermiculite at 16 ^{o}C. Storage condition for maximizing shelf life of another species in the same genus, *A. heterophyllus* is 11-13 ^{o}C with 85-90 % RH (Singh, 1972). Haq (2006) in his monograph on *A. heterophyllus* reported that it has a short viability period (3-10 days) under normal condition.



T1 = Earthen pot inside wet vermiculite at 16 ^{o}C; T2 = same container of T1 at ambient temperature

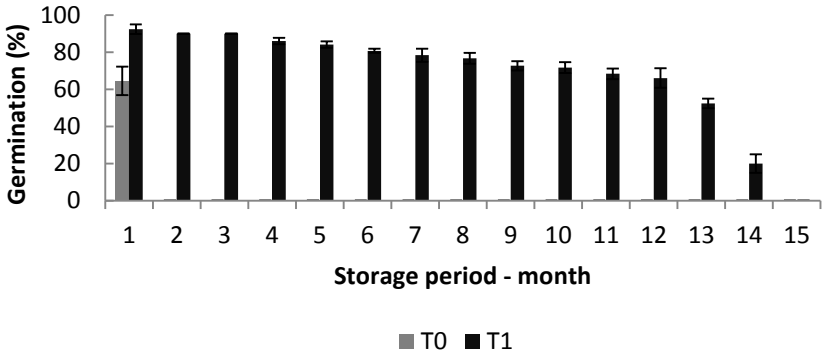
Fig. 1. Germination pattern of *A. hirsutus* seeds under storage conditions

3.2. Calophyllum inophyllum

Maturity index for seed collection is when fruits attain greenish-yellow. Fully matured fruits are available during December-January. Generally, 7 to 8-year-old tree begins to flower, it occurs twice a year (April-May & August-September) and fruits attain maturity within 3-4 months (Kumaresan, 2001; Prabakaran & Britto, 2012). Seed weight was 135-215 seeds per kg. It is a single seeded fruit. De-coating helped to improve seed germination (>90 %); hence, it is a pre-sowing treatment for enhancing seed germination. The thick leathery fruit wall delays seed germination due to mechanical dormancy. Kadambi (1957) referred in his article that removal of seed coat is effective for early and improved seed germination of *C. inophyllum*. Similarly, Gunaga *et al*. (2011) also reported that the de-coated seeds of *C. inophyllum* have quick germination than that of seeds with seed coat and found 96 per cent germination. Moisture content of the fresh seed was 56.34 per cent and the lowest safe moisture content was 44 per cent, which helped to maintain viability under lower temperature (16 ^{o}C). Seed viability was very much decreased with desiccation, i.e., <30 % MC, as reported earlier in *Hopea ponga* and *Azadirachta indica* (Muralikrishna & Chandrashekar, 1997; Nayal *et al*., 2000). The lowest safe MC maintained during storage in earthen pots that kept in bucket filled with wet vermiculite at 20 °C.

3.2.1. Viability: Viability of the fresh de-coated seeds was tested through germination trial in the laboratory and had an average of 94 per cent germination. Prabakaran and Britto (2012) also reported more or less similar result for the species. Seed germination in this study commenced from 18 DAS and culminated in 81 days as reported in earlier studies by Kumaran *et al*. (1998) and Gupta *et al*. (2009).

3.2.2. Seed storage: Germination pattern of the seeds under storage condition showed that viability of seeds could maintain only up to one month with 64.44 per cent germination under ambient condition (Fig. 2). However, seeds stored under T1 condition (seeds in earthen pot kept inside wet vermiculite at 16 ^{o}C) maintained their viability up to 14 months with an average of 20 per cent germination. Study revealed that the best storage condition for *C. inophyllum* is the T1. Hathurusingha and Ashwath (2012) reported in their study that more than 70 per cent of *C. inophyllum* seeds maintained viability for more than eight months in warm (25−30 °C) and humid environments. Seeds of *C. inophyllum* lost viability due to its recalcitrant nature as reported earlier (Hathurusingha & Ashwath, 2012). However, Prabakaran and Britto (2012) stated that seeds of the species have intermediate nature. The present study revealed that *C. inophyllum* seeds are vulnerable to chilling injury, hence, unsuited for cold storage. *C. inophyllum* seeds maintained their viability for an appreciable period if stored in warmer environments.



T0 = Polythene bag under ambient temperature; T1 = Earthen pot kept inside wet vermiculite at 16 ^{o}C

Fig. 2. Germination pattern of *C. inophyllum* seeds under storage conditions

3.2.3. Seed longevity: Figure 2 depicts the seed longevity of *C. inophyllum* under storage at an interval of one month. Seed longevity is the time lag between seed collection and the time up to which seeds remain fit for germination. Generally, seeds of *C. inophyllum* lose viability under storage due to their oily nature (Nair, 2000). Result of the study indicated that seeds kept under T0 maintained viability only for one month with an average, 68 per cent of the viability of fresh seeds. But in the seeds stored under T1, maintained 98 per cent of the viability of fresh seeds at the end of first month storage. It gradually decreased to 55 per cent during 13th month and further reduced to 21 per cent at 14th month. Previous studies reported that seeds of *H. parviflora* extend viability up to 40 days when stored in mud pot at 10 °C and *A. indica* in sealed container at 15 °C (Sunilkumar & Sudhakara, 1998; Nayal *et al*., 2000). Gupta *et al*., (2009) noticed the seeds of *C.*

inophyllum wrapped in moist paper towels in plastic box at 4-10 °C maintain viability up to four months. Another report showed that seeds of *Calamus longisetus* maintain viability for eight months when stored in polythene bags kept in sack filled with saw-dust at 4 °C (Pillai & Menon, 2011). The present study showed that seeds of *C. inophyllum* have higher MC at the time of harvest and are intolerant to desiccation as reported by Hathurusingha and Ashwath (2012); hence they are highly recalcitrant (CABI, 1998). The most effective storage condition for the seed is storage in earthen pot kept in bucket filled with wet vermiculite at 20 °C. Ultimately, the study helps to the production of planting stock as and when required.

3.3. *Dysoxylum malabaricum*

Trees flowered from February to April and the fruits were matured during June-August as reported earlier (Anon, 1981). Maturity index for seed collection was bright yellow fruits having longitudinal fissures. Seeds exposed from the fruit were consumed by wild animals and birds, mainly Malabar giant squirrel, Hornbills, monkeys, porcupines, etc. as reported earlier (Anon, 1981). Similarly, seeds fallen on the forest floor were also infested by Dipteran pest. Therefore, seeds should be collected directly from trees when the above mentioned maturity index appears. Average number of fruits was seven per kg and about 3-7 seeds were found in each fruit. Twenty five seeds were in one kilogram of fruits. Seed weight was 125-130 seeds per kilogram. Moisture content (MC %) of the fresh seed was 55.46 per cent, which indicate the recalcitrant nature of the seeds as reported in earlier study by Chacko (2009). The high moisture content of seeds susceptible to the infestation of fungi and bacteria. Because of the higher moisture level, the seeds are more prone to heat damage when they dry under direct sun. They are intolerant to desiccation and affected seed viability below the lowest possible moisture level. The lowest possible moisture level is about 45 per cent for retaining seed viability (Fig. 3).

Seed germination was decreased with desiccation as reported earlier in *Hopea ponga* and *Azadirachta indica* (Muralikrishna & Chandrashekar, 1997; Nayal *et al*., 2000). The lowest safe moisture content was maintained during storage in earthen pot kept in bucket filled with wet vermiculite at 20 °C, and in the same type of container and medium at ambient temperature.

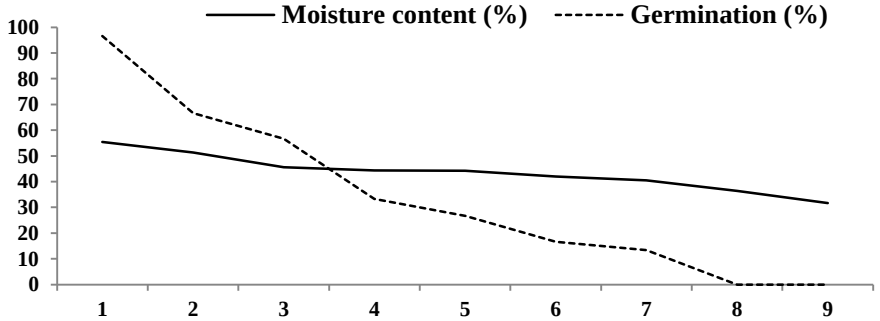


Fig. 3. Optimization of moisture content

The de-coated fresh seeds had higher viability (96.63 ± 0.06 % germination); whereas, seeds with seed coat had poor germination (16.67 ± 2.35 %). Similarly, the de-coated seeds commenced their germination from 14 DAS and it culminated at 45 days and the seeds with seed coat initiated germination only from 34 DAS and continued up to 113 days. The result indicated that de-coating is the most effective pretreatment for enhancing seed germination. In an earlier report says that germination of fresh de-coated seeds starts with 13 DAS (Chacko, 2009).

De-coating helped to avoid chemical inhibitors present in seed coat, which inhibits seed germination (McCormack, 2004). Removal of dark brown fleshy seed coat also helped to avoid fungal infestation while storage. Similar results were reported in *Garcinia gummi-gutta*, *Osyris lanceolata* and *Syzygium cumini* (Chacko & Pillai, 1997; Mwang' ingo *et al*., 2004; Sivasubramaniam & Selvarani, 2012).

3.3.1. Seed storage: Viability of seeds under storage conditions is given in the Table 2. Due to the recalcitrant nature, seeds lost viability within one week under normal condition. According to Chacko (2009), seeds of *D. malabaricum* are recalcitrant and hence lose viability rapidly under ambient as well as low temperature. The present study showed that seeds with seed coat in open tray (T0) and de-coated seeds in cotton bag (T2) at ambient temperature lost their viability within a week. Similarly, seeds with seed coat in cotton bag at 4 ^{o}C (T3) and tied fruits (with GI wire) in saw-dust at 4 ^{o}C (T6) were also became non-viable at the end of first week. De-coated seeds stored in open tray under ambient temperature (T1) and in cotton bag at 4 ^{o}C (T4) maintained viability for two weeks. Tied fruits in cotton bag at 4 ^{o}C cold (T7) maintained seed viability up to six weeks; however, seed germination was minimal. Wax-coated seeds in cotton bag inside saw-dust at 4 ^{o}C (T5) and at ambient temperature (T8) maintained their viability up to 8 and 12 weeks respectively with minimal germination. De-coated seeds in earthen pot kept inside wet vermiculite at ambient (T10) maintained their viability up to 12 weeks. Similarly, De-coated seeds in earthen pot inside wet vermiculite at 20 ^{o}C (T9) also maintained their viability up to 12 week with a better performance than T10.

Saw dust and vermiculite used as storage medium for regulating the seed moisture. It is inferred that T9 and T10 are suitable seed storage condition for *D. malabaricum* and among them T9 is the best one. Chacko (2009), in his study reported that seeds of *D. malabaricum* retained their viability only for about two weeks under ventilated ambient condition.

3.3.2. Seed longevity: The study indicated that shelf life of *D. malabaricum* seeds can be extended up to 12 weeks (about 38 % of the original viability) under T9 condition (storage of de-coated seeds in earthen pot inside wet vermiculite at 20 ^{o}C). However, seeds stored at ambient condition could not maintain viability even for a week. Earlier studies reported that shelf life of *Hopea parviflora* seeds can be extended up to 40 days with 87 per cent germination when stored in mud pots at 10 °C and *Azadirachta indica* in sealed container at 15 °C (Sunilkumar & Sudhakara, 1998; Nayal *et al*., 2000). Another study revealed that seeds of *Calamus longisetus* maintained viability up to eight months with more than 70 per cent germination when stored in polythene bag inside saw-dust at 4 °C (Pillai & Menon, 2011).

The present study revealed that de-coating can improve germinability of seeds of *D. malabaricum*. Since the seeds are recalcitrant, they intolerant to desiccation (ISTA, 1996). The effective method for prolonging seed longevity is storage in earthen pot inside wet vermiculite at 20 °C.

Table 2. Seed germination of *D. malabaricum* under different storage conditions (mean ± se)

Storage duration (week)	Storage condition						
	T1	T4	T5	T7	T8	T9	T10
1	35.00 ± 1.67	10.00 ± 0.55	13.00 ± 0.58	8.00 ± 0.26	14.89 ± 0.51	87.67 ± 2.52	55.00 ± 5.00
2	10.00 ± 0.56	9.72 ± 0.35	11.00 ± 0.58	6.13 ± 0.50	13.89 ± 0.51	83.33 ± 2.89	49.33 ± 1.15
3	0.00	0.00	10.22 ± 0.84	6.00 ± 0.50	13.78 ± 0.39	76.67 ± 2.89	42.00 ± 5.29
4	0.00	0.00	9.22 ± 0.19	5.00 ± 0.50	12.89 ± 0.77	71.67 ± 2.89	33.33 ± 2.89
5	0.00	0.00	10.22 ± 1.17	5.00 ± 0.50	9.55 ± 1.35	67.67 ± 2.52	32.33 ± 2.52
6	0.00	0.00	10.55 ± 0.69	4.77 ± 1.26	7.55 ± 0.39	66.00 ± 1.73	30.00 ± 2.00
7	0.00	0.00	9.55 ± 0.39	0.00	6.11 ± 0.69	62.33 ± 2.52	34.00 ± 1.73
8	0.00	0.00	3.33 ± 0.25	0.00	9.44 ± 0.51	60.67 ± 1.15	29.33 ± 1.15
9	0.00	0.00	0.00	0.00	7.33 ± 1.00	57.67 ± 2.52	28.67 ± 1.15
10	0.00	0.00	0.00	0.00	3.66 ± 0.58	50.67 ± 1.15	27.67 ± 2.52
11	0.00	0.00	0.00	0.00	4.63 ± 0.61	43.33 ± 2.89	19.33 ± 1.15
12	0.00	0.00	0.00	0.00	3.33 ± 0.21	37.00 ± 1.00	11.67 ± 2.89
13	0.00	0.00	0.00	0.00	0.00	10.00 ± 0.65	0.00
14	0.00	0.00	0.00	0.00	0.00	0.00	0.00

***Note**: T1 = De-coated seeds in open tray at ambient; T4 = De-coated seeds in cotton bag at 4 ºC cold storage; T5 = Wax coated seeds in cotton bag in saw-dust at 4 ºC cold storage; T7 = Tied fruits in cotton bag at 4 ºC cold storage; T8 = Wax coated seeds in cotton bag in saw-dust at ambient; T9 = De-coated seeds in earthen pot kept in bucket filled with wet vermiculite at 20 ºC; T10 = same container at ambient.*

T0 (Seeds with seed coat in open tray at ambient temperature); T2 (De-coated seeds in cotton bag at ambient); T3 (Seeds with seed coat in cotton bag at 4 ºC cold storage); T6 (Tied fruits in saw-dust at 4 ºC cold storage) did not show any positive results and hence were not included in the table)

3.4. Gluta travancorica

The tree flowers during February-May and the fruits mature from May to July as reported earlier (Anon, 1981). Fruit size was 3.3-4.0 cm in diameter and 2.5-3.0 cm in length and 55-65 seeds weighed a kilogram. Moisture content of the fresh seeds was about 47 per cent and the lowest moisture content suitable for storage was 38 per cent and it was maintained during storage in polythene bag inside saw-dust at 16 °C temperature. Viability of the fresh seeds was very good with an average of 99.7 per cent germination. Germination of the fresh seeds commenced from 18

DAS and continued up to 143 days. Whereas, in the earlier report fresh seeds have 92 per cent germination and it starts with 24-38 DAS (Chacko, 2009).

3.4.1. Seed storage and longevity: Viability of seeds under storage is given in Table 3. Viability of the seeds stored in cotton bag inside sawdust at 16 ^{o}C temperature (T2) was maintained up to 20 months. Average seed germination at the end of second month was about 98 per cent. It was gradually decreased to 23 per cent at 18th month and 6 per cent at 20th month. Similarly, 92 per cent germination was obtained during second month under T1 condition (seeds in polythene bag at 16 ^{o}C) and it decreased to 12 and 6 per cent during 16 and 18 months of storage. In the case of seeds stored under T0 condition (Seeds in polythene bag at ambient temperature), 87 per cent germination during second month and decreased to 24 per cent at the end of 8 month, thereafter lost their viability. Germination of the seeds stored under T3 condition (wax-coated seeds in polythene bag inside sawdust at ambient) was 64 and 23 per cent during second and fourth month, thereafter lost their viability. Seeds of *G. travancorica* are reported to be recalcitrant and lose their viability within a month under natural conditions (Jose & Pandurangan, 2003). Chacko (2009) reported in his study that seeds of *G. travancorica* can be stored in ambient conditions up to 3½ months without significant loses of viability. In an another study, seeds stored in closed polycarbonate bottle under warm-humid condition (20 ^{o}C with 40 % RH) enabled to prolong their viability up to 17 months with 25 per cent germination (Jose & Pandurangan, 2013). Although the tropical recalcitrant seeds may be stored only for short periods (Bonner, 1990), the present study revealed that viability of the seeds of *G. travancorica* can be maintained up to 20 months under suitable storage conditions like seeds in cotton bag inside sawdust at 16 ^{o}C temperature.

Table 3. Seed germination of *G.travancorica* under different storage conditions (mean ± se)

Storage period (month)	Storage condition			
	T0	T1	T2	T3
2	87.33 ± 1.15	91.67 ± 1.53	98.33 ± 0.58	63.67 ± 0.58
4	75.33 ± 3.06	83.89 ± 2.46	96.33 ± 1.53	23.33 ± 1.15
6	60.77 ± 1.33	74.06 ± 2.55	95.61 ± 1.84	0.00
8	23.67 ± 1.53	62.89 ± 3.42	94.97 ± 1.00	0.00
10	0.00	54.56 ± 2.36	92.97 ± 2.63	0.00
12	0.00	43.06 ± 2.43	86.76 ± 1.56	0.00
14	0.00	34.06 ± 0.63	66.76 ± 1.56	0.00
16	0.00	12.39 ± 0.92	46.42 ± 1.41	0.00
18	0.00	3.06 ± 2.02	23.09 ± 1.14	0.00
20	0.00	0.00	6.42 ± 1.51	0.00
22	0.00	0.00	0.00	0.00

Note: T0 = Polythene bag at Ambient; T1 = Polythene bag at 16 ^{o}C: T2 = cotton bag inside saw dust at 16 ^{o}C; T3 = wax-coated seeds in polythene bag inside sawdust at ambient

3.5. Syzygium cumini

Seeds directly collected from the trees were devoid of pest infestation. Hence, collection of fruits from tree is advisable for getting pest free seeds. Earlier study reported that seed viability of *S.*

cumini significantly higher when fruits plucked from the trees than in fallen fruits (Radhamani *et al*., 2005). Fully matured fruits are available during April-May as reported by Rai (1978 & 1985). About 700-750 seeds weigh (fresh de-pulped seeds) in one kilogram. Moisture content of fresh seeds was 55.35 per cent. The lowest safe moisture level of the seeds was 40 per cent and it maintained during storage in earthen pot at 16 ^{o}C. Freshly collected seeds had higher viability with 97.77 per cent germination under laboratory condition. More or less similar result reported by Abbas *et al*. (2003). However, Rai (1985) reported only 60 per cent germination for fresh seeds of the species. Seed germination commenced 13 DAS and culminated at 60 days. Since the species is highly recalcitrant, its viability loses drastically while desiccate below 35 per cent MC as reported by Chacko (2009). Other studies also stated that seeds of *S. cumini* are desiccation sensitive and exhibit recalcitrant behavior (Patil *et al*., 1997; Schmidt, 2002; Abbas *et al*., 2003; Baxter *et al*., 2005). However, Anandalakshmi *et al*. (2005) reported that seeds of *S. cumini* are found to be tolerant to desiccation up to 10% moisture content.

Seed storage and longevity: Viability of seeds under storage is given in Table 4. Seeds stored in double polythene bag at 4 ^{o}C (T2) lost their viability within one month. Whereas, seeds in single polythene bag inside saw-dust at ambient temperature (T5) maintained 25 per cent of the viability of fresh seeds. Seeds in single polythene bag at ambient temperature (T0) and at 4 ^{o}C (T1) maintained viability up to two months with 24 and 13 per cent viability of fresh seeds. Similarly, seeds in cotton bags at 4 ^{o}C (T3), single polythene bag inside saw-dust at 16 ^{o}C (T4) and earthen pot at ambient (T7) maintained viability up to three months with 15, 14 and 6 per cent respectively. However, seeds stored in earthen pot inside saw-dust at 16 ^{o}C (T6) maintained 56 per cent viability of fresh seeds at the end of first month and gradually decreased to 11 per cent at 6 months after storage. The study indicated that T6 is the most suitable storage condition for extending shelf life of seeds. According to Rai (1985), under ambient condition seeds of the species maintain their viability only for 15-30 days. Another study by Anandalakshmi *et al*. (2005) reported that 15 to 20 °C is the favourable temperature for seed storage of *S. cumini*. Similarly, they stated that seeds of *S. cumini* are able to prolong their viability when stored in polythene bag under 20 °C. However, Stephen *et al*. (2012) reported that seeds of *S. cumini* stored at low temperature maintained viability for 127 days. Patil *et al*. (1997) also reported that *S. cumini* seeds remain viable when stored at 5-8 °C. Pushpkar and Babeley (2001) reported in their study that viability of *S. cumini* seed maintains in sealed glass bottle under room conditions. Radhamani *et al*. (2005) stated that seeds of *S. cumini* maintain their viability at 15 °C for a long period. However, their viability lost within 8 days at ambient temperature. They also reported that the maximum retention of viability is recorded in plastic petri dishes with perforated covers (84 %), followed by perforated polythene bags (78 %). Murthy and Singh (2009) stated that lifespan of S. *cumini* seeds can be increased by subjecting to various treatments, such as PEG 6000, ABA, KNO_3, coating with charcoal, etc. and then store at 20 ± 2 °C. These treatments, probably be switched off germination processes and/or induced dormancy (Kermode, 1990). The present study could extend shelf life of the seeds of *S. cumini* up to six months when they stored in earthen pot at 16 ^{o}C.

Table 4. Seed germination of *S. cumini* under different storage conditions (mean ± se)

Storage period (month)	Storage condition						
	T0	**T1**	**T3**	**T4**	**T5**	**T6**	**T7**
1	34.16 ± 3.19	26.58 ± 0.16	35.00 ± 1.92	40.83 ± 1.67	24.16 ± 3.19	54.75 ± 1.45	29.25 ± 0.96
2	23.33 ± 3.85	12.58 ± 1.73	24.16 ± 1.67	20.83 ± 1.67	0.00	29.17 ± 1.67	25.83 ± 0.96
3	0.00	0.00	15.00 ± 1.92	14.08 ± 0.69	0.00	24.00 ± 0.67	5.58 ± 0.78
4	0.00	0.00	0.00	0.00	0.00	19.83 ± 0.69	0.00
5	0.00	0.00	0.00	0.00	0.00	10.25 ± 0.50	0.00
6	0.00	0.00	0.00	0.00	0.00	10.25 ± 0.50	0.00
7	0.00	0.00	0.00	0.00	0.00	0.00	0.00

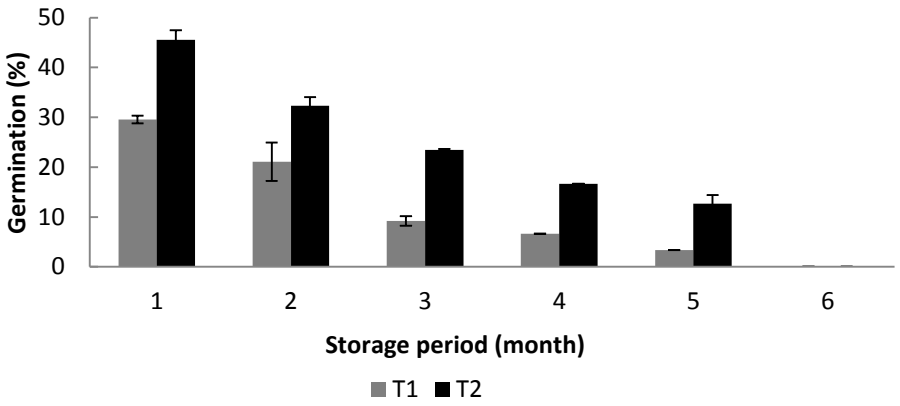
***Note**: T0 = Seeds in single polythene bag at ambient temperature; T1 = Seeds in single polythene bag at 4 °C; T3 = Seeds in cotton bags at 4 °C; T4 = Seeds in single polythene bag inside saw-dust at 16 °C; T5 = Seeds in single polythene bag inside saw-dust at ambient; T6 = Seeds in earthen pot inside saw-dust at 16 °C; T7 = Seeds in earthen pot at ambient temperature*

T2 (Seeds in double polythene bag at 4 °C) did not show any positive results and hence not included in the table

3.6. Syzygium travancoricum

Mature fruits are available during May-June as reported by Subramanian *et al*. (1987). Pest infestation was minimum on seeds, which directly collected from trees. Hence, collection of fruits from tree is advisable for getting pest free seeds. Number of de-pulped fresh seeds weighed in one kilogram is about 12,500-12,600. Moisture content of the processed seed was 45 per cent and the lowest safe moisture level of the seeds was 38 per cent, it maintained till five months during storage in earthen pot kept inside wet vermiculite at ambient temperature. Viability of fresh seed was medium with about 58 per cent germination under laboratory condition. Seeds commenced its germination from 4 DAS and continued up to 41 days. Earlier study also reported an average of 50% seed germination for the species (Subramanian *et al*., 1987).

Seed storage and longevity: Viability of seeds stored under different conditions is depicted in Figure 4. Seeds stored in single polythene bag under ambient condition lost their viability within one month. Seeds in earthen pot kept inside wet vermiculite at 20 °C (T1) and at ambient temperature (T2) maintained their viability up to five months. However, seeds stored under T2 condition maintained about 79 per cent of the viability of fresh seeds at the end of first month and gradually decreased to 22 per cent during fifth month. The study revealed that T2 is the most suitable storage condition for extending shelf life of the seeds of *S. travancoricum*.



Note: *T1= Seeds in earthen pot inside wet vermiculite at 20 °C; T2 = Seeds in earthen pot inside wet vermiculite at ambient*

Fig. 4. Germination of *S. travancoricum* under storage condition

Generally, seed source selection, right stage for seed collection, processing, pre-treatment and storage are significant for efficient utilization of the seeds of any species and each stage is equally important. To avoid detrimental genetic effects in seed collection the following measures were considered. i) Prefer stands with heavily fruiting trees in close proximity to each other, ii) within the preferred stand, collect from at least 15 trees which are preferably at least 100 m apart, and iii) collect from vigorous trees of good form as reported in earlier work by Chacko *et al*. (2002). Seeds should collect during large quantity of viable seeds available on trees (peak fruiting period). Usually, during this period most fruits and seeds will be matured. Early or late fruiting preceding an early or late flowering can have the high risk of self-pollination and inbreeding (Chacko *et al*., 2002). Further, fruits with small or underdeveloped seeds are likely to mature or dehisce more quickly than those with normally developed seeds. Consequently, the early part of seed crop is often of poor physiological and genetic quality and should be avoided.

Maturity index of fruits/seeds is significant for seed collection and other handling procedures. Determination of the best collection time is pre-supposes knowledge of structural changes in fruits and seeds during the latter part of the maturation period. Maturity indices vary with species. Fruit colour changes from green to yellow was the optimum maturity for the collection of *A. hirsutus*. Similarly, fruits attain greenish-yellow for *C. inophyllum* and bright yellow fruits having longitudinal fissures for *D. malabaricum* were the maturity indices for the respective species. Seed processing and pre-treatment is important in seed handling for improving seed germination and it is varied in each species. Seed processing will help to get clean, pure seeds of high physiological quality, which can be stored and easily handled during succeeding process, such as pretreatment, and sowing. De-pulping of *A. hirsutus, S. cumini* and *S. travancoricum* helped to improve their seed germination. Similarly, de-coating of seeds enhanced seed germination of *C. inophyllum* and *D. malabaricum*.

Moisture content (MC) of fresh seeds, critical moisture content (CMC), the best storage condition and viability period of the targeted species is given in Table 5. Species subjected for the present

study had higher MC. High moisture content creates ideal environment for infestation of mycoflora. Moist seeds respire that create heat and consume oxygen. If oxygen is depleted due to inadequate aeration, fermentation replaces respiration. Recalcitrant seeds pose a problem as they are intolerant to desiccation. They must be dried to the critical moisture level. Seeds with high moisture content are more prone to heat damage; hence, direct sun-drying was avoided and dried to the lowest possible MC level under open desiccation by air circulation using fan.

Table 5. Moisture content of fresh seeds, critical moisture content (CMC), the best storage condition and viability period of the targeted species

Sl. No.	Species	MC (%) of fresh seeds	CMC (%)	Viability period		The best storage condition
				Seeds stored under normal condition (control)	Seeds stored under the best storage condition	
1	*Artocarpus hirsutus*	49.99	40.00	Three weeks	10 months	EP inside wet vermiculite at 16 ^{o}C
2	*Calophyllum inophyllum*	56.34	44.00	One month	14 months	
3	*Dysoxylum malabaricum*	55.46	45.00	< one week	12 weeks	EP inside wet vermiculite at 20 ^{o}C
4	*Gluta travancorica*	47.00	38.00	Eight months	20 months	Cotton bag inside sawdust at 16 ^{o}C
5	*Syzygium cumini*	55.35	40.00	Two months	Six months	EP inside saw-dust at 16 ^{o}C
6	*Syzygium travancoricum*	45.00	38.00	< one month	Five months	EP inside wet vermiculite at ambient temperature

Note: *EP = earthen pot*

Seed storage is also vital, since it secure the supply of quality seeds for planting programmes as and when required. In seasonal climate with relatively short planting season, sowing time is normally determined by the wish to have plantable size seedlings at the beginning of planting season. Hence, seeds must often be stored during the period from harvest to sowing. To maintain viability over a prolonged period it is important that the optimal storage environment for the species is met, as far as possible. However, even under the best storage condition, some species will survive only for a very short period. Deterioration may be delayed by adopting the best possible storage conditions, but long term storage is not possible for recalcitrant seeds. The most suitable storage condition for *A. hirsutus* and *S. cumini* was seeds stored in earthen pot kept inside wet vermiculite/saw-dust at 16 ^{o}C. Similarly, the same type of container at 20 °C for *C. inophyllum* and *D. malabaricum* and ambient temperature for *S. travancoricum*. However, storage of seeds in cotton bag inside sawdust at 16 ^{o}C was the best condition for *G. travancorica*. The study revealed that longevity of recalcitrant seeds can be extended for 3-18 months if they stored under suitable storage conditions.

4. CONCLUSIONS

Investigation on storage practices in recalcitrant seeds concluded that the suitable storage condition is significant to extend viability period of seeds where it normally loses within a few days. It cater seed supply as and when required. Open desiccation of seeds to the lowest possible moisture level (critical moisture content) by air circulation using fan helped to maintain viability under storage. The critical moisture content was 40 per cent for *A. hirsutus* and *S. cumini*, 38 per cent for *G. travancorica* and *S. travancoricum*, 44 per cent for *C. inophyllum*, and 45 per cent for *D. malabaricum*. Optimal storage environment is required to maintain seed viability over a prolonged period. Even under the standardized storage condition, a few species responds only for a short period. However, long term storage is not possible for recalcitrant seeds. Effective storage container for *A. hirsutus*, *C. inophyllum*, *D. malabaricum*, *S. cumini* and *S. travancoricum* is the earthen pot, which kept inside a bucket filled with wet vermiculite/saw-dust. Similarly, the most suitable storage temperature is 16 ºC for *A. hirsutus*, *G. travancorica* and *S. cumini*, and 20 °C for *C. inophyllum* and *D. malabaricum* at 45±5% relative humidity. However, room temperature is suited for *S. travancoricum*. Maturity index is very much important for an effective seed collection and is different in each species. Maturity index can be determined by the change of fruit colour from green to yellow in *A. hirsutus*, greenish-yellow in *C. inophyllum* and bright yellow fruits with longitudinal fissures in *D. malabaricum*. Actual germination potential of seeds can be fully attained through pre-sowing treatments. De-pulping gave the best result in *A. hirsutus*, *S. cumini* and *S. travancoricum*. Similarly, de-coating was the most suitable pre-treatment for *C. inophyllum* and *D. malabaricum*.

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Artocarpus hirsutus Lam.

Taxonomy and nomenclature

Species: *Artocarpus hirsutus* Lam.

Family: Moraceae

Common names: Wild Jack fruit

Vernacular/Local name: Anjili, Ayiniplavu

Description: Tall evergreen tree attains 35-40 m height and 4.5 m girth, with a straight clean bole and dense foliage. Bark: dark grey, smooth with milky white latex. Young branch-lets covered with brown hairs. Leaves: simple, alternate, stipulate, petiolate, ovate or elliptical, margin entire in mature trees. Flowers: unisexual, minute and yellowish-green in colour. Male flowers are in axillary spikes and pendulous. Female flowers are in axillary ovoid spikes. Fruit: sorosis, globose or ovoid, covered with spines and turns yellow when ripe. Fruit contains numerous white ovoid seeds, measures about 16-18 mm long.

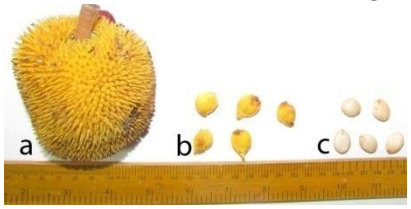
Distribution: The tree is endemic to Western Ghats mostly in evergreen and semi-evergreen forests, also in plains. It occurs throughout Kerala. The tree grows in altitudes ranging from sea level to 1000 m elevation with heavy rainfall.

Uses: Timber is hard and durable; hence, used for construction, furniture, boat-building, etc. Ripe fruit is sweet and edible. Seeds are also edible, usually fried as a snack.

Flowering and fruiting: Yellowish green axillary spikes appear from December. Fruit ripens during April-June. Mature yellow colored fruits are consumed by birds, squirrels, monkeys, etc.

Seed collection: Fruits are ready for collection from April-June. Seed can be collected either from trees or ground. It is advisable to collect them from ground, when they fall after ripening.

Seed extraction and processing: After collection, pulp should be removed from the seeds by rubbing with hand. Clean and dry them under shade before sowing.



a)Fruit b) seeds with pulp c) De-pulped seeds

Seed Weight: About 2200-2300 seeds weigh in one kilogram.

Seed dormancy and pre-treatment: Naturally, the seeds do not possess any dormancy; hence, no pretreatment required.

However, de-pulping enhances seed germination and it is better (92%) than seeds with pulp (67%) (Chacko, 2009).

Seed germination: Fresh de-pulped seeds are sown in germination trays contain vermiculite and watering regularly. Germination type is hypogeal. Seed germination commences 11 days after sowing and continues up to 18 days. Fresh seeds have 88±2.52 per cent germination. However, open desiccation of seeds up to 40 per cent moisture content has higher germination (97±3.56%). Soon after germination, the seedlings prick out and transplant in suitable containers (poly bags/root trainer). Longer polythene bags are used if the seedlings are to be maintained in nursery for longer periods (Chacko *et al*., 2002). Arrange poly-potted seedlings either under full sunlight or 50 per cent shade (shade net) in the nursery.

Seed storage and viability: Since the seeds are recalcitrant, they lose their viability under storage (CABI, 1998). Under ambient condition seeds remain viable for about three weeks. However, seeds maintain their viability up to 10 months if suitable storage condition is given like seeds storage in the earthen pot kept in wet vermiculite at 16^{o}C.

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Calophyllum inophyllum L.

Taxonomy and nomenclature

Species: *Calophyllum inophyllum* L.

Family: Clusiaceae/Guttiferae

Common names: Alexandrian laurel, Dilo oil tree

Vernacular/Local name: Punna

Description: Moderate sized evergreen swamp forest tree with 8-15 m height and 45 cm girth. Bark: dark brown or blackish and deeply fissured. Leaves: simple, opposite, estipulate, petiolate, lamina elliptic-oblong, obovate, base acute, glabrous, margin entire. Flowers: bisexual, white, fragrant, axillary racemes/racemose panicles. Peduncle is long and pedicel slender. Sepals 4, outer smaller, concave, inner longer, petalloid, reflexed with fine hairs. Petals 4, oblong and spreading. Stamens many, filamentous in 4 bundles, stigma large, mushroom shaped. Fruit: drupe, globose, 2.5-3.8 cm diameter, greenish, smooth, with scanty pulp.

Distribution: Distributed as paleotropics, and native from East Africa, southern coastal India to Malaysia and Australia. It is a characteristic species of the Littoral Forest where it occur in association with other species. In Kerala, the species is found along the backwaters and river banks.

Uses: Wood is fairly strong and used for beams, railway carriages and cabinet work. Decoction of flowers is given for venereal diseases. Seed oil is used in soap manufacture, illuminant, lubricant, healing agent. It has anti-neuralgic and antibiotic properties.

Flowering and fruiting: Generally, 7 to 8-year-old trees begin to flower. It flowers twice a year (April-May & August-September) and fruits mature within 3-4 months.

Seed collection: Maturity index is when fruits attain greenish-yellow colour and fully matured fruits are available during December-January. Fruit collection can be done either from tree or from ground after natural fruit fall.

Seed extraction and processing: Peel off (de-coating) the leathery fruit wall, since it is the best pre-sowing treatment for enhancing seed germination (Gunaga *et al.*, 2011). Open desiccate the de-coated seeds up to optimum moisture content (44%) for sowing or storage.

a) Fruit b) Seed (without fruit wall)
c) De-coated seed

Seed Weight: About 135-215 fruits weigh in one kilogram.

Seed dormancy and pre-treatment: Mechanical dormancy due to seed coat can be overcome by de-coating. De-coat the seeds by gentle tapping on seed coat with wooden stick or hammer very carefully.

Seed germination: Fresh seeds are sown in germination trays containing vermiculite and watering regularly. Germination type is hypogeal. Seed germination commences from 18 days after sowing and culminated at 81 days with an average of 94.44 ± 0.96 per cent germination.

Seed storage and viability: It loses viability on storage due to oily nature (Troup, 1921; Nair, 2000). Seeds maintain viability only up to one month under ambient condition. Seed viability can be extended up to 14 months by storing seeds in earthen pot kept inside wet vermiculite/saw-dust at 16^{o}C.

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Dysoxylum malabaricum Bedd. ex Hiern

Taxonomy and nomenclature

Species: *Dysoxylum malabaricum* Bedd. ex Hiern

Family: Meliaceae

Common names: White cedar

Vernacular/Local name: Vellakil

Description: Tree grows up to 35 m height with 2.5-3 m girth (Troup, 1921). Bark: greyish-yellow with warty lenticels, outer bark dead and corky. Leaves: compound, imparipinnate, leaflets 7-11, alternate, opposite or sub-opposite, apex acuminate, margin entire. Flowers: bisexual, greenish-yellow, fragrant, axillary panicles. Calyx: short, deeply 4 lobed. Petals: 4, linear-oblong, sub-acute. Anthers: 8, stigma capitates and 4 lobed. Fruit: capsule, bright yellow when ripe with 3-4 seeds. Seeds: trigonus, testa reddish-brown.

Distribution: Endangered evergreen trees endemic to Western Ghats and distributed in the evergreen forests from North Kanara southwards to Kerala. It also found in semi-evergreen forests.

Uses: Wood is durable, used in construction and decorative paneling. Wood oil is a remedy for ear and eye diseases and decoction of wood used for rheumatism (Nair *et al*., 2004).

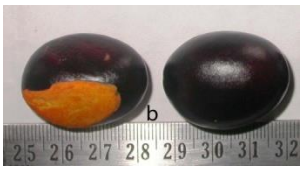
Flowering and fruiting: Flowering during February to April and fruits ripen from June to August.

Seed collection: Maturity index: bright yellow fruits having longitudinal fissures. Seeds exposed from the fruit usually consume by wild animals and birds, mainly Malabar giant squirrel, Hornbills, monkeys, etc. Similarly, seeds fallen on the forest floor will be infested by Dipteran pest. This accounts for marked paucity of natural regeneration (Anon, 1981; Troup, 1921). Hence, advisable to collect seeds directly from trees when the above mentioned maturity index appears. In order to maintain proper environment during transportation they should be transported in sack placed in cardboard box, which provide insulation and protection of its contents.

a) Fruit

Seed extraction and processing: Fruits split open and extract seeds soon after reaching the processing centre. Carefully remove seed coat (de-coating) using a sharp knife and treat with systemic fungicide (Captan) to prevent fungal infection. Moisture content of fresh seeds is 55

per cent. High seed moisture content create ideal environment for infestation of mycoflora. Because of the higher moisture level, the seeds are more prone to heat damage when dry under direct sun. They are intolerant to desiccation and affect seed viability below the critical moisture level. Hence, reduce MC to the lowest possible level (45%) under open desiccation.



b) Seeds with seed coat

c) De-coated seeds

Seed Weight: Average of seven fruits is weighed per kg and about 3-7 seeds in each fruit. Twenty five seeds are in one kilogram of fruits. Seed weight is 125-130 seeds per kilogram.

Seed dormancy and pre-treatment: De-coating help to avoid chemical inhibitors present in seed coat, which inhibit seed germination and to avoid fungal infestation while storage (Chacko & Pillai, 1997; Sivasubramaniam & Selvarani, 2012).

Seed germination: Fresh seeds are sown in germination trays containing vermiculite and water it regularly. Germination type is epigeal. Germination of de-coated seeds commences from 14 days after sowing and end at 45 days with an average of 97 per cent germination.

Seed storage and viability: Seeds lose their viability within one week under ambient condition. However, seeds storage in earthen pots kept inside wet vermiculite at 20°C maintain seed viability up to 12 weeks.

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Gluta travancorica Bedd.

Taxonomy and nomenclature

Species: *Gluta travancorica* Bedd.

Family: Anacardiaceae

Common names: Red-wood tree

Vernacular/Local name: Chenkurinji

Description: Evergreen tree attains 35-40 m height with 4.5-5 m girth. Bark: smooth, greyish-brown, blaze pink with black and acrid exudation. The plant may allergic and chemical irritation. Leaves: simple, alternate, estipulate, petiolate, glabrous, apex obtuse, margin entire, crowded at the tip of the branches. Flower: cream coloured, bisexual, arranged in axillary and terminal panicles. Fruit: brown colored drupe, woody, globose, tough and rough shell bearing single seed adherent to the pericarp. Fruit size is about 3.3-4.0 cm diameter and 2.5-3.0 cm in length.

Distribution: It is confined to the Southern Western Ghats in wet evergreen forests, over a limited area (600-1400 m). The Wild Life Sanctuary, Shenduruni, Kollam District is named after this tree - Chenkurinji. As per IUCN, it is a threatened species. In Kerala, it is reported in the Districts of Wayanad, Palakkad, Idukki, Kottayam, Kollam and Thiruvananthapuram.

Uses: Timber is highly merchantable and used in ship building, furniture and turnery in carving industries.

Flowering and fruiting: Flower during February-May and ripened fruits available during May-July.

Seed collection: Mature fruits can be collected either from the ground or from tree in cloth bags and immediately transported to the processing centre.

Seed extraction and processing: Fresh seeds have about 47 per cent moisture content. Open desiccate them to 38-40 per cent moisture content under shade for storage.

Seeds of *Gluta travancorica*

Seed Weight: About 55-65 seeds weigh per kilogram.

Seed dormancy and pre-treatment: Partial or full seed coat removal enhances germination as compare to seeds with seed coat (Chacko, 2009). Soaking in cold water for 24 hours prior to seed sowing is another pre-treatment for the species (Troup, 1981).

Seed germination: Fresh seeds are sown in germination trays containing vermiculite or in nursery beds and watering regularly. Germination is hypogeal. Fresh seeds have high viability with an average of 99.7 (± 3.36) per cent germination. Germination commences from 18 days after sowing and continues up to 143 days. The species can be raised successfully by direct sowing or planting out one year old nursery raised seedlings.

Seed storage and viability: Viability of seeds can be maintained up to 20 months if they stored in cotton bag inside sawdust at 16^{o}C. However, seeds are viable only up to 4 months under ambient condition.

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Syzygium cumini (L.) Skeels

Taxonomy and nomenclature

Species: *Syzygium cumini* (L.) Skeels

Family: Myrtaceae

Common names: Black plum

Vernacular/Local name: Njara, Njaval

Description: Evergreen tree attains an average of 30 m height and 4 m girth. Bark: white, light pink inside, slightly rough on old stems with shallow cracks and depressions, exfoliating in woody scales. Leaves: simple, opposite, ovate, oblong, long-acuminate at apex, acute at base, nerves many, close, margin entire. Flowers: bisexual, 6-9 mm across, greenish-white, fragrant, sub-sessile; calyx tube 3 mm broad, turbinate; filaments 7 mm long. Fruit: berry 10 x 7 mm, obovoid, deep blue.

Distribution: It is found under a wide range of environmental conditions including tropical and sub-tropical climates. In India, it is distributed throughout the area, including the Andaman Islands, nearly in all the states, except arid regions. Outside India, the tree occurs in Sri Lanka, Burma, Malaysia and southward in Australia. In Kerala, it occurs in evergreen and semi evergreen forests and also in sacred groves up to 1800 m.

Uses: Fruit is edible and used as traditional medicines in divergent ethno-botanical practices (Reynertson *et al*., 2005). Different parts of the species reported for its antioxidant and anti-microbial activities (Chandrasekaran & Venkatesalu, 2004; Veigas *et al*., 2007).

Flowering and fruiting: Sweet scented flowers appear from December-February. Fruits ripen during April-June. Fruits consumed by birds, monkeys, squirrels and human being and get widely dispersed. Flowering and fruiting season may vary depends on the locality.

Seed collection: Collection of mature fruits directly from tree is advisable for pest free seeds. Seed viability is significantly higher if fruits collect directly from trees (Radhamani *et al*., 2005). It can be collected from trees by shaking branches when fruits turn dark black.

Seed extraction and processing: Fruits kept in water for 24 hours and de-pulp them by rubbing with hand; wash and air dry them under shade. Seed germination is very poor when they are sown with the outer pulp. Moisture content of fresh seeds is about 55 per cent. Open desiccate the seeds up to the optimum moisture level for storage (40%).

a) Fruits b) De-pulped seeds

Seed weight: About 700-750 seeds weigh per kg (fresh de-pulped seed). However, seed weight varies with provenance.

Seed dormancy and pre-treatment: Naturally the seeds possess no difficulty for germination. However, de-pulping recommended as the best pre-sowing treatment since it improves germination.

Seed germination: Fresh seeds are sown in germination trays containing vermiculite or in nursery beds and watering regularly. Germination type is hypogeal. Usually, seeds germinate with multiple seedlings due to the poly embryonic nature. Fresh seeds have higher viability with 97.77 (±1.93) per cent germination under laboratory condition. Seed germination commences from 13 days after sowing and culminated at 60 days. Since it is highly recalcitrant, viability loses drastically while desiccate below 35 per cent moisture content (Chacko, 2009).

Seed storage and viability: Viability of seeds can be extended up to six months if they stored in earthen pot inside saw-dust at 16^{o}C. However, it loses viability within two months of storage under ambient condition.

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Syzygium travancoricum Gamble

Taxonomy and nomenclature

Species: *Syzygium travancoricum* Gamble

Family: Myrtaceae

Common names: Syzygium

Vernacular/Localname: Poriyal, Vathamkolli maram

Description: Medium sized evergreen tree attains 25 m height. Bark: surface greyish-brown, longitudinally fissure, peeling off in thin irregular flakes; inner bark grey; branch-lets tetragonus. Leaves: simple, opposite, estipulate, glabrous, lamina ovate or ovate-oblong, base narrowed and decurrent on petiole, apex acuminate, acumen folded, obtuse, margin entire, lateral nerves parallel but very irregular, distant, prominent, looped near the margin forming indistinct intra-marginal nerve. Flowers: bisexual, white, mostly in axillary lax cymose corymbose; calyx tube short, 1 mm across, lobes 4, very short; no thickened staminal disc; petals white, calyptrate; stamens numerous, free, bent inwards at middle when in bud; ovary inferior, 2-celled, ovules many; style 1; stigma simple. Fruits: berry, oblong-obtuse on both sides and attains a purple or deep violet, pericarp juicy. Single seeded fruit.

Distribution: Critically endangered tree endemic to southern Western Ghats in evergreen and semi-evergreen forests. It is a dominant tree species of the unique wetland ecosystems like Myristica swamps and plays a critical role in water storing and maintaining ground water level. The species is found in a few sacred groves in Thiruvananthapuram, Kollam, Pathanamthitta, Alappuzha, Ernakulam and Thrissur districts of Kerala (Sasidharan, 2006). Population of the species is declined considerably due to over-exploitation (logging and wood harvesting) and habitat degradation. Similarly, natural regeneration is very poor.

Uses: It is a rare medicinal plant. It has astringent, bactericidal, hypoglycemic, neuro-psycho-pharmacological properties.

Flowering and fruiting: Flowering starts during March and mature fruits available during May-July. The mature fruits are consumed by birds, squirrels, etc.

Seed collection: Collection of fruits from tree is advisable for pest free seeds. Fresh fruits can be collected from trees by shaking branches when attains purplish/deep violet/maroon-red colour.

Seed extraction and processing: Freshly collected fruits immediately transport to the processing centre. Fruits are kept in water for 24 hours and de-pulped by rubbing with hand; wash and air dry them under shade. Moisture content of the processed fresh seeds is about 45 per cent. Desiccate the de-pulped seeds to the lowest safe moisture level (38%) under shade.

a) Fruits b) De-pulped seeds
c) De-coated seeds

Seed Weight: Number of seeds per kg is about 12,500-12,600 (de-pulped seeds).

Seed dormancy and pre-treatment: De-pulping is the pre-sowing treatment, since it enhances seed germination. Viability of fresh seed is medium.

Seed germination: Fresh seeds are sown in germination trays containing vermiculite or in nursery beds and watering them regularly. Germination type is hypogeal. Germination of fresh seeds is about 57.67±2.52 per cent under laboratory condition. Germination commences from 4 days after sowing and culminates with 41 days.

Seed storage and viability: Seeds are under recalcitrant group. Viability of seeds can be extended up to five months when it store in earthen pot inside wet vermiculite at ambient temperature. However, seeds lose their viability within one month under normal condition.

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