Advance technology of tropical tree seed handling in Indonesia for high quality seed and seedling productions

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Abstract. Seed, as a primary input, plays a vital role for establishment of forest plantation and for any afforestation program. In the recent years, forest and land rehabilitation and community forestry become a great emphasis for Indonesian national forestry programs that make the requirement of seed has multiplied manifold. Seed has become a valuable commodity and thus needs a prudent planning and sophisticated innovated equipment to support procurement of high-quality seeds and seedlings. In the last few years, research and development in seed science and technology have made significant progress. Basic problems faced in tree seed procurement in the tropic are seed characters of recalcitrant and intermediate which well known for drastically deteriorating in seed viability and vigor, sensitive to drying process and low storability. Applied technology for improving seed and seedling quality can be conducted by invigoration methods including physical invigoration (hydro-priming, osmo-priming, matri-conditioning, gamma-ray irradiation) and physiological invigoration (hormone priming, micronutrient, bio-priming, ultra-fine bubble). Seed storage technique has been developing for preparation of planting program and in-situ conservation through seedling storage and cryopreservation. In seed distribution scheme, seed and seedling certifications were developed by compiling the seed testing and seed quality standard of Indonesian Nasional Standard.

Keywords: certification, invigoration, intermediate, recalcitrant

1. Introduction
Seed is a primary input and the most effective tool for plant propagation in a small size and light, easy to transport from seed sources, and more possible to produce in a big scale for productive forest plantation and for any afforestation program. In propagation and conservation of a species, seeds play a vital role. In recent years owing to greater emphasis on community forestry, plantation forest development, reforestation and critical land rehabilitation, the requirement of seed has multiplied manifold [1]. Large quantities of seed are needed every year to raise the nursery stock for propagating the desired plant species. A plentiful supply of quality seed, i.e. high in viability and vigor, is therefore one of the prerequisites to make such activities successful.

The control of seed quality requires consistent effort from seed collection, processing and storage (Figure 1). Failure in application of sound principles at any stage will result in loss of seed quality. Seed qualities usually refer to the genetic, physical and physiological states of the seed and the precise definition of quality depends on the use to which the seed will be applied [2]. All stage affects each other, and the overall influence is cumulative [3, 4]. There are many publications on seed collection, processing, and storage of tree seed, especially in temperate regions. In tropical regions, for some species that are commonly cultivated in small scale farmer or in industrial forest estate, the seed handling technology has
been well known. However, there were still very few literatures for some Indonesian tropical indigenous species.

The development of technology in producing such high technology equipment to encourage the high-quality seed production will be needed. Most of sophisticated equipment has been innovated to help seed technologies in expanding their methods and formulas to present the better tree seed technology. Developed methods for tree seed handling of intermediate and recalcitrant seed characters could be conducted by seedling storage and cryopreservation. The duration of the viability of the seeds in nature, vary widely among species due to their varied maturation time and storage physiology. In recent years, developed methods in improving seed germinability by introducing a few technical methods in seed invigoration has tremendously encouraged the new perspective of seed technology. Seed testing also still develop to guarantee the economically distributed seeds. Nobble, a founder of modern seed testing, found the differences in germination and growth within a seed lot, or averaged between seed lots, and called this phenomenon “driving force”, namely “seed vigor” [5]. Seed vigor is more promising, sensitive, and accurate seed quality character reflecting potential seed germination, field emergence, and seed storage ability under different conditions than standard germination. Thus, vigor tests have been developed to a better forecast of field sowing potential [6, 7]. In view of the increasing importance of seed quality in forestry and the numerous challenges in handling, testing and storage of forest seed, the paper will present some technology in seed handling of Indonesian forest tree species.

![Diagram of factors affecting seed quality](image)

**Figure 1.** Factors affecting seed quality [11]
2. Seed Collection

2.1 Seed collection techniques

Successful in seed collection requires the knowledge of what, where, when and how to collect the seed from the seed sources. There are many techniques and different equipment used in seed collection. Each method can be used effectively depending on the purpose of seed collection, resource and equipment availability, and characteristics of tree stand, and site. The seed collection techniques can be classified into three categories [8, 9]:

a. Collection of fallen seeds or fruits from the forest floor
b. Collection directly from standing trees with access from the ground
c. Collection of fruits by tree climbing

Seed collection time can be predicted by observation on flowering and fruiting development (phenology study). Period of fruit development can be used to develop the model/instrument for seed maturity prediction, such as on tembesu (Fagraea fragrans) [10] (Figure 2). Instrument for predicting seed maturity makes it possible to produce high quality seeds at the time of physiologically optimum seed maturity so that the seeds produced have high quality.

Figure 2. Instrument for predicting of seed maturity of tembesu (Fagraea fragrans) based on flower and fruit stages development (photo: Pramono, 2015)

Seeds maturity is a major concern of various methods of collection, whether they are collections from standing trees or fruit on the forest floor. Fruit or seed color has been reported as reliable index of seed maturity for several Acacia spp., Pinus merkusii, Melia azedarach, Sterculia foetida, Gmelina arborea, and Trema orientalis [11, 12, 13, 14]. Change of fruit or seed color, for example for orthodox seeds, is followed by the decrease of seed moisture and lipid content, and increase of protein and carbohydrate content [14]. For intermediate seeds such as Sterculia foetida, seed maturity is followed by increase of lipids and carbohydrate and decrease of protein [13]. The different seed characteristics have different physical, physiological and biochemical tendencies.
2.2 Fruit temporary storage and transportation
Temporary storage is intended to store fruits or seeds at a field station that is normally restricted to a short period during seed collection and pre-processing. Fruits or seeds should be stored under shade and shelter to protect them from direct sunlight, heating and rain. The fruits/seeds should be raised slightly from the ground to avoid moisture when the containers are not waterproof. Bags and containers should be made from material that allows maximum air circulation without spilling seed, for examples baskets or hessian bags [15].

Recalcitrant seeds impose a problem in this context since they are intolerant of desiccation [16]. They must be dried down to the lowest levels for safe storage and maintained moist throughout storage. The best solution for recalcitrant seeds is to reduce the transit period as much as possible. When the seeds are quickly germinated following collection, the germinated seeds should be delivered directly to the nursery. The germinated seeds should be packed properly by adding moist media into the container during conveyance to the nursery.

Transport time from collection site to processing unit should be as short as possible, since it is difficult to maintain a proper environment in temporary storage during transportation. For example, bags and containers must inevitably be piled at this stage, and several factors are difficult to control during transport. Safety measures depend on the transport time, and the type and condition of the fruits or seeds [15].

3. Seed Processing
3.1 Pre-curing
Pre-curing is the deliberate storage and slow air drying of fruits and contained seeds in order to render them more suitable for subsequent operations of drying, extraction and long-term seed storage. Seed maturation and fruit drying are the processes assisted by pre-curing. Fruits in natural condition are not all ripe at the same time, even for the same species and in the same forest. Thus, even when a collection is perfectly timed at the peak of maturity, the embryo of the seeds may not be fully developed when the cone or fruit is ripe. Such seeds require after-ripening and the embryo grows to full size before germination. More mature seeds exhibit greater vigor and have better potential to establish as a vigor seedling. Pre-curing has two rationales: 1) to promote after-ripening of immature fruits, and 2) to ease extraction of seed where rapid desiccation may cause extraction problems, in extreme case is hardening [15]. Some species need the pre-curing treatment to promote after-ripening of immature fruits, such as Pinus merkusii, Tectona grandis, Swietenia macrophylla [4], Sleichera oleosa [17] and Sterculia foetida [13].

3.2 Seed extraction
Extraction of seeds from the fruit needs a specific technique to get good quality seeds. Many types of seed are more vulnerable to damage when extracted, e.g. recalcitrant seeds and seed with a thin fragile seed coat. Possible bulk reduction by extraction should be undertaken with care to avoid hampering viability. Fruits, which must be after-ripened, should obviously not be extracted but maintained moist throughout field handling [15].

The methods of extracting seeds from fruits are determined mainly by the physical characteristics of the fruits. Fleshy fruits are treated by a de-pulping process that usually involves a combination of soaking in water with pressure or gentle abrasion. Cones and other woody or leathery fruits are first dried until cone scales open or seeds become detached from the placenta of the fruit, and then treated manually or mechanically by tumbiling or threshing in order to separate the seeds from the dry fruits [4, 15].
Table 1. Extraction classification according to the seed pre-storage and storage requirements of some species

| Classification treatment | Species |
|--------------------------|---------|
| - Seeds that must be dried for extraction and storage | Albizia spp., Acacia spp., Casuarina spp., Eucalyptus spp., Tectona grandis, Swietenia spp., Pinus spp., Toona spp., Albizia spp., Cassia sp., Delonix sp., Leucaena spp., Caliandra spp. |
| - Seeds that must be kept moist at all times, both during cleaning and storage (i.e. recalcitrant species) | Agathis spp., Shorea spp., Dipterocarpus spp., Hopea spp., Quescus spp., Castanea spp., Azadirachta sp., Melia excelsa, Magnolia blumei |
| - Seeds that must be kept moist for extraction, then dried for storage | Gmelina spp., Melia azedarach, Neolamarckia spp., Nuclea orientalis, Maesopsis emenii |

3.3. Seed drying

For medium- or long-term storage of many species, a moisture content of 4–8% is recommended. This is considerably less than the moisture content of freshly collected seeds. Reduction of moisture content can be achieved in most species by placing the seeds in an ambient atmosphere of 15-20% relative humidity for a sufficiently long period to allow the seeds to reach moisture content in equilibrium with relative humidity. The effectiveness of air-drying depends on local climatic conditions. Reduction to 12–18% moisture content is frequently possible, if attention is paid to adequate aeration of the seed. Reduction to less than 8% is impossible in most temperate situations and in some areas of wet tropics, because average relative humidity remains too high [15]. Table 2 describes the relationship between seed moisture content and their effect on seed performances.

Table 2. The relationship between seed moisture content and their effect on seed performances

| Seed moisture content (%) | Effect on seed |
|---------------------------|----------------|
| Moisture content >45% - 60% | Germination begins |
| Moisture content >18% - 45% | The seed may heat (due to a rapid rate of respiration and energy release) |
| Moisture content >12% - 18% | Fungus growth can occur |
| Moisture content >8% - 12% | Insect activity much reduced |
| Moisture content 4% - 8% | Sealed storage is safe |

In recalcitrant seeds, reduction in moisture content causes the reduction in seed germination, e.g. Dipterocapaceae [19, 20]. While for intermediate seeds, such as Sterculia foetida, reduction in seed moisture content within 9-12% is still safe to maintain seed viability without a significant deterioration [4]. The determination of the lowest safe moisture content is very important to improve the storability of seeds. The lowest safe moisture content of seed to be stored in each species is different based on the seed characteristics.

3.4. Seed cleaning, sorting and selecting

Seed cleaning is a separation of seed from other species and non-seed fragments such as fruit fragments, leaves or twigs. Cleaning may be undertaken by sifting, blowing, winnowing, flotation etc. A further
process after seed cleaning is sorting the seeds that can be conducted in mechanical process in which the goal is to achieve a high level of seed purity and quality in the final product. While seed selection is mainly aimed at obtaining healthier seeds, it can also be used to maintain and improve the quality of the seed variety.

Most large tropical seeds are more effectively handled manually. Some small and finely sized seeds such as *Eucalyptus* sp., *Neolamarckia* sp. *Octomeles sumatrana*, and *Melaleuca* sp. are cleaned by filtering with a mesh-sized sieve. Seed selection and sorting can be done based on seed weight and size. Selection is carried out to separate filled seeds from empty seeds, other types of seeds and impurities. Generally, seed weight and size are the basis for seed sortation. Seed selection and sortation can be done using seed gravity table, immersion or floatation techniques, screening of certain sizes, and blowers [21]. Some results of seed selection research show that *Mimusops elengi* seeds in size of 14.0-19.9 mm produce higher germination rate than other seed sizes [22], *Melia azedarach* seeds with length ≥11 mm and diameter ≥6.5 mm produces more vigorous seedlings and ready for planting [23] and *Albizia procera* seeds with diameter > 4.7 mm has the optimal seedling growth in height and diameter [24].

4. Seed Storage

Storage may be defined as the preservation of viable seeds from the time of seed collection until they are prepared for sowing. When seed for afforestation can be sown immediately after collection, no storage is needed. The best sowing date for a given species being raised in a nursery depends on: a) the anticipated date of planting, itself dependent on seasonal climate, and b) the time needed in the nursery for planting stock of the species to reach the right size for out-planting. It is rare that the sowing date coincides with the best date for seed collection, as a matter of fact it is necessary to store the seed for varying periods which may be:

a. Up to one year when both seed production and afforestation are regular annual events, but it is necessary to await the best season for sowing.

b. 1 – 5 years or more when a species bears an abundant seed crop at intervals of several years and enough seed must be collected in a good year to cover annual afforestation needs in intermediate years of poor seed production.

c. Long-term storage for purposes of conserving genetic resources. The period of storage will vary according to the seed longevity of the species and the storage conditions but will be measured in decades in species that are easy to store.

The seed storage behavior, at first, is classified into two classes, orthodox and recalcitrant [25]. The additional category was proposed to complete the seed characteristics, i.e., intermediate which is found in-between orthodox and recalcitrant [26]. Storage of recalcitrant seeds is still a major objective in research. Some Shorea species suffered chilling damage at or below 14°C, but they survived for about 180 days at 4°C, whereas, some Parashorea and Hopea species survived for 20 days at 4°C but they were all dead within 30 days. The chilling damage, dehydration, early germination and fungal attack were the biggest problems. Recalcitrant seeds include several large seeds that cannot withstand appreciable drying without injury. Whereas some temperate recalcitrant species have been stored successfully for several years, seed longevity in tropical recalcitrant can be measured in days or weeks.

Recently, some researchers reported an advance technology of storing recalcitrant seeds. Several techniques are offered to provide a medium and long storage of recalcitrant seeds. The use of juvenile material of seed tissues (in vitro propagation) is carried out by using cryopreservation method that is successfully developed and applied to more than 1000 species of plants [27]. Other methods such as encapsulation-dehydration, vitrification and desiccation are also used by using mature zygotic or somatic embryos, cotyledon and apical buds, which can last up to 6-12 months [28]. The objective of in vitro storage techniques is mainly to conserve genetic resources of rare species. The techniques need high
technology equipment, expensive supporting materials, reliable experts and high accuracy with high risk of contamination [29]. Therefore, a prudent approach of innovative technology to handling recalcitrant seeds is urgently needed. Storing of forest tree species in the form of seedlings has been proven to store recalcitrant seeds for more than one year. The technology is more promising in a practical scale and what more applicable in storage technology is that which touches users, suppliers, producers and breeders in the nursery.

5. Seed Treatment before Germination
The development of seed into independent seedlings is affected by a number of environmental and plant factors. The latter include physiological and physical characteristics of the seed. These to some extent, can also be modified by environmental factors [30].

5.1. Seed germination pre-treatment
The seeds of most tree species germinate readily when subjected to favorable environmental conditions. Even if a condition seems to be ideal, seeds of some species do not germinate until they undergo physical or physiological changes. Such seeds are said to be dormant. The underlying causes of such dormancy operate through physiological, morphological, physical, chemical, mechanical or any combination of these factors [31]. Five distinct types of dormancy viz., embryo dormancy, seed coat dormancy, induced dormancy, immature embryo dormancy and double dormancy occur prominently in tree seeds [30].

The methods used to overcome seed dormancy depend on the type of dormancy. It is commonly believed that seed dormancy is controlled by the simple presence or absence of combinations of gibberellins, cytokinin and inhibitors and can be overcome when such inhibitors have leached out. Several types of seed dormancy, their causes and pre-treatments that should be employed are described in Table 3.

Table 3. Type of dormancy, causes, pre-sowing treatments and several examples of forest tree species

| Type of dormancy     | Causes of dormancy                                                                 | Pre-sowing treatments                    | Species                                           |
|----------------------|-----------------------------------------------------------------------------------|-----------------------------------------|--------------------------------------------------|
| Embryo dormancy      | Dormancy is apparent due to growth inhibiting chemicals                             | After-ripening treatment                 | Terminalia sp., Tectona grandis, Agathis sp., Styx benzoin |
| Seed coat dormancy   | Seeds have thick, hard or wax covered coats that completely prevent water or oxygen uptake by the embryo or light absorption or mechanically restrict megagametophytes and embryo growth or restrict outward diffusion of inhibiting substances | Mechanical scarification, Chemical scarification, Hormone treatment: gibberellic acid (GA3), indole acetic acid (IAA), indole butyric acid (IBA) | Acacia spp., Cassia spp., Delonix sp., Parkia sp., Terminalia sp., Quercus sp., Sapiinus sp., Falcataria moluccana, Leucaena spp., Styx benzoin, Callophyllum inophyllum |
| Double dormancy      | Usually involves an impermeable seed coat and embryo dormancy                      | Combined treatment (after-ripening and scarification, etc.) | Tectona grandis, Styx benzoin                    |
5.2. Seed invigoration
Seed invigoration can partially improve the germination capability, uniform seedling emergence, seedling vigor and growth of deteriorated poor quality seedlots through some metabolic and physiological repairs within the seed [32]. Invigoration can be carried out by several methods that rely on the type of agents. These include physical invigoration (irradiation, thermal shock), biological treatment, matrix conditioning, and osmo-conditioning (hydro-priming, osmo-priming, hormone priming, halo-priming, hardening, humidification and stratification) [33, 34]. The effectiveness of invigoration in the enhancement of seed germination of plants was reported on some species with the techniques described in Table 4 [35].

Table 4. Priming stages and seed conditioning treatments

| Activities          | Osmo-conditioning                                                                 | Matrix-conditioning                                              | Hydration-dehydration                                           |
|---------------------|-----------------------------------------------------------------------------------|------------------------------------------------------------------|-----------------------------------------------------------------|
| Moisturizing        | Seeds are placed in a closed container filled with straw paper saturated with a solution, moisturized for 72 hours | Seeds are placed in a closed container, containing ashes/sawdust + seeds + water (v/v = 0.4:1:1) then evenly mixed | Seeds are placed in a closed container filled with water-coated straw paper, moisturized for 72 hours |
| Controlled humidity | - Every 6 hours the seeds are stirred evenly for 3 minutes                         | - Every 6 hours the seeds are stirred evenly for 3 minutes         | - Every 6 hours the seeds are stirred evenly for 3 minutes       |
|                     | - Every 24 hours, water/solution is added to replace the amount of water lost       | - Every 24 hours, water/solution is added to replace the amount of water lost | - Every 24 hours, water/solution is added to replace the amount of water lost |
| Initial drying      | Dried at room temperature for 72 hours                                             | -                                                                | Dried at room temperature for 72 hours                           |
| Washing             | Washed in running water                                                           | Washed in running water                                           | Washed in running water                                          |
| Drying and packing  | - Dried at room temperature for 120 hours                                          | - Dried at room temperature for 120 hours                         | - Dried at room temperature for 120 hours                        |
|                     | - Packed in containers that match the character of the seed                         | - Packed in containers that match the character of the seed       | - Packed in containers that match the character of the seed      |

Some advanced potential methods applied without chemical materials are gamma irradiation and hydropriming using ultrafine bubble. Gamma irradiation has a profound influence on plant growth and development by inducing genetical, cytological, biochemical, physiological and morphogenetic changes in cells and tissues depending on the levels of irradiation [36]. Low doses of irradiation may increase the enzymatic activation and awakening of the young embryo, which results in stimulating the rate of cell division and affects not only the germination, but also the vegetative growth [37, 38]. The biological effect of gamma radiation is mainly due to the formation of free radicals by the hydrolysis of water, which may result in the modulation of an anti-oxidation system, accumulation of phenolic compounds and chlorophyll pigments [39, 40]. Treatment of tree seed with low dose gamma irradiation has been...
found to improve seed germination and seedling growth [41]. Table 5 shows the effect of gamma irradiation on the germination and seedling growth of *Magnolia champaca* [42].

**Table 5.** The influence of various doses of gamma irradiation on the germination capacity and seedling growth of *Magnolia champaca*

| Doses (Gy) | Germination percentage (%) | Seedling height (m) | Seedling root collar diameter (cm) |
|------------|----------------------------|---------------------|-----------------------------------|
| 0          | 44.00±1.5 bcd              | 17.05±0.7 b         | 3.14±0.1 b                        |
| 5          | 49.00±4.9 abc              | 28.14±0.7 a         | 3.97±0.1 a                        |
| 10         | 59.33±1.6 a                | 29.88±1.0 a         | 4.17±0.1 a                        |
| 15         | 50.00±3.9 abc              | 27.48±1.2 ab        | 3.38±0.1 a                        |
| 20         | 52.33±2.2 ab               | 24.47±1.2 ab        | 3.68±0.1 ab                       |
| 40         | 45.00±5.9 bcd              | 24.33±1.2 ab        | 3.76±0.2 ab                       |
| 60         | 37.67±8.1 d                | 28.22±2.3 a         | 3.95±0.3 a                        |
| 80         | 0.33±0.3 e                 | 30.32±2.1 a         | 4.11±0.2 a                        |
| 100        | 0.33±0.3 e                 | 20.33±3.8 b         | 3.65±0.4 b                        |

F-test: 14.3** 21.4** 6.7**

Notes: The same letter behind the numbers in the same column shows no significant difference at level of 5%. ** in F-test bar shows that seed lots have significant effects on seed quality parameters.

![Figure 3](image_url)  

**Figure 3.** Performance of *Magnolia champaca* seedlings at 6 six months old grown from irradiated seeds at doses 0 (A), 5 (B), and 10 Gy (C) (photo: Zanzibar, 2016)

Ultra fine bubbles (UFB) or nanobubbles (NB) are bubbles with a diameter of sub micrometer order [43]. In the recent years, the UFB physiological promotion and oxidation effect have been reported. A series of investigations have reported that water-containing UFBs can accelerate the growth of plants [44]. UFBs could produce reactive oxygen species (ROS) and the amount of ROS had positive correlation with the UFB/NB density. The moderate level of exogenous ROS produced by UFB/NB water played an important role in seed germination [45]. Study on the *Gmelina arborea*, *Falcataria moluccana* and
Albizia chinensis showed that the UFB could improve the low vigor seeds [46, 47, 48]. In fact, seeds with very low germination that cannot be improved by invigoration treatment using GA$_3$ or PEG, can be improved its viability and vigor using UFB, as in A. chinensis seeds (Figure 4).

![Germination capacity improving using ultra fine bubbles treatment on Gmelina arborea, Falcataria moluccana and Albizia chinensis](image)

**Figure 4.** Germination capacity improving using ultra fine bubbles treatment on Gmelina arborea, Falcataria moluccana and Albizia chinensis

6. Seed Testing

6.1. Indonesian National Standard for seed testing

The International Seed Testing Association (ISTA) was established in 1924 to work towards a vision of uniformity in seed testing internationally [49]. Most species in ISTA’s seed sampling and testing are agricultural species and temperate tree species, and only a little part of it is tropical tree species which is listed in the ISTA rules. The seed testing for Indonesia tropical tree species has been developed based on scientific knowledge and the accumulated experience of those working in seed testing and quality control. Until 2019, the seed testing method was compiled in the form of RSNI that included 87 species of forest trees.

6.2. Rapid test of seed viability

The tetrazolium topography test is a rapid viability test that is most widely used to estimate seed viability [49]. Tetrazolium topography is a biochemical test that can be used to quickly assess seed viability, namely:

a. If the seeds must be sown immediately after harvesting.

b. Seed with a long dormancy.

c. Seeds that show slow germination.

d. If a very fast estimate of the potential of seed germination needed.

e. It can also be used to determine the viability of individual seed at the end of the germination test especially if the seeds are suspected of dormancy.

f. To find out the germination and various types of crop damage and or damage due to processing (damage due to heating, mechanical damage, damage due to insects).

g. To solve the problems found in germination testing, if the reasons for abnormal causes are unclear, it is suspected that they are due to treatment with pesticides, and so on.
Other advance technique of rapid test for seed viability is imaging and spectroscopy techniques. In big scale of tree seed production, imaging and spectroscopy techniques for detecting seed quality have developed rapidly with widespread applications in non-destructive seed quality determination. X-radiography is very useful in forest seed analysis. It provides a very rapid and accurate analysis of the internal structure of seeds, identifying empty, insect-damaged, or poorly developed seeds. The development and applications of emerging techniques in the analysis of seed viability, includes near infrared spectroscopy, hyperspectral and multispectral imaging, Raman spectroscopy, infrared thermography, and soft x-ray imaging methods [50]. X-radiography has proven useful for studying the seeds from many wild species, which often can be empty or poorly formed [51]. BaCl$_2$ can be used as a contrast agent to determine seed viability of *Pinus merkusii* with a concentration of 20% and 30 minutes of soaking time. Viable seeds characterized by seeds have a complete structure (endosperm, embryo and seed coat), seeds do not absorb contrasting materials and the level of physical damage is not more than 25%. The use of BaCl$_2$ contrast concentration 10% and 30 minutes soaking time did not affect the germination of mahogany (*Swietenia macrophylla*) seeds. This treatment can be used to determine the viable and non-viable mahogany, in which the viable seeds interpreted when endosperm filling the seed cavity is not wrinkled and pitch black and not absorbed by contrast agents more than 25% [52].

NIR spectroscopy instruments are used for research and other purposes, considerable advantages in terms of use cost over other optical sensing techniques, scanning seeds tends to obtain higher precision [53]. The information on chemical composition of seeds, for instance lipids, proteins, and carbohydrates, can be captured by NIR; however, it might be easily affected by the uniformity of sample distributions due to the fact that only one a single spot of samples is applied [54].

7. Seed vigor testing

Seed vigor is a more promising seed quality character reflecting potential seed germination, field emergence and seed storage ability under different conditions than standard germination. Electrical conductivity of the seed leachates is regarded as an indicator of seed maturity and vigor. High electric conductivity is attributed to low level of vigor and immature seeds lower the electric conductivity. Seeds with low electric conductivity would be more mature of high vigor [55, 56]. An inverse relation between electrical leachate conductivity and seed germination and normal seedling emergence in nursery has been studied for *Acacia mangium* [7]. The electrical conductivity test had the highest accuracy with $R^2 = 0.6278$ for greenhouse test and $R^2 = 0.4057$ for nursery test. The usage of the electrical conductivity test for predicting normal seedling emergence could be suitable in *A. mangium* nursery.
Figure 5. Linear correlation between electrical conductivity test and seed germination level of greenhouse test (a), and number of normal seedlings in nursery test (b)

8. Conclusion
In afforestation and reforestation programs, seed has become a valuable commodity, and its collection, identification, processing, testing, storage and certification requires prudent planning. Advance technology of seed handling is highly beneficial in improving the quality of seeds and seedlings production of forest tree species. Some advanced technologies such as seed maturity predicting, rapid test of viability, seed vigor and testing, gamma irradiation, and ultra fine bubbles can be applied to improve and guarantee the quality of tree seeds.

Acknowledgement
The authors greatly appreciate colleagues of FTSTRDC for their to share her/his information/photos for this manuscript that make this paper more valuable.

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