TREE BREEDING PROGRAMMES BY FRIM FOR FOREST PLANTATION ESTABLISHMENT: PRESENT AND FUTURE

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ABSTRACT

The timber industry has been a driving force of the Malaysian economy. This is expected to continue, in line with the steadily increasing global demand and value for timber and timber products. However, depending solely on natural forests to satisfy this demand will lead to widespread environmental degradation and loss of biodiversity. Therefore, in an effort to reduce dependency on natural forests, the Malaysian government has formulated policies to establish "work forests", which are forest plantations that are able to supply timber sustainably. To achieve this, there is a need for a continuous supply of high-quality planting materials. Hence, it has become a core objective of the Plant Improvement Program under the Forest Biotechnology Division of Forest Research Institute Malaysia (FRIM) to conduct tree breeding programmes to develop high-quality planting materials of desirable forest tree species. This paper summarizes the decades of tree breeding programmes conducted by FRIM and the future prospects of these research projects. More specifically, six forest tree species will be discussed, which are Jati (Tectona grandis), Meranti tembaga (Shorea leprosula), Acacia hybrid, Sesenduk (Endospermum diadenum), Meranti temak nipis (Shorea roxbughii) and Meranti sarang punai (Shorea parvifolia).

Key words: Selection, genetic variations, progeny trial, clonal trial, seedling seed orchard

INTRODUCTION

The timber industry has been an integral part of Malaysia's socio-economic development for almost a century. Exports of timber and additional timber products increased by almost RM 22.3 billion in 2018 to RM 23 billion in 2019 (Department of Statistics, 2019). In the 1940s, the industry comprised only primary processing for the production of sawn timber but has now developed into secondary and tertiary processing (Awang et al., 2007). This includes the production and export of furniture, flooring, mouldings and a variety of other timber products. This growth is in line with the steady increasing global demand and value for timber products. It is safe to conclude that the timber industry will continue to be a driving force for the Malaysian economy.

Thus, it is no surprise that the Malaysian government has formulated policies to establish "work forests", which are forest plantations that are able to supply timber sustainably. Besides, there is also a growing effort to rehabilitate degraded natural forests. To achieve these initiatives, there is a need for a continuous supply of high-quality planting materials. Hence, it has become a core objective of the Plant Improvement Program under the Forest Biotechnology Division of Forest Research Institute Malaysia (FRIM) to conduct research activities for the development and genetic improvement of the selected tree species to be planted in forest plantations. This includes identifying potential mother trees, conducting progeny trials, establishing seedling seed orchards, clonal trials and a variety of other research projects in which subsequently resulting in the empowerment of germplasms bank.

This paper summarizes the decades of tree breeding programmes on the selected six species; Jati (*Tectona grandis*), Meranti tembaga (*Shorea leprosula*), *Acacia* hybrid, Sesenduk (*Endospermum diadenum*), Meranti temak nipis (*Shorea roxburghii*) and Meranti sarang punai (*Shorea parvifolia*), conducted by FRIM and the future prospects of these research projects. These six species were selected based on the Forest Plantation Species listed by the Malaysian Timber Board (MTIB), Compensatory Forest Plantation Project launched by the Forestry Department of Peninsular Malaysia in 1982 and also FRIM's initiatives.

MATERIALS AND METHODS

As mentioned previously, six forest tree species will be discussed in this paper, as shown in Table 1:

General Concepts/Terms used in Tree Improvement Programmes

a) Clonal trial: "A test of the vegetative propagules from a given donor" (Zobel and Talbert, 1984). Similar to the progeny trial, the clones are planted in the replicated field trial. The growth performance of the trial is evaluated regularly.
b) Family: Family refer to the "individuals that are more closely related to each other or groups of individuals who have one of both parents in common" (Zobel and Talbert, 1984). In this paper, the term "family" does not refer to a taxonomic category.
c) Half-sib family: "The group of related individuals when only one parent is common" (Zobel and Talbert, 1984).
d) Plus tree: Plus tree is defined as the selected tree that has been graded for the sources on production for further breeding study (Hettasch et al., 2002).
e) Progeny trial: Progeny refer to the "trees produced from the seed of a parent tree. Progeny tests are established to determine the genetic worth of the parent trees or for determination of other genetic characteristics" (Zobel and Talbert, 1984). Conceptually, in the progeny trial, the seedlings are planted in the replicated field trial. The growth performance of the trial is evaluated regularly (Hettasch et al., 2002).
f) Seed orchard: "An area where superior phenotypes or genotypes are established and managed intensively and entirely for seed production" (Zobel and Talbert, 1984).

Table 1: Species discussed in the paper

Tree species	Brief Description of Tree Breeding Programmes
Tectona grandis	Progeny trial, clonal trial, Invention Disclosure (ID) of clones.
Shorea leprosula	Progeny trial, Seedling seed orchard.
Acacia hybrid	Generation of hybrids, clonal trial, the ID of clones
Endospermum diadenum	Progeny trial, the ID of clones
Shorea roxbughii	Progeny trial
Shorea parvifolia	Progeny trial

RESULTS AND DISCUSSION

JATI (*Tectona grandis*)

Teak (*T. grandis*), locally known as Jati, is a large tree species that is highly prized worldwide for its wood quality (Akram and Aftab, 2016). Regarded as a paragon of timber, teakwood is widely used due to its appealing aesthetics, and natural resistance towards pests and weather. Teakwood is used in construction, from bridges to interior wood panelling, furniture, musical instruments, wallboards, woodwork, boxes, kitchen tables and other interior fittings (Ramachandran et al., 2011).

The species grows naturally in tropical monsoon climates, like Myanmar, India, Laos and Northern Thailand. However, teak is a highly adaptive species that is able to grow in a wide range of environmental conditions, thus can now be found in numerous regions. Teak was believed to be introduced to Southeast Asia during the fourteenth century (Hansen et al., 2015). Optimal conditions for teak growth are in regions with 1200 mm to 2500 mm of annual rainfall and high light intensity, making Peninsular Malaysia an ideal location for the species (Hansen et al., 2015).

Teak has become a common species incorporated in forest plantations across the tropics including Malaysia, due to the optimal environmental conditions and the insatiable demand for teakwood. However, most early introductions of the species were on a pilot basis, while large-scale forest plantations were only established more recently (Hansen et al., 2015). The establishment of forest plantations has fuelled a growing demand for good-quality planting materials, making tree improvement and tree breeding an important research area.

CLONAL TRIAL OF JATI (*T. grandis*)

The first teak provenance resource stand was established at FRIM Research Station (SPF) Mata Ayer, Perlis in the 1950s. The resource stand was established using provenances from Thailand, Indonesia, India, Papua New Guinea, Trinidad and Sabah. A progeny trial using selected genotypes of the provenance resource stand was established at Forest Reserve Papulut, Gerik, Perak in 2002.

A total of 15 clones were selected based on the performance of a progeny trial of the 29 families planted in Papulut Forest Reserve, Gerik, Perak. The clonal trial plots were established at SPF Selandar (Melaka), SPF Jeli (Kelantan) and SPF Mata Ayer (Perlis). The trial plots were laid out in Randomized Complete Block Design (RCBD) with four blocks and 16 ramets per clones. Thus, making a total of 240 ramets were planted with distances of 4m × 4m, making the total plot areas amounting to 0.4 hectares/each.

The overall analysis of the teak growth data at the age of 3, 4 and 5 years old at SPF Jeli and SPF Mata Ayer indicated that there were five most promising clones in term of growth performances (parameters: Height and Diameter at Breast Height) and stability. The five clones, namely; T24, T3, T28, T4 and T1 showed the best growth ranking throughout the 5 years' data assessed (Table 2).

Then, based on the individual analysis of the teak growth performances at SPF Jeli and SPF Mata Ayer (data not shown), these five clones also showed among the top growth ranking. Besides, clones T16 and T17 ranked among the top five best growth performances at SPF Mata Ayer throughout the three years of data assessed (data not shown). Contrary to its performance at SPF Mata Ayer, clones T16 and T17 showed unfavourable growth performances at SPF Jeli. These findings might indicate that there was a significant Clone by Site interaction. Both clones T16 and T17 showed a stable growth performance at SPF Mata Ayer throughout the five years of data assessed.

In short, findings showed that there are five selected clones namely; T24, T3, T28, T4 and T1 based on good and stable growth performances at the age of 3, 4 and 5 years old at SPF Jeli and SPF Mata Ayer. On the other hand, there are two additional clones namely T16 and T17 are recommended to be planted specifically in North, Peninsular Malaysia. These 7 clones have been registered under Invention Disclosure (ID) at FRIM's level.

Clonal teak trees have been found to have better growth performance compared to seed-origin trees. Research by Medeiros et al. (2019) reported that *T. grandis* clonal trees outperformed seed-origin trees by 50% in total volume and 48% in Diameter at Breast Height (DBH). This is because clonal trees are able to capture both additive and non-additive genes, which results in better gains compared to trees propagated from plus trees (Hai et al., 2007). However, it also needs to be noted that the growth performance of both clonal and seed propagated trees is not a constant, as phenotypic responses of genotypes in differing environmental conditions need to also be considered (Ding et al., 2008). A study conducted in Costa Rica found that genotype by environment interaction (GxE) only accounted for 2.5% of the total phenotypic variation in *T. grandis* (Murilo et al., 2019). Nevertheless, as *T. grandis* is a species with diverse genetic variation, GxE could play a bigger role in different regions.

At this stage, FRIM has plans to establish teak plantations using the high-performing clones, to supply rural communities with a sustainable and cheaper source of teakwood. This will allow for the expansion of rural economies that are based on producing handicrafts and furniture. The long-term aim is to establish teak plantations with shorter harvesting cycles, allowing for a continuous supply of teakwood.

Table 2: Summary of the Growth parameters of Clonal trial of *T. grandis* planted at two locations (SPF Jeli and SPF Mata Ayer)

Growth at 3 years old						Growth at 4 years old						Growth at 5 years old					
Clone	**DBH (cm)**	**(±) STDEV**	**Clone**	**HT (m)**	**(±) STDEV**	**Clone**	**DBH (cm)**	**(±) STDEV**	**Clone**	**HT (m)**	**(±) STDEV**	**Clone**	**DBH (cm)**	**(±) STDEV**	**Clone**	**HT (m)**	**(±) STDEV**
T24	5.99	2.19	T28	5.79	1.58	T24	7.27	2.74	T28	6.89	1.54	T28	10.72	3.21	T1	9.73	3.30
T3	5.65	2.31	T24	5.71	2.03	T28	7.25	2.10	T3	6.77	2.78	T3	10.24	4.66	T3	9.12	3.10
T28	5.57	1.95	T3	5.67	2.25	T3	7.11	2.84	T4	6.67	3.08	T24	9.91	3.27	T4	8.97	3.08
T4	5.35	2.60	T4	5.61	2.77	T4	6.63	2.98	T24	6.54	2.14	T4	9.54	3.65	T25	8.96	2.65
T1	5.09	2.34	**T16**	**5.53**	**2.52**	T1	6.20	2.83	T1	6.36	2.48	T1	9.39	3.52	T28	8.62	2.30
T16	**4.76**	**2.34**	A12	5.16	1.91	**T17**	**5.95**	**2.85**	**T16**	**6.34**	**2.91**	B49	8.95	4.04	**T16**	**8.59**	**4.09**
T17	**4.57**	**2.32**	T1	5.04	1.97	**T16**	**5.94**	**2.65**	A12	6.04	2.24	**T17**	**8.81**	**3.50**	T24	8.41	2.54
B49	4.55	2.26	**T17**	**5.01**	**2.16**	T26	5.81	2.70	T26	5.85	2.40	T26	8.71	3.48	T8	8.34	3.33
T26	4.50	2.10	T25	4.90	2.28	B49	5.76	2.93	**T17**	**5.85**	**2.85**	A12	8.48	2.77	T26	8.10	2.89
A12	4.40	1.62	T26	4.80	2.04	A12	5.64	1.95	T25	5.72	2.55	T25	8.37	2.59	**T17**	**8.00**	**2.62**
B82	4.39	1.91	B49	4.58	1.71	B82	5.63	2.52	T8	5.53	2.34	B82	8.22	3.40	B49	7.78	3.36
T25	4.14	1.96	T18	4.49	2.42	T25	5.30	2.09	B49	5.43	2.30	**T16**	**8.16**	**3.95**	A12	7.75	2.82
T5	4.06	2.09	T8	4.39	1.91	T8	5.19	2.49	B82	5.26	2.07	T8	7.87	3.60	B82	7.55	2.96
T8	3.97	2.05	T5	4.28	2.19	T18	5.15	2.62	T18	5.20	2.71	T18	7.69	4.01	T5	7.31	3.27
T18	3.93	2.16	B82	4.02	1.63	T5	4.95	2.59	T5	4.98	2.79	T5	7.45	3.28	T18	6.78	2.93

MERANTI TEMBAGA (*Shorea leprosula*)

Shorea leprosula is locally known as Meranti Tembaga or Seraya Tembaga. In 2010, it has been classified by IUCN as an endangered species. However, the distribution of this species is still abundant throughout Malaysia (Peninsular Malaysia, Sabah and Sarawak). Thus, in Malaysia, *S. leprosula* is classified as Least Concern (LC). This species is common on well-drained soils distributed from lowland to hill forests up to 600m altitudes. In Borneo, the species can be found on clayey soils, acidic and intermediate igneous rocks and periodically flooded alluvium (Chua et al., 2010).

Even though *S. leprosula* is not a listed tree species promoted for forest plantation development programs in Malaysia (Hashim et al., 2015), FRIM still conducts breeding studies for the species. This is because *S. leprosula* is an indigenous species to Malaysia and has high genetic diversity (Lee et al., 2000), which is a good basis for tree improvement programmes. On the other hand, export demand for this species in the timber industry is still very high due to the good wood quality. Unfortunately, the current practice is to harvest the trees from natural forest areas. Moreover, the study by Widiyatno et al., (2014) indicated that *S. leprosula* is among the tropical species that can help in the rehabilitation of logged-over forest areas. Therefore, having high-quality planting materials for long-term conservation effort is advantageous.

SEEDLING SEED ORCHARDS (SSO) OF MERANTI TEMBAGA (*Shorea leprosula*)

In 1997, through a collaboration between FRIM and Forestry Department of Peninsular Malaysia (JPSM), progeny trial plots for *S. leprosula* had been established at Ulu Sedili Forest Reserve, Johor and Kemasul Forest Reserve, Pahang. Forty half-sib families were tested in these trials. However, only the trial plot at Ulu Sedili Forest Reserve remains today. The main objective of the trial plot is to evaluate the progenies' growth performances, to identify the best mother trees that can act as a future source for the production of high-quality planting materials. The progeny trial plot was also established with a long-term objective to convert the trial plot into SSO, subsequently as an ex-situ conservation effort.

Seeds (half-sib) of *S. leprosula* were collected from 40 selected mother trees located in five forest reserve (FR) areas in Peninsular Malaysia namely Sungai Menyala FR (Negeri Sembilan), Bukit Rengit FR (Pahang), Bangi FR (Selangor), Gombak FR (Selangor) and Tranum FR (Pahang). The 40 selected mother trees were chosen based on the phenotypically superior plus trees characteristics; height, diameter at breast height, clear bole height, crown size, straightness, stem form, non-forking, branch size and angle, and dominant crown. Collected seeds were germinated and grown at FRIM's nursery. Selection of the seedlings before planting was done at the age of 8 months when the seedlings have reached a height of 45 to 60 cm. The selection criteria were based on the uniformity in height and being free from disease and pest infestation.

Superior plus trees were evaluated based on phenotypic assessment, whereby random numbers of samples per families were evaluated and graded based on plus tree grading criteria's;

(i) Straightness : 1 to 4
(ii) Stem form : 1 to 4
(iii) Forking: 1 to 4 (1 = ¼ ; 2 = ½ ; 3 = ¾ ; 4 = top)
(iv) Crown dominance: 1 to 3
(v) The third branch size: 1 to 4 (1 = ½ - ¾ ; 2 = ½ ; 3 = ¼ - ½ ; 4 = ¼)
(vi) The third branch angle : 1 to 4 (1 = 25˚; 2 = 45˚; 3 = 65˚; 4 = 90˚)

In 2018, assessment on the genetic evaluation and DNA profiling of *S. leprosula* germplasm established in Ulu Sedili FR, Johor was conducted. The DNA of a total 379 selected progenies were assessed using 15 microsatellite markers. The selected 379 progenies were selected based on the growth performance at 20 years old (data not shown).

Findings showed each profile are distinctive (none of any two samples shares a similar profile) and can be used as a denomination for registration and verification of superior trees. The genetic diversity parameters estimated showed high levels of genetic diversity. The mean number of allele per locus (Aa) for the entire germplasm was 13 whereas the expected heterozygosity (He) was 0.7121. These values are comparable or even higher than the values reported on *S. leprosula* and others dipterocarps from natural forests (Ng et al. 2009; Lee et al. 2006, 2013).

At the population level (collected source), the He ranged from 0.6762 (Bangi FR) to 0.7163 (Tranum FR) and the Aa ranged from 5.60 (Tranum FR) to 11.27 (Gombak FR). At the level of half-sib family, the He ranged from 0.5577 (Bangi F13) to 0.7163 (Tranum F39) and the Aa ranged from 4.20 (Bangi F14, Gombak F24 and Gombak F35) to 5.67 (Sungai Menyala F06 and Bukit Rengit F09). In conclusion, in term of levels of genetic diversity, the *S. leprosula* germplasm established has a diverse gene pool. With a broad genetic base, this germplasm is potentially suitable for application in breeding and as an ex-situ conservation area for *S. leprosula* in the centre region of Peninsular Malaysia.

Other than quantitative growth performances and the level of genetic relatedness, the plus trees to be selected for the establishment of SSO were also evaluated in term of the phenotypic (qualitative). The scores assigned for selected Candidate Plus Trees (CPTs) were then calculated in percentage (%). The results of the CPTs are shown in Table 3.

In summary, a total of 144 superiors plus trees were selected to be maintained as mother trees in the establishment of SSO, while a total of 552 inferior trees were marked for felling (total planted trees were 1280 and survival rate at 20 years old was 54%). This will serve as the first Seedling Seed Orchard of Meranti tembaga in Malaysia. The information gained from this study has provided a splendid basis for future research and most importantly, we now have a pool of genebank with high genetic diversity of *S. leprosula*. The SSO will be able to continuously supply high-quality planting materials of *S. leprosula*. Hence, will allow for the establishment of forest plantations and forest rehabilitation program, thus reducing the dependency on natural forests to supply *S. leprosula* timber.

Table 3: Ranking of CPTs of 40 half-sib families of *S. leprosula* based on average score (%)

Family	Score (%)	Rank	Family	Score (%)	Rank
F4	87.08	1	F39	79.21	21
F22	85.28	2	F28	77.42	22
F6	83.55	3	F13	77.23	23
F30	83.33	4	F20	76.75	24
F7	82.92	5	F10	76.46	25
F24	82.29	6	F31	76.17	26
F27	82.09	7	F19	76.11	27
F5	81.81	8	F11	75.88	28
F3	81.79	9	F9	75.31	29
F36	81.60	10	F23	75.28	30
F1	81.11	11	F16	75.21	31
F2	81.04	12	F18	74.45	32
F37	80.33	13	F17	74.27	33
F15	79.47	14	F47	74.09	34
F12	79.24	15	F38	73.44	35
F8	79.05	16	F35	73.13	36
F32	78.86	17	F29	73.07	37
F14	78.43	18	F25	72.36	38
F45	78.25	19	F26	58.33	39
F21	78.21	20	F34	50.33	40

ACACIA HYBRID

Acacia auriculiformis and *Acacia mangium* are native trees of Papua New Guinea and Indonesia. These trees cross-pollinate to produce a hybrid that grows faster than that of its parent trees. *Acacia* hybrid has attracted attention from the industrial player of forest plantation and has become the most planted forest species, especially in Vietnam. Even though Malaysia and Indonesia are still focusing on *A. mangium*, lately, as the *Ceratocystis* wilt disease outbreak in Malaysia, Indonesia and Vietnam, many industrial players started to switch to *Eucalyptus pellita* and *A.* hybrid.

The physical and mechanical properties of *A.* hybrid are a mixture of the properties displayed by the parents (e.g: shrinkage, moisture absorption, slide and split resistance, static bending and rupture strength). *Acacia* hybrid has the physical resemblance of *A. mangium* but the wood density characteristic is higher than that of *A. mangium*, which resembled *A. auriculiformis*. It has better mechanical strength as compared to the parent which is a good quality for pulping (Sein and Mitlohner, 2011). *A. hybrid* has also been found to grow faster than *A. mangium* and *A. auriculiformis* (Dinh and Huy 2016).

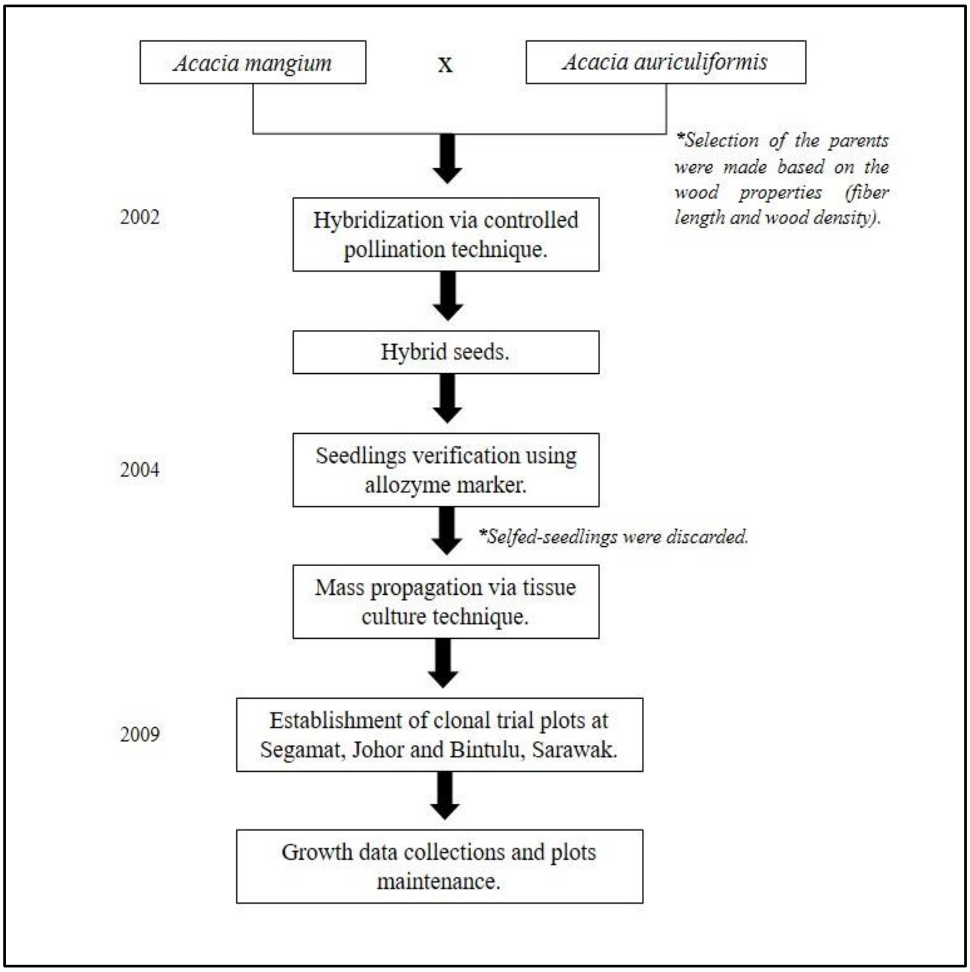
CLONAL TRIAL OF *ACACIA* HYBRID

The desirable characteristics of *A.* hybrid make it a viable candidate for forest plantations, especially to replace the current *A. mangium* plantations that have been devastated by wilt disease caused by *Ceratocystis* fungus.

FRIM in collaboration with the National University of Malaysia (UKM) had conducted a study on the development of a high-density linkage map for *A. mangium* and *A. auriculiformis* (*A.* hybrid) using Cleaved Amplified Polymorphic Sequences (CAPS) and microsatellite (SSR) markers since 2004. *Acacia* hybrid was produced via a controlled pollination hybridization technique using two parent trees from *A. mangium* (male) and *A. auriculiformis* (female). There were two methods involved, which were emasculation and direct pollination. In the emasculation method, all the stamens were discarded before the pollen was transferred onto the stigma. In the direct method, pollen from *A. mangium* was transferred to unemasculated *A. auriculiformis* flowers using a paintbrush. The study was initiated to develop clones of *A. hybrid* for future uses in commercial forest plantation programmes.

Preliminary assessment of the growth traits (height and diameter at breast height) showed significant variations among the 210 clones tested. The clonal trials are still ongoing. In 2016, research on the wilt disease caused by *Ceratocystis* fungus was initiated. The pathogens were tested against the existing clones. The data from the study were promising, showing key desirable characteristics such as being fast-growing and having tolerant towards *Ceratocystis* wilt disease.

Figure 1: Flow chart of the clonal trial plots establishment of Acacia hybrid (A. mangium X A. auriculiformis)



FRIM's level. These clones have shown promise based on their growth performance and the stability of the clones across two locations while showing resistance against *Ceratocystis* pathogens. The clones have the potential to become ideal candidates for future *Acacia* plantations.

SESENDUK (*Endospermum diadenum*)

Endospermum diadenum (synonym: *Endospermum malaccense*) is a medium to large, fast-growing and light-demanding species that can grow up to 40m. The characteristics of this tree make it an ideal candidate to be planted in degraded forests and forest plantations (Hassan et al., 2009; Ahmad, 2014) and is considered to be a good alternative for rubberwood (Ismaili et al., 2017). Commonly known in Malaysia as Sesendok, it is a lucrative timber in the forestry industry. Its light wood is used for general purposes such as making clogs, matches, toothpicks, toys, disposable chopsticks and other daily used items, making (Taharin et al., 2015).

SESENDUK (*Endospermum diadenum*) TREE BREEDING PROGRAMMES

Due to the desirable characteristics of Sesendok, FRIM has listed it as one of the 8 potential indigenous species that can be planted in forest plantations. However, obtaining planting materials of Sesendok has proven to be difficult. Although the species flowers yearly, sometimes even twice a year in Malaysia, obtaining wild seeds of *E. diadenum* is not an easy process. This is because the seed of *E. diadenum* is heavily predated by insects (Ang, 1997). Besides, the seedlings are also very fragile and can easily be dehydrated due to having few root hairs. Therefore, FRIM's Sesendok tree breeding program has focused on the production of good planting materials for Sesendok. This includes obtaining seeds from superior mother trees and the development of clones.

Three trial plots to evaluate the growth performance of Sesendok seeds and tissue culture have been established at SPF Jeli (Kelantan), SPF Selandar (Melaka), Bukit Hari FRIM Kepong and SPF Mata Ayer (Perlis) in 2015. Unfortunately, the trial plot at SPF Mata Ayer (Perlis) was lost to a fire, caused by a burning orchard nearby. One high performing Sesendok clone has been identified, that has the potential to be used for future forest plantation programs. This clone, srp001, has been ID-ed at FRIM's level. The ongoing research at the trial plots will serve as the foundation for future Sesenduk tree breeding programs.

MERANTI TEMAK NIPIS (*Shorea roxbughii*)

Shorea roxburghii, commonly known as white meranti or meranti temak nipis, is from the family of Dipterocarpaceae. The species is native to most parts of Southeast Asia and can be found in Peninsular Malaysia, Thailand, Cambodia, Vietnam, Laos, Myanmar and east of India (Pooma et al., 2017). It grows in lowland dipterocarp forest, semi-evergreen forests and limestone forests (Chua et al., 2010). The species can grow up to 40 m tall (Raju et al. 2011) and is highly tolerant of hot weather conditions, making it ideal for tropical climates (Pooma et al., 2017).

Generally, the species is harvested for its timber and resin (Pooma et al., 2017). The IUCN Red List classified *S. roxburghii* as Vulnerable (VU) (Pooma et al., 2017) but under Malaysia Plant Red List, this species is classified as Near Threatened (NT) (Chua et al., 2010). Pooma et al., (2017) has suggested that the ex situ collections of *S. roxburghii* should be conducted to conserve the species. Furthermore, the species is listed as a conservation priority in Southeast Asia. Monitoring and management of the harvesting of this species have been recommended to ensure the sustainability of the species.

PROGENY TRIAL OF MERANTI TEMAK NIPIS (*Shorea roxbughii*)

FRIM has started a *S. roxburghii* tree improvement program through the selection of plus trees. Initially, 51 Candidate Plus Trees (CPTs) were selected for grading. Among the criteria that were taken into assessment are height, diameter at breast height, crown size, straightness, stem form, crown dominancy, angle of the third branch, size of the third branch, the ability of the tree to self-pruning, non-forking and wood properties. Based on the tree grading evaluation, a total of 27 plus tree were selected out of the 51 CPTs.

The 27 half-sib families are being tested in progeny trials. Seeds from these trees were collected at the end of April 2017. After dewinging, seeds were germinated on a 100% sand bed. At the age of one year old, the seedlings were planted at SPF Mata Ayer (Perlis), SPF Jeli (Kelantan) and SPF Setiu (Terengganu). Planting activities at all sites were conducted at the onset of the rainy season. The progeny trial plots were laid out in Randomized Complete Block Design (RCBD) with 4 trees per family (27 families in total), replicated by 12 blocks, by the distance of 4m X 4m, making the total number of trees planted were 1296 trees with the total areas of 2.1 hectares.

These three locations were selected based on their different environmental and soil properties. SPF Mata Ayer has sandy loam type of soil, extremely hot weather condition and most importantly, it was an endemic region to *S. roxburghii*. Secondly, SPF Jeli has silty clay loam type of soil and higher annual rainfall. Third, the main reason for choosing SPF Setiu is to experiment with the Beach Ridges Interspersed with Swales (BRIS) type of soil. The current survival rate of the trees in these progeny trials is at > 85%, which is very promising.

These progeny trial plots will serve as the foundation to improve *S. roxburghii* planting materials. It is also an effort to introduce the indigenous species to industrial-scale plantations. Furthermore, these trial plots have the capacity to be converted into Seedling Seed Orchards (SSO) which would provide selected materials (seeds sources) for future studies and also serve as conservation plots.

MERANTI SARANG PUNAI (*Shorea parvifolia*)

Shorea parvifolia, locally known as Meranti Sarang Punai, is a tree species in the Dipterocarpaceae family. It is native to Southeast Asia and can be found in Peninsular Malaysia, Thailand, Sumatra and Borneo. It can grow up to 65m with a trunk diameter of 2m. However, most of the largest *S. parvifolia* trees have been logged, leaving mostly average height trees in the wild. It is relatively versatile, able to grow on clayey soils, sandy soils, swampy areas, riverbanks and hillsides.

The timber of this tree is pinkish-brown with white resinous streaks. It is usually used for panelling, furniture, plywood, boxes and a variety of other uses. *S. parvifolia* is listed as Endangered (EN) under the IUCN red list (Ashton, 1998). However, under Malaysia Plant Red-List, it is classified as Least Concern (LC) for Borneo and Data Deficient (DD) for Peninsular Malaysia (Chua et al., 2010).

PROGENY TRIAL OF MERANTI SARANG PUNAI (*Shorea parvifolia*)

FRIM’s tree breeding programme for *S. parvifolia* is relatively new, having only started in 2019. Planting materials for the establishment of a progeny trial plot are currently being prepared, with the long-term objective of converting the site into a seedling seed orchard.

CONCLUSION

Tree breeding is vital for the establishment of forest plantations and rehabilitating degraded forests. These are key aspects of achieving sustainable forestry. Despite the decades' worth of tree breeding programmes at FRIM, there is still a long journey ahead for this research field. Both the past and present projects have shown promise and limitless potential, but it is only through continuous effort and collaborations with key stakeholders that can we truly develop and benefit from this field.

The establishment of the genetic trial plots (progenies and clones) help to contribute towards the empowerment of the trees species germplasms. In addition, seeds sources gain from these germplasms were originated from selected plus trees/planting materials, consequently increasing the yield of timber. These planting materials will be very important for forest plantation and forest rehabilitation programs, hence reducing the dependency on natural forest.

ACKNOWLEDGEMENTS

We would like to thank the Forestry Department of Peninsular Malaysia (JPSM), various states forestry departments, National University of Malaysia (UKM), Ta Ann Plantation (Bintulu, Sarawak), universities and private companies involved in these tree breeding programmes.

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