CLONAL EVALUATION FOR EARLY GROWTH PERFORMANCE OF *TECTONA GRANDIS LINN* (TEAK) PLANTED AT THREE LOCATIONS

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ABSTRACT

Tectona grandis, commonly known as teak, is a large tree species that can grow up to heights of 30 m. T. grandis is highly prized all over the world for its renowned wood qualities. Since T. grandis is an exotic species, obtaining quality planting materials is difficult. In order to provide quality planting materials that can grow optimally, clonal trials are vital to test the performance of the clones. Therefore, this study aims to evaluate the early growth performance of 15 T. grandis clones planted at multiple locations. A total of 15 clones were selected based on superior plus trees characteristics, and then were macro-propagated via a budding technique, from a clone bank located at FRIM's research station (SPF) Mata Ayer, Perlis. Following the preparation of the planting materials, the clonal trial plots were established at SPF Jeli (Kelantan), SPF Mata Ayer (Perlis) and SPF Selandar (Melaka). The trial plots were laid out in Randomized Complete Block Design (RCBD) with four replicates and four ramets per clones. Thus, making a total of 240 ramets were planted with the distances of 4m × 4m, making the total plot areas amounting to 0.4 hectares/each. The height (m) data were analysed by the Analysis of Variance (ANOVA), following by a Tukey post-hoc test at the age of 5 months, 14 months and 38 months. In summary, based on the comparison of the three Site's locations and based on the comparison of growth performance among the 15 teak clones, ANOVA test showed a highly significant difference with p-value < 0.05, at the age of 5 months, 14 months and 38 months. Overall, teak trees planted at SPF Jeli and SPF Mata Ayer showed better survival rates and growth performance as compared to SPF Selandar. Besides, the early assessment showed that there were three clones namely; T24, T3 and T4 have the best growth performance throughout the 38 months data collected. Growth data are still being collected to assess the stability of the clones tested across multiple locations.

Key words: clonal trial, genetic variations, environment, stability, macro-propagation

INTRODUCTION

Tectona grandis, commonly known as teak, is a large tree species that can grow up to heights of 30 m. *T. grandis* is highly prized all over the world for its renowned wood qualities, namely its high resistance towards weather and pests (Akram and Aftab, 2016). Often regarded as a paragon of timber, teakwood is extensively used in construction, from bridges to interior wood panelling. Due to teakwood's appealing aesthetics, it is also used as decorative plywood to produce furniture, musical instruments, wallboards, woodwork, boxes, kitchen tables and other interior fittings (Ramachandran *et al*., 2011).

T. grandis grows naturally in tropical monsoon climates, such as India, Myanmar, Laos and Northern Thailand. The species can also be found in many parts of Southeast Asia, believed to be introduced during the fourteenth century (Hansen *et al*., 2015). Teak

is a highly adaptive species that is able to grow over a wide range of environmental conditions, from dry regions with only 500mm annual rainfall to areas with up to 5000 mm annual rainfall. However, optimal conditions for *T. grandis* are in regions that have 1200 mm to 2500 mm of annual rainfall (Hansen *et al*., 2015). Moreover, *T. grandis* is also a light-demanding species. As Peninsular Malaysia is a tropical country with lots of sunlight and an annual rainfall of 2500mm, it is an ideal location for the species.

Based on the optimal environmental conditions needed for this species and the insatiable demand for teakwood, *T. grandis* has become a common species incorporated in forest plantations across the tropics including Malaysia. 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.

Tree improvement is the process of genetically improving a tree species. This includes improving the growth rate, stem form, wood quality, pest resistance and other desirable characteristics. Tree improvement and tree breeding for *T. grandis* have been conducted in Thailand, India and Indonesia since the 1950s (Hansen *et al*., 2015). Since then, research and planting material production has been initiated in many countries.

Availability of high-quality planting materials is a major limiting factor in *T. grandis* plantation programs, especially when teak is grown as an exotic species. This is mainly because teak germination is poor and sporadic. It is estimated that only five seedlings are produced for every 100 seeds sown (Phengduang, 1993). Taking into account the low germination rate, the amount of seeds required to establish a hectare of a teak plantation is about 14400 seeds, but the amount would vary according to environmental conditions and planting distance (Phengduang, 1993).

A 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). Both plantations being at the same site and under similar management conditions. 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.

Therefore, when developing clonal tree varieties, it is vital that clonal trials are conducted to test the performance of the clones. This is to ensure that the clonal trees are indeed superior in terms of yield, physical quality features (such as stem form, and wood quality) and are able to grow optimally at desired sites. Thus, the objectives of this study are to test the stability of *T. grandis* clones at multiple locations and to evaluate the potential for the *T. grandis* clones to provide high-quality planting materials. Information gathered from this study would help indicate the feasibility of establishing teak trees plantation with high yielding clones in Peninsular Malaysia.

MATERIALS AND METHODS

Plant materials

A total of 15 clones were macro-propagated via a budding technique, from a clone bank of *T. grandis* located at FRIM's research station (SPF) Mata Ayer, Perlis. The clone bank was established from the outcrossed seeds collected from a provenance resource stand which was established in 1974. The provenance resource stand was planted with teak provenances from Thailand, Indonesia, India, Papua New Guinea, Trinidad and Sabah.

The clones were selected based on the plus trees criteria such as height, diameter at breast height, straightness and stem form. The clones were coded started with T, B and A following by the number coded for the specific clones. The difference among the three coded clones is the morphology of the leaves. For clones T, the leaves were shiny, smooth and darker green in colour resembling teak originated from India. For clones A, the leaves were coarse and had fine hairy, whereas, for clones B, the leaves were smooth and smaller than clones T and A, resembling the teak originated from Myanmar.

Clonal trial plots establishment

The clonal trial plots of *T. grandis* were established in June and August 2014 at FRIM's research station (SPF) Jeli (Kelantan) and SPF Mata Ayer (Perlis), respectively. Whereas the trial plot at SPF Selandar (Melaka) was established in October 2016. The trial plots were laid out in Randomized Complete Block Design (RCBD) with four replicates and four ramets per clones. Thus, making a total of 240 ramets (15 clones × 4 replicates × 4 trees) were planted with the distances of 4 m × 4 m, making the total plot areas to 0.4 hectares/each. The trial plots were cleaned and maintained every three months.

Statistical Analysis

Growth data (height) were collected every three months during the first two years, and every six months at the age of three to five years old. The data of height (cm) were analysed at the age of 5 months, 14 months and 38 months. The data were analysed by the

Univariate Analysis of Variance (ANOVA), following by a Tukey post-hoc test using Statistical Package for the Social Sciences (IBM SPSS Statistics 22).

RESULTS AND DISCUSSION

Comparison of the growth performance and survival rates of Teak at 5 months, 14 months and 38 months based on location differences

Based on the comparison of the Site's location, Analysis of Variance (ANOVA) test showed a highly significant difference of growth performance with the p-value < 0.05, whereby p = 0.000 (Table 1). This finding indicated that there were high variations in the growth performance among 15 teak clones tested at three different locations; SPF Jeli (Kelantan), SPF Mata Ayer (Perlis) and SPF Selandar (Melaka) at the age of 5 months, 14 months and 38 months.

Table 1: Univariate Analysis of Variance (ANOVA) Tests for Site Comparison

Growth trait (Height, HT)		Sum of Squares	df	Mean Square	F	Sig.
HT_5 months	Contrast	6.810	2	3.405	33.490	.000
	Error	50.127	493	.102		
HT_14 months	Contrast	81.081	2	40.541	57.415	.000
	Error	348.107	493	.706		
HT_38 months	Contrast	1105.705	2	552.852	110.409	.000
	Error	2468.612	493	5.007		

Results of the survival rates showed that the teak trees were vulnerable after planting. This is because the percentage of survival rates was only decreasing until 5 months old and remain stagnant from 5 months old until 3 years old. Teak trees planted at SPF Jeli and SPF Mata Ayer showed high survival percentage with 86.7% and 80.8%, respectively. Whereby, teak trees planted at SPF Selandar showed the lowest survival rate (Table 2).

Table 2: Survival rates (%) of Teak at 5 months, 14 months and 38 months based on location differences

Site/ Age	5 months	14 months	38 months	Rank
SPF Jeli	86.7	86.7	86.7	1
SPF Mata Ayer	80.8	80.8	80.8	2
SPF Selandar	52.2	52.2	52.2	3

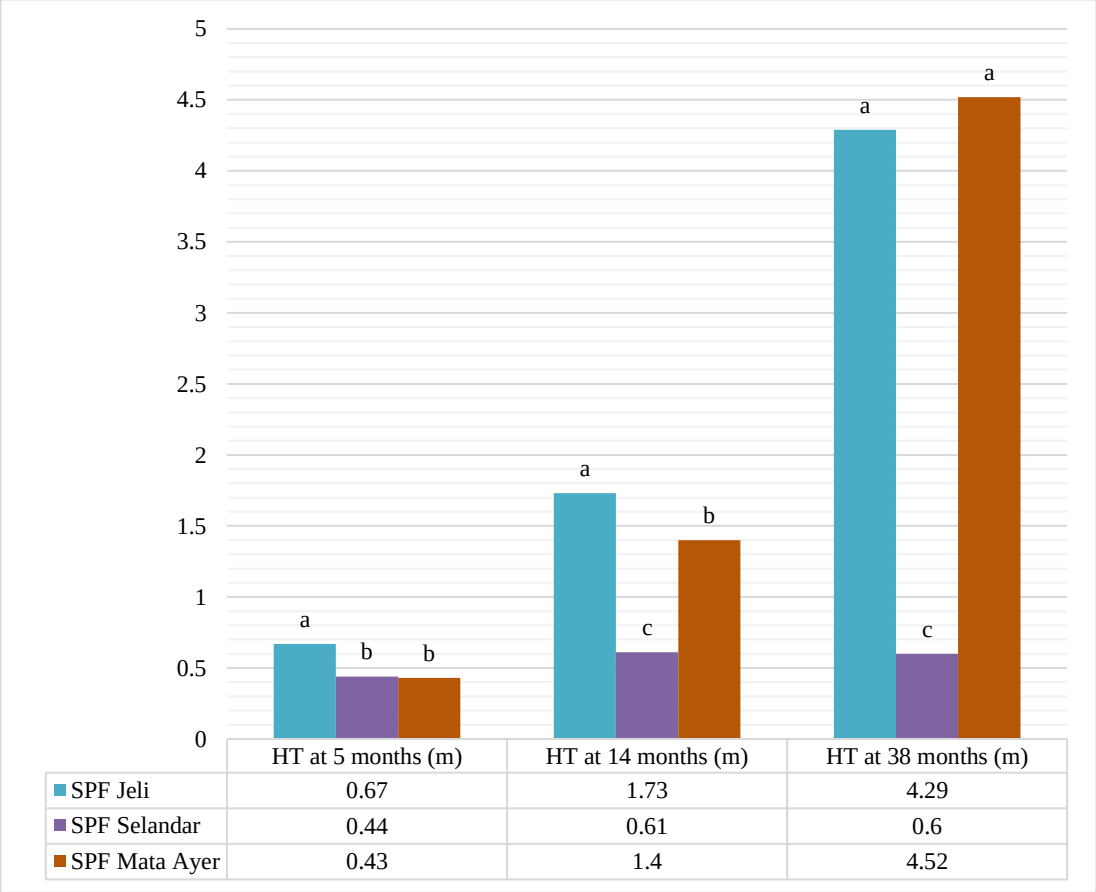
Following the ANOVA, Tukey post-hoc test revealed the variations among the three site's location (Figure 1). At an early age (5 months), the teak growth significantly better at SPF Jeli as compared to SPF Selandar and SPF Mata Ayer (Figure 1). The overall height at SPF Jeli was 0.67a ± 0.39 (STDEV) m, while at SPF Selandar and SPF Mata Ayer were 0.44b ± 0.18 m and 0.43b ± 0.28 m respectively.

At the age of 14 months, the teak growth at SPF Mata Ayer was increasing, showing the overall height at the second (1.4b ± 0.83 m), following SPF Jeli (1.73a ± 1.00 m) and significantly higher than SPF Selandar (0.61c ± 0.33 m).

There is a significant difference in the teak growth performance between site SPF Jeli and SPF Mata Ayer only during the age of 5 months and 14 months. But at the age of 38 months, even though SPF Mata Ayer showed the highest overall height which was 4.52 m (Figure 1), but the difference between the growth performance was not significant.

The teak growth performance at SPF Selandar showed that the trees were stunted. There was no apparent height increment could be observed throughout the 38 months' growth observation. The difference in growth performance become visible at the age of 14 and 38 months (Figure 1). This significant differences in growth performances might be due to the different environmental conditions such as rainfall regime, weather condition, soil physical and chemical characteristics and also the site's elevation. Additionally, based on the observation at SPF Selandar, the teak trees growth performance was significantly affected by environmental conditions.

Figure 1: Overall height (HT) at 5, 14 and 38 months at three site locations (SPF Jeli, SPF Selandar and SPF Mata Ayer)



	HT at 5 months (m)	HT at 14 months (m)	HT at 38 months (m)
SPF Jeli	0.67	1.73	4.29
SPF Selandar	0.44	0.61	0.6
SPF Mata Ayer	0.43	1.4	4.52

Survival rates and comparison of the growth performance of Teak at 5 months, 14 months and 38 months based on Clone differences

Based on the comparison among 15 teak clones, ANOVA test showed a highly significant difference with the p-value < 0.05 (Table 3). Tukey post-hoc test revealed that there are high variations among the 15 clones tested (Table 4, 5 and 6). At the age of 5 months old, the highest height was recorded by clone T5 (0.74 m) followed by clones T3, T1, T8 and T28 (Table 4). Then, at the age of 14 months old, the highest height was recorded by clone T24 (2.11 m), followed by clones T4, T5, T3 and T1 (Table 5). Again at the age of 38 months old, the highest height was recorded by clone T24 (2.11m), followed by clones A12, T4, T3 and T26 (Table 6).

The growth pattern showed that the clones were unstable throughout the 38 months of recorded data. However, clones T24, T4 and T3 showed repeated best growth performance at the age of 14 months and 38 months old (Table 5 and 6).

In general, survival rates of the 15 different clones scored more than 50%. The survival percentage ranged from 61.4% to 90.9%, with clone T3 was the highest, and clone T26 and T16 were the lowest. There were 4 clones recorded more than 80% survival percentage which was B82, T4, T1 and T3 included (Table 4 – Table 6).

Many studies on forest plantation species such as *Acacia* and *Eucalyptus* have shown that clonal planting materials have significantly increased the productivity of the plantations. Therefore, enhancing the productivity of teak plantation via clonal trials research is much more promising compared to increasing the plantation areas (Palanisamy et al., 2009).

In this study, planting materials were prepared via a budding technique which is an insertion of budpatch on the stumps (stump is a rootstock which was usually prepared 1 to 2 years early). The challenge with the teak propagation is that, its low germination rate. A study by Phengduang (1993), reported that only 5% seedlings could be produced from germinated seeds. Therefore, vegetative propagation is preferred in mass propagating the teak species. Furthermore, clonal materials could only be obtained via vegetative propagation. Yahya et al., (2019) has reported a successful micropropagation technique using nodal segments of the young mother plants. This finding would largely benefit the teak plantation sector as it would reduce the time taken to prepare the planting materials and the tissue culture plantlets are much more uniform and disease-free.

Clonal plantation of teak is not new in Malaysia, pioneer studies have been conducted on the feasibility of planting teak in mass production. In order to ensure the reliability and future of teak clonal forestry, using the best clones in optimal silvicultural management should be a priority in plantation establishment. Many aspects should be taken into consideration such as economically important wood quality and efficient mass propagation technique.

Table 3: Univariate Analysis of Variance (ANOVA) Tests for Clones Comparison

Dependent Variable		Sum of Squares	df	Mean Square	F	Sig.
HT_5months	Contrast	5.360	14	.383	3.570	.000
	Error	51.577	481	.107		
HT_14months	Contrast	25.559	14	1.826	2.176	.008
	Error	403.629	481	.839		
HT_38months	Contrast	217.063	14	15.504	2.221	.006
	Error	3357.254	481	6.980		

Table 4: Mean Height (HT) at 5 months old, Standard Deviation (STDEV) and survival rates of 15 Clones

Clone	HT (m) at 5 months old	(±) STDEV	Survival rates (%)
T5	0.74a	0.39	77.3
T3	0.68ab	0.38	90.9
T1	0.64abc	0.36	81.8
T8	0.58abcd	0.43	77.3
T28	0.57abcd	0.24	77.3
B82	0.56abcd	0.33	88.6
T24	0.54abcd	0.34	65.9
T4	0.51abcd	0.25	84.1
T17	0.46bcd	0.30	72.7
T25	0.45bcd	0.42	72.7
A12	0.45bcd	0.24	72.7
T26	0.45bcd	0.22	61.4
T16	0.44bcd	0.20	61.4
B49	0.39cd	0.36	65.9
T18	0.38d	0.31	77.3

Table 5: Mean Height (HT) at 14 months old, Standard Deviation (STDEV) and survival rates of 15 Clones

Clone	HT (m) at 14 months old	(±) STDEV	Survival rates (%)
T24	2.11a	1.19	65.9
T4	1.57ab	0.97	84.1
T5	1.55ab	0.87	77.3
T3	1.52ab	0.84	90.9
T1	1.49ab	0.87	81.8
T26	1.42ab	0.95	61.4
T16	1.36b	1.15	61.4
B82	1.33b	0.75	88.6
T8	1.31b	0.98	77.3
T25	1.28b	0.83	72.7
B49	1.25b	1.12	65.9
A12	1.22b	0.63	72.7
T28	1.19b	0.84	77.3
T18	1.15b	0.90	77.3

T17	1.14b	0.81	72.7

Table 6: Mean Height (HT) at 38 months old, Standard Deviation (STDEV) and survival rates of 15 Clones

Clone	HT (m) at 38 months old	(±) STDEV	Survival rates (%)
T24	5.55a	2.16	65.9
A12	4.35ab	2.38	72.7
T4	4.16ab	3.25	84.1
T3	4.15ab	2.85	90.9
T26	4.14ab	2.34	61.4
T16	3.80ab	3.25	61.4
T25	3.72ab	2.74	72.7
T1	3.57b	2.67	81.8
T28	3.57b	2.75	77.3
T17	3.31b	2.92	72.7
T5	3.27b	2.54	77.3
B49	3.09b	2.17	65.9
T8	2.98b	2.38	77.3
T18	2.98b	2.72	77.3
B82	2.00b	2.09	88.6

CONCLUSION

The early assessment showed that there were three clones namely; T24, T3 and T4 have the best growth performance throughout the 38 months' data collected. Additionally, the teak growth at SPF Jeli (Kelantan) and SPF Mata Ayer (Perlis) showed better performance and there wasn't a significant difference in the growth performances between the two sites. Growth data are still being collected to assess the stability of the clones tested across multiple locations.

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