

ASSESSMENT OF EARLY SURVIVAL AND GROWTH PERFORMANCE OF *SHOREA ROXBURGHII* PLANTED IN PROGENY TRIAL AT MULTIPLE LOCATIONS

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ABSTRACT

Even though current forest plantation practices in Malaysia are focusing on planting exotic species such as *Acacia mangium* and *Eucalyptus sp.*, several disease incidences such as wilt disease had caused significant losses to the planters. Therefore, FRIM has taken an initiative to explore indigenous species such as *Shorea roxburghii* which has the potentials to be grown as a forest plantation. *S. roxburghii* or locally known as meranti temak nipis is from the family of Dipterocarpaceae. Generally, this species is harvested from the natural forest for its timber. Many reforestation efforts in Malaysia and Indonesia have proved that *S. roxburghii* is a robust species with a high survival rate and considerably fast growth for indigenous species. Several studies on silviculture practices, reforestation and rehabilitation using the *S. roxburghii* species have been conducted, but none focuses on the genetic resources of the species. Therefore, improvement through the selection of plus trees has been initiated with the main objective to provide high-quality planting materials resources. In this study, the variations on the growth performance among the families grown at different sites will be evaluated. The study was started with the seeds collected from the 27 selected mother trees. The seeds were then germinated and grew at nursery until mature before the establishment of the progeny trial plots at three FRIM's research station (SPF); SPF Jeli (Kelantan), SPF Mata Ayer (Perlis) and SPF Setiu (Terengganu). The progeny trial plots were laid out in Randomized Complete Block Design (RCBD), with a total of 3240 seedlings; SPF Jeli (864 seedlings), SPF Mata Ayer (1296 seedlings) and SPF Setiu (1080 seedlings). Upon the establishment of the progeny trial plots, the growth data were collected every three months' interval. This paper will be discussing the findings on the survival rates and early growth performance (16 months old) of the 27 families. The assessment of the height (HT) parameter at 16 months old showed that there were high variations among the Site, Family and Site by Family interactions with p values < 0.000 . Survival rates of the seedlings were very promising, varied from 81.9% (SPF Jeli) to 96.4% (SPF Mata Ayer), whereas SPF Setiu scored 95.7%. In terms of growth performances, seedlings at SPF Jeli scored the highest overall HT (152.4 cm), followed by SPF Mata Ayer (107.97 cm) and SPF Setiu (92.7 cm). Whereas for the families' variations, the top three highest HT scored by the families F22 (128.4 cm), F38 (125.98 cm) and F48 (125.92 cm). The forthcoming outcome from this study would be an improved seeds sources for high-quality planting materials. Besides, the progeny trial plots could be converted into Seedlings Seeds Orchards which would also serve as germplasm in an effort towards genetic conservation.

Keywords: families, half-sib, progeny trial, variations

INTRODUCTION

Shorea roxburghii or also known as white meranti and locally known as meranti temak nipis is from the family of Dipterocarpaceae. The species is native to Southeast Asia countries such as Peninsular Malaysia, Thailand, Cambodia, Vietnam, Laos, Myanmar and east of India (Pooma et al., 2017). It can be found in lowland dipterocarp forests, semi-evergreen forests and limestone forests (Chua et al., 2010). It has been reported that this species can grow up to 40 m tall (Raju et al. 2011) and is highly tolerant to hot weather conditions (Pooma et al., 2017).

Generally, this species is harvested for its timber and resin (Pooma et al., 2017). In Malaysia, even though logging activities have been recorded, the data from the Peninsular Malaysia Fourth National Forest Inventory in 2007 showed there are approximately 232 200 stems with a diameter at breast height above 30 cm (Chua et al., 2010). The IUCN Red List classed *S. roxburghii* as a Vulnerable (VU) species (Pooma et al., 2017) but under Malaysia Plant Red List, this species is classed as Near Threatened (NT) (Chua et al., 2010). Pooma et al., (2017) has suggested that the ex situ collections of *S. roxburghii* should be made. Furthermore,

the species has also been identified as a conservation priority in Southeast Asia. Monitoring and management of the harvest of this species have also been recommended to ensure sustainability.

The study by Ho et al. (2018) demonstrated that *S. roxburghii* is suitable to be planted in disturbed or degraded areas such as ex-tine mine. The study conducted by Mohamad-Fakhri et al. (2020) also proved that *S. roxburghii* can survive in Beach Ridges Interspersed with Swales (BRIS) soil. Reforestation efforts in Malaysia for example has planted *S. roxburghii* in Secondary Forest at Chikus Forest Reserve and the results have proved that *S. roxburghii* is a robust species with a high survival rate and considerably fast growth for indigenous species (Parsada, 2013). Several studies on silviculture practices, reforestation and rehabilitation using the *S. roxburghii* species have been conducted, but none focuses on the genetic resources of the species.

Thus, an improvement through the selection of plus tree study has been initiated with the main objective is to provide high-quality planting materials. 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). However, the genetic superiority of the selected plus tree is still needed to be tested. The probabilities of the progenies from selected plus tree to have good genotype are high due to reasonable heritability. Seeds collected from the selected plus tree is grown and planted in the progeny trial. Conceptually, in the progeny trial, the seedlings are planted in the replicated field trial. The growth performance of the trial is evaluated regularly. In this paper, the variations on the early growth performance among the families grown at three different sites will be discussed. Family (or Families) in this paper 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. Whereas, half-sib family is "The group of related individuals when only one parent is common" (Zobel and Talbert, 1984).

Improvement of the tree species through genetic materials will help produce high quality and accredited breeds to support the forest plantation industry. Besides, this effort will significantly reduce the dependency on timber from the native forest. These progeny trial plots will also serve as the foundation in improving *S. roxburghii* planting resources. It is also an effort to introduce the indigenous species to industrial-scale forest plantations. Furthermore, these trial plots can be converted into Seedling Seed Orchards (SSO) which have the capacity to provide selected materials (seeds sources) for future studies and forest plantation establishment. SSO would also serve as conservation plots. Seed orchard is defined as "an area where superior phenotypes or genotypes are established and managed intensively and entirely for seed production" (Zobel and Talbert, 1984). The trial plots establishment has increased the number of field gene banks and seeds collection, consequently empowering the nation's germplasm bank.

MATERIALS AND METHODS

Selection of Superior Plus Tree

A total of 27 plus trees were selected out of 51 Candidate Plus Trees (CPTs), The selection criteria were based on the tree grading evaluation. Among the criteria that were taken into the assessment are as follow; height, diameter at breast height, crown size, straightness, stem form, crown dominancy, angle of the third branch, size of the third branch and non-forking. The sampling activities were conducted at natural forest areas in Perlis since *S. roxburghii* is native to north Peninsular Malaysia. The GPS coordinate of the locations was recorded.

Table 1: Details of the 27 selected mother trees

No.	Family	Longitude and latitude	Altitude
1	F4	N6 33.085 E100 14.289	36 m
2	F5	N6 33.210 E100 14.318	53 m
3	F11	N6 30.871 E100 14.618	27 m
4	F16	N6 29.671 E100 13.907	22 m
5	F22	N6 39.228 E100 14.828	64 m
6	F23	N6 39.392 E100 18.941	66 m
7	F27	N6 39.198 E100 14.872	59 m
8	F28	N6 39.165 E100 14.870	62 m
9	F31	N6 39.259 E100 14.951	61 m
10	F33	N6 39.333 E100 15.079	74 m
11	F34	N6 39.282 E100 14.889	63 m
12	F35	N6 39.429 E100 14.760	57 m
13	F36	N6 39.430 E100 14.788	58 m
14	F37	N6 39.660 E100 14.592	60 m
15	F38	N6 39.223 E100 13.728	-3 m
16	F39	N6 39.253 E100 13.544	22 m
17	F40	N6 39.287 E100 13.556	35 m

18	F42	N6 39.064 E100 14.202	51 m
19	F43	N6 39.060 E100 14.217	53 m
20	F44	N6 39.165 E100 14.114	62 m
21	F45	N6 39.371 E100 13.984	55 m
22	F46	N6 39.017 E100 14.279	54 m
23	F47	N6 36.197 E100 12.923	49 m
24	F48	N6 35.820 E100 13.072	43 m
25	F49	N6 31.840 E100 12.964	26 m
26	F50	N6 38.992 E100 14.403	59 m
27	F51	N6 39.165 E100 14.224	39 m

Preparation of the Planting Materials

Seeds were collected at the end of April 2017. Seeds obtained were about 600 grams to 5.0 kg depending on the families (1kg contain about 1000 seeds). After dewinging, seeds were germinated on a 100% sand bed. Germinated seedlings were then transferred into polybags containing growth media of topsoil, rice husks and sand in the ratios of 2:1:1. Seedlings were maintained at SPF Mata Ayer, Perlis until reach maturity for the planting activities.

Establishment of the progeny trial plots at three locations

At the age of one year old, the seedlings were planted at FRIM's research station (SPF), Jeli, Mata Ayer and Setiu. Planting activities at all sites were conducted at the onset of the rainy season in May and October 2018. The progeny trial plots were laid out in Randomized Complete Block Design (RCBD) with 4 trees per family (27 families in total), replicated by 8 blocks (at SPF Jeli), 12 blocks (at SPF Mata Ayer) and 10 blocks (at SPF Setiu), by the distance of 4m X 4m, making the total number of trees planted were 864 trees, 1296 trees and 1080 trees (respectively), and the total trial plot areas of 1.4 hectares, 2.1 hectares and 1.7 hectares (respectively).

The three locations were selected based on the different environmental and soil properties. SPF Mata Ayer has sandy loam type of soil, extremely hot weather conditions and most importantly *S. roxburghii* is native to North Peninsular Malaysia. Second, SPF Jeli on the other hand located in hilly areas that have 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.

Data Collection and Statistical analysis

Data were collected every three months' intervals during the first two years. Growth performance based on total height (cm) data at 16 months old were analysed using the Statistical Package for the Social Sciences (IBM SPSS Statistics 22). Analysis of Variances (ANOVA) was assessed and variations among the families were evaluated by Tukey post-hoc test.

RESULTS AND DISCUSSION

Assessment of the growth performance of *S. roxburghii* aged 16 months at three locations: SPF Jeli, Kelantan, SPF Mata Ayer, Perlis and SPF Setiu, Terengganu

Based on the Analysis of Variance (Table 2), there were highly significant differences ($p < 0.000$) of the growth performance among the three trial sites, families and there were also significant interactions between Site and Families.

Overall, SPF Jeli recorded the highest mean of Total Height (HT) at 152.36 cm, followed by SPF Mata Ayer (107.97 cm) and SPF Setiu (92.73 cm). Tukey post hoc test also revealed that there were high variations among the three trial sites. However, in terms of survival rates, SPF Mata Ayer led with 96.4%, followed by SPF Setiu (95.7%), while SPF Jeli scored the lowest survival rate with 81.9% (Table 3).

In terms of Sites locations, SPF Jeli has higher annual rainfall and lower mean annual temperature as compared to SPF Mata Ayer and SPF Setiu. On the other hand, the soil series of each site is different. SPF Jeli has Taitak and Renggam soil series, SPF Mata Ayer has Pokok Sena, whereas SPF Setiu has Jambu soil series. The soil type in SPF Setiu is considered disturbed soil. Beach Ridges Interspersed with Swales (BRIS) soil has high sand particles, high surface temperature, infertile, low cation exchange capacity (CEC) and low water holding capacity (Mohamad-Fakhri et al., 2020). This type of soil also has very low nutrients. These limitations are the main factors contributing to the lowest growth performance observed in SPF Setiu. It has to be noted that not many plant species can survive in these environmental conditions but *S. roxburghii* seedlings have very high survival rates of more than 95%. Besides, another study on the planting of *S. roxburghii* at SPF Setiu using three different media amendments, showed approximately the same HT (90.75 cm) at 24 months old, using only topsoil as the media (Mohamad-Fakhri et al., 2020). Our record showed HT (92.73 cm) at 16 months old and the planting activities of seedlings also using only topsoil as the media.

On the other hand, SPF Jeli is located in natural forest areas where wild elephants can still be seen, there were traces of the wild elephants at several blocks observed during the data collection activities which caused harm towards the seedlings planted. This external factor might have influenced the lowest survival rate observed at SPF Jeli. Whereas at SPF Mata Ayer and SPF Setiu, on

several occasions, traces of wild boar also have been observed. Fortunately, it doesn't affect much on the survival rates of the seedlings.

Overall growth performance based on the Families factor showed that the highest HT scored by F22 (128.4 cm), F38 (125.98 cm), F48 (125.92 cm) and F4 (125.42 cm), whereas the lowest HT scored by F27 (86.0 cm) and F23 (87.7 cm). Then, in terms of survival rates, in general, all Families scored more than 80% (Table 4). The highest survival rate scored by F11 (98.3%), followed by F48 (97.5%) and F44 (96.7%), whereas the lowest survival rate scored by F27 (82.5%) and F49 (86.7%) (Figure 1).

Table 2: Analysis of Variance (ANOVA) for the Mean HT of the 27 half-sib Families planted at three locations (SPF Jeli, SPF Mata Ayer and SPF Setiu)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	2099485.074 ^a	80	26243.563	14.669	0.000
Intercept	39000541.412	1	39000541.412	21799.775	0.000
Site	1542827.794	2	771413.897	431.190	0.000
Family	301905.193	26	11611.738	6.491	0.000
Site * Family	240945.960	52	4633.576	2.590	0.000
Error	5206089.299	2910	1789.034		
Total	45828664.240	2991			
Corrected Total	7305574.373	2990			

Table 3: Mean Height (cm), SE, Tukey Post-hoc test and Survival Rate (%) of the 27 half-sib Families planted at three locations (SPF Jeli, SPF Mata Ayer and SPF Setiu)

Sites	Mean HT \pm Standard Error (SE)	Tukey Post-hoc test of Mean HT	Survival Rates (%)
SPF Jeli	152.36 \pm 1.60	a	81.9
SPF Mata Ayer	107.97 \pm 1.20	b	96.4
SPF Setiu	92.73 \pm 1.32	c	95.7

S. roxburghii has been planted at SPF Segamat (Johor), SPF Bidor and Bukit Gantang (Perak) for reforestation of logged-over forest areas and rehabilitation of degraded and disturbed areas. SPF Segamat is a logged-over forest area, SPF Bidor is an ex-tin mine, whereas Bukit Gantang was a paddy field.

Among the main impediment in the forest plantation industry is the need for huge land for the plantation. However, if *S. roxburghii* can even survive in degraded and disturbed areas, this species can be used for forest plantation and it would help save the land usage consequently rehabilitate the degraded and disturbed areas. The study conducted by Ho et al. (2018) has proven that *S. roxburghii* can survive to be planted at an ex-tin mine, whereas our study and Mohamad-Fakhri et. al. (2020) have proven that the species can also survive well even when planted in BRIS soil.

Second, industrial players are inclined towards exotic species such as *Acacia* sp. and *Eucalyptus* sp mainly due to the fast growth and robust characteristics. The study by Ho et al. (2018) also showed that the growth of *S. roxburghii* could reach Mean Annual Increment (MAI) as high as 3.9 cm. yr⁻¹ for diameter at breast height (DBH) and 2.8 m. yr⁻¹ for total height (HT). This is considerably fast growth for indigenous species. In comparison with our experiences in conducting progeny trial of *S. leprosula*, the highest recorded MAI for DBH was 1.68 cm. yr⁻¹, while the highest MAI for HT was 1.3 m. yr⁻¹ (Nor-Fadilah et al., 2018). Even though there was a difference in age comparison between the studies, but the growth performance of *S. roxburghii* was faster than *S. leprosula*. These qualities (fast-growth and high survival rates) showed that *S. roxburghii* has the potentials to be introduced as forest plantation species.

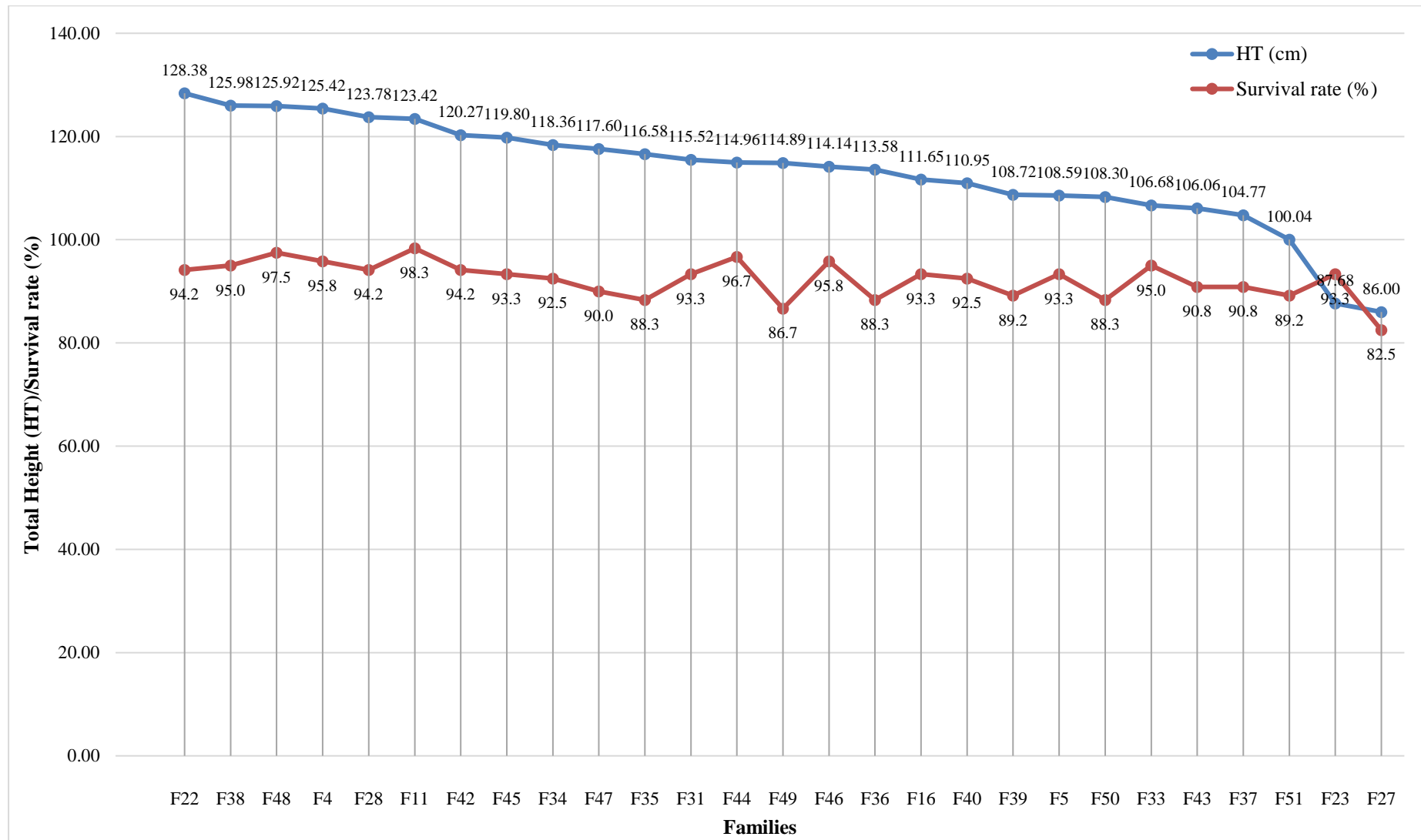
The study also indicated that there was a significant variation in the growth performance of *S. roxburghii* among the three sites and indicating that the best growth performance was observed at SPF Segamat (Ho et al., 2018). Our study showed that the early growth performance of *S. roxburghii* at SPF Jeli (out of the three trial locations) is the best. The distribution of *S. roxburghii* is native to the Northern region of Malaysia. Naturally, *S. roxburghii* can only be found at Perlis and north of Kedah (Perlis and Kedah are located in the North of Malaysia). Both findings indicating that *S. roxburghii* may be able to adapt to various environmental conditions since SPF Segamat is located in the Southern region of Malaysia, whereas SPF Kelantan and SPF Setiu are located in the East Coast region.

Table 4: Overall Mean of Total Height (cm), STDEV, Tukey Post-hoc test and Survival Rate (%) of the 27 half-sib Families planted at three locations (SPF Jeli, SPF Mata Ayer and SPF Setiu)

Family	Mean HT (cm)	± STDEV	Tukey Post-hoc test	Survival rates (%)
F22	128.38	45.57	a	94.2
F38	125.98	54.59	ab	95.0
F48	125.92	44.28	ab	97.5
F4	125.42	50.99	abc	95.8
F28	123.78	56.29	abc	94.2
F11	123.42	47.74	abc	98.3
F42	120.27	45.12	abcd	94.2
F45	119.80	52.43	abcd	93.3
F34	118.36	51.51	abcd	92.5
F47	117.60	55.19	abcd	90.0
F35	116.58	47.10	abcd	88.3
F31	115.52	41.56	abcd	93.3
F44	114.96	45.33	abcd	96.7
F49	114.89	42.85	abcd	86.7
F46	114.14	47.44	abcd	95.8
F36	113.58	48.49	abcd	88.3
F16	111.65	39.47	abcd	93.3
F40	110.95	43.67	abcd	92.5
F39	108.72	53.54	abcde	89.2
F5	108.59	46.83	abcde	93.3
F50	108.30	49.05	abcde	88.3
F33	106.68	52.21	bcdef	95.0
F43	106.06	46.47	bcdef	90.8
F37	104.77	45.09	cdef	90.8
F51	100.04	50.86	def	89.2
F23	87.68	41.52	ef	93.3
F27	86.00	60.88	f	82.5

**Mean with the same alphabet showed no significant difference at 0.05*

Figure 1: Mean of Total Height (cm) and Survival Rate (%) of the 27 half-sib Families planted at three locations (SPF Jeli, SPF Mata Ayer and SPF Setiu)



Assessment of the growth performance of *S. roxburghii* aged 16 months at SPF Jeli, Kelantan

Based on the Analysis of Variance (Table 5) for the mean of HT at SPF Jeli, there were highly significant differences ($p < 0.001$) of the growth performance among the 27 Families tested in the progeny trial.

The growth performance at SPF Jeli is very promising, the highest HT scored by F28 (189.79 cm) and F22 (176.62 cm), whereas the lowest HT scored by F23 (114.96 cm). Then, in terms of survival rates, even though in overall SPF Jeli scored the lowest survival rate, 26 out of 27 Families tested scored more than 70%. The lowest survival rate was scored by F49 (68.8%) while the highest survival rate was scored by F46 (96.9%) (Figure 2). Tukey Post-hoc test revealed that the variations among the Families in terms of growth performance were similar from the highest mean HT until the 25th recorded mean HT (Table 6). On the other hand, standard error (SE) and standard deviation (STDEV) observed were considered as high (data for STDEV is not shown). High STDEV indicated that there are high variations among the progenies within a Family.

Table 5: Analysis of Variance (ANOVA) for the Mean HT of the 27 half-sib Families planted at SPF Jeli, Kelantan

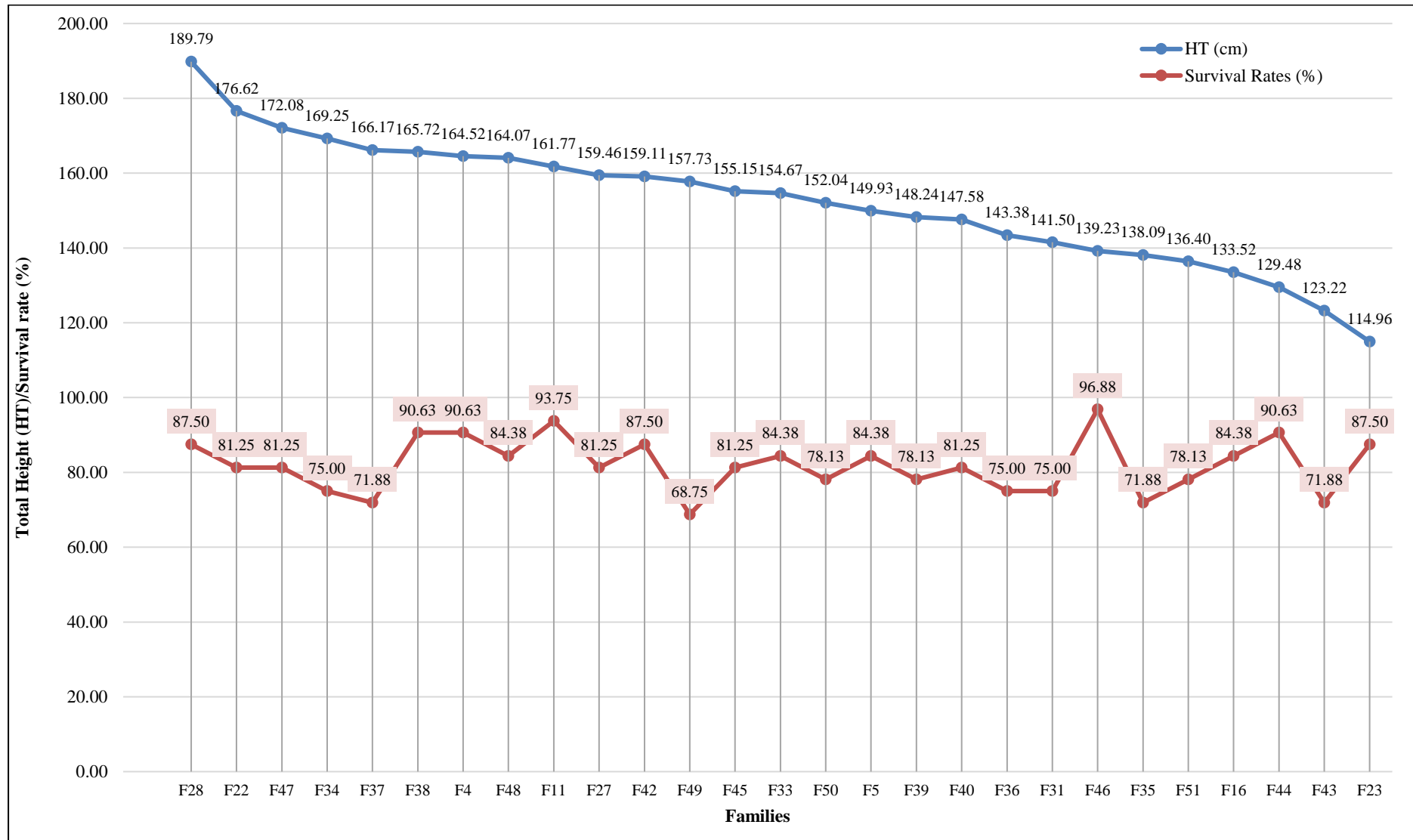
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	201045.269	26	7732.510	2.163	0.001
Within Groups	2434061.108	681	3574.245		
Total	2635106.377	707			

Table 6: Mean of Total Height (cm), SE, Tukey Post-hoc test and Survival Rate (%) of the 27 half-sib Families planted at SPF Jeli, Kelantan

Family	Mean HT (cm)	± SE	Tukey Post-hoc test	Survival Rates (%)
F28	189.79	11.91	a	87.5
F22	176.62	9.70	ab	81.3
F47	172.08	14.35	abc	81.3
F34	169.25	13.31	abc	75.0
F37	166.17	9.03	abc	71.9
F38	165.72	12.83	abc	90.6
F4	164.52	11.39	abc	90.6
F48	164.07	9.18	abc	84.4
F11	161.77	10.60	abc	93.8
F27	159.46	13.12	abc	81.3
F42	159.11	10.22	abc	87.5
F49	157.73	9.57	abc	68.8
F45	155.15	13.33	abc	81.3
F33	154.67	12.14	abc	84.4
F50	152.04	11.67	abc	78.1
F5	149.93	9.74	abc	84.4
F39	148.24	14.91	abc	78.1
F40	147.58	10.09	abc	81.3
F36	143.38	13.59	abc	75.0
F31	141.50	11.43	abc	75.0
F46	139.23	10.55	abc	96.9
F35	138.09	12.85	abc	71.9
F51	136.40	14.84	abc	78.1
F16	133.52	7.97	abc	84.4
F44	129.48	10.71	abc	90.6
F43	123.22	13.49	bc	71.9
F23	114.96	9.90	c	87.5

*Mean with the same alphabet showed no significant difference at 0.05

Figure 2: Mean of Total Height (cm) and Survival Rate (%) of the 27 half-sib Families planted at SPF Jeli



Assessment of the growth performance of *S. roxburghii* aged 16 months at SPF Mata Ayer, Perlis

Based on the Analysis of Variance (Table 7) for the mean of HT at SPF Mata Ayer, there were highly significant differences ($p < 0.000$) of the growth performance among the 27 Families tested in the progeny trial. In general, the growth performance of the seedlings at SPF Mata Ayer is second best after SPF Jeli. The highest HT scored by F45 (123.63 cm), whereas the lowest HT scored by F27 (61.74 cm). Overall, SPF Mata Ayer scored the highest survival rates (96.4%). Five families scored 100% survival rates which are F48, F22, F31, F11 and F37. Only one Family scored lower than 90.0% which is F51, 87.5% (Figure 3).

Tukey Post-hoc test revealed that the variations among the 27 tested Families in terms of growth performance were similar from the highest mean HT until the 24th recorded mean HT (Table 8). However, there were high variations between the seven Families (F45, F35, F4, F48, F38, F22 and F31) that scored the top of mean HT with the lowest bottom three Families (F51, F23 and F27). On the other hand, standard error (SE) and standard deviation (STDEV) observed were considered as high (data for STDEV is not shown). High STDEV indicated that there are high variations among the progenies within a Family.

Table 7: Analysis of Variance (ANOVA) for the Mean HT of the 27 half-sib Families planted at SPF Mata Ayer, Perlis

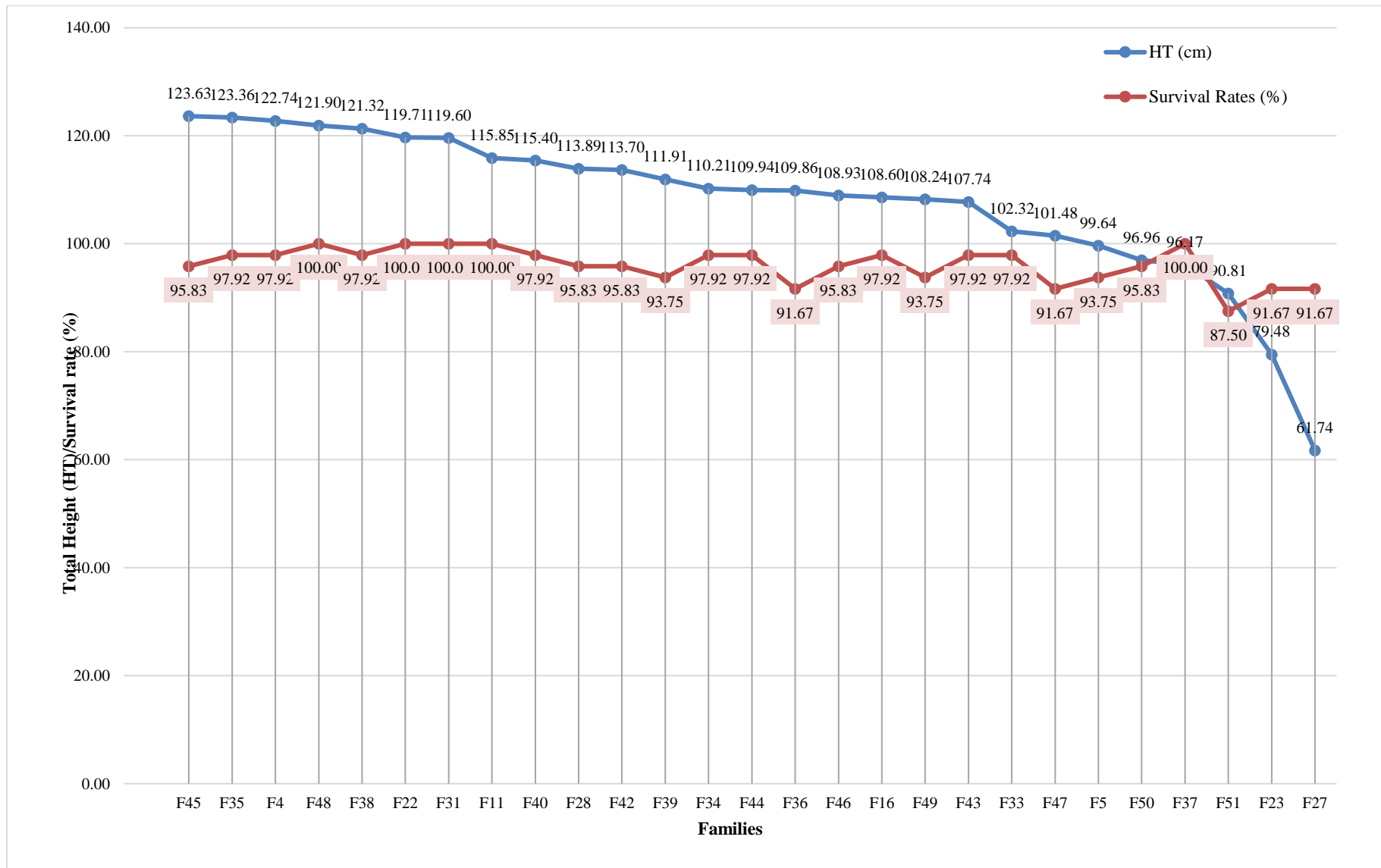
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	234859.048	26	9033.040	6.707	.000
Within Groups	1645772.998	1222	1346.786		
Total	1880632.047	1248			

Table 8: Mean of Total Height (cm), SE, Tukey Post-hoc test and Survival Rate (%) of the 27 half-sib Families planted at SPF Mata Ayer, Perlis

Families	Mean HT (cm)	± SE	Tukey Post-hoc test	Survival Rates (%)
F45	123.63	6.90	a	95.8
F35	123.36	5.85	a	97.9
F4	122.74	4.60	a	97.9
F48	121.90	5.03	a	100.0
F38	121.32	5.00	a	97.9
F22	119.71	4.76	a	100.0
F31	119.60	4.99	a	100.0
F11	115.85	5.47	ab	100.0
F40	115.40	4.43	ab	97.9
F28	113.89	4.08	ab	95.8
F42	113.70	4.99	ab	95.8
F39	111.91	6.40	ab	93.8
F34	110.21	5.64	ab	97.9
F44	109.94	6.78	ab	97.9
F36	109.86	6.36	ab	91.7
F46	108.93	4.74	ab	95.8
F16	108.60	5.70	ab	97.9
F49	108.24	4.81	ab	93.8
F43	107.74	6.04	abc	97.9
F33	102.32	6.32	abc	97.9
F47	101.48	5.84	abc	91.7
F5	99.64	5.90	abc	93.8
F50	96.96	5.23	abc	95.8
F37	96.17	4.27	abc	100.0
F51	90.81	4.67	bc	87.5
F23	79.48	4.64	cd	91.7
F27	61.74	4.76	d	91.7

*Mean with the same alphabet showed no significant difference at 0.05

Figure 3: Mean of Total Height (cm) and Survival Rate (%) of the 27 half-sib Families planted at SPF Mata Ayer



Assessment of the growth performance of *S. roxburghii* aged 16 months at SPF Setiu, Perlis

Based on the Analysis of Variance (Table 9) for the mean of HT at SPF Setiu, there were highly significant differences ($p < 0.000$) of the growth performance among the 27 Families tested in the progeny trial. In general, the growth performance of the seedlings at SPF Setiu is considered the lowest as compared to the SPF Jeli and SPF Mata Ayer. The highest HT scored by F44 (110.33 cm), whereas the lowest HT scored by F27 (56.97 cm). Overall, SPF Setiu scored the second-highest survival rate (95.7%). Nine families scored 100% survival rates which are F44, F11, F34, F31, F45, F5, F51, F33 and F23. There was one Family that scored significantly lower survival rate which is F27 with 72.5% (Figure 4).

Tukey Post-hoc test revealed that the variations among the 27 tested Families in terms of growth performance were similar from the highest mean HT until the 21st recorded mean HT (Table 10). However, there were high variations between the highest mean HT (F44) with the lowest six Families (F40, F33, F37, F39, F23 and F27). On the other hand, standard error (SE) and standard deviation (STDEV) observed were considered as high (data for STDEV is not shown). High STDEV indicated that there are high variations among the progenies within a Family.

Table 9: ANOVA for the Mean HT of the 27 half-sib Families planted at SPF Setiu, Terengganu

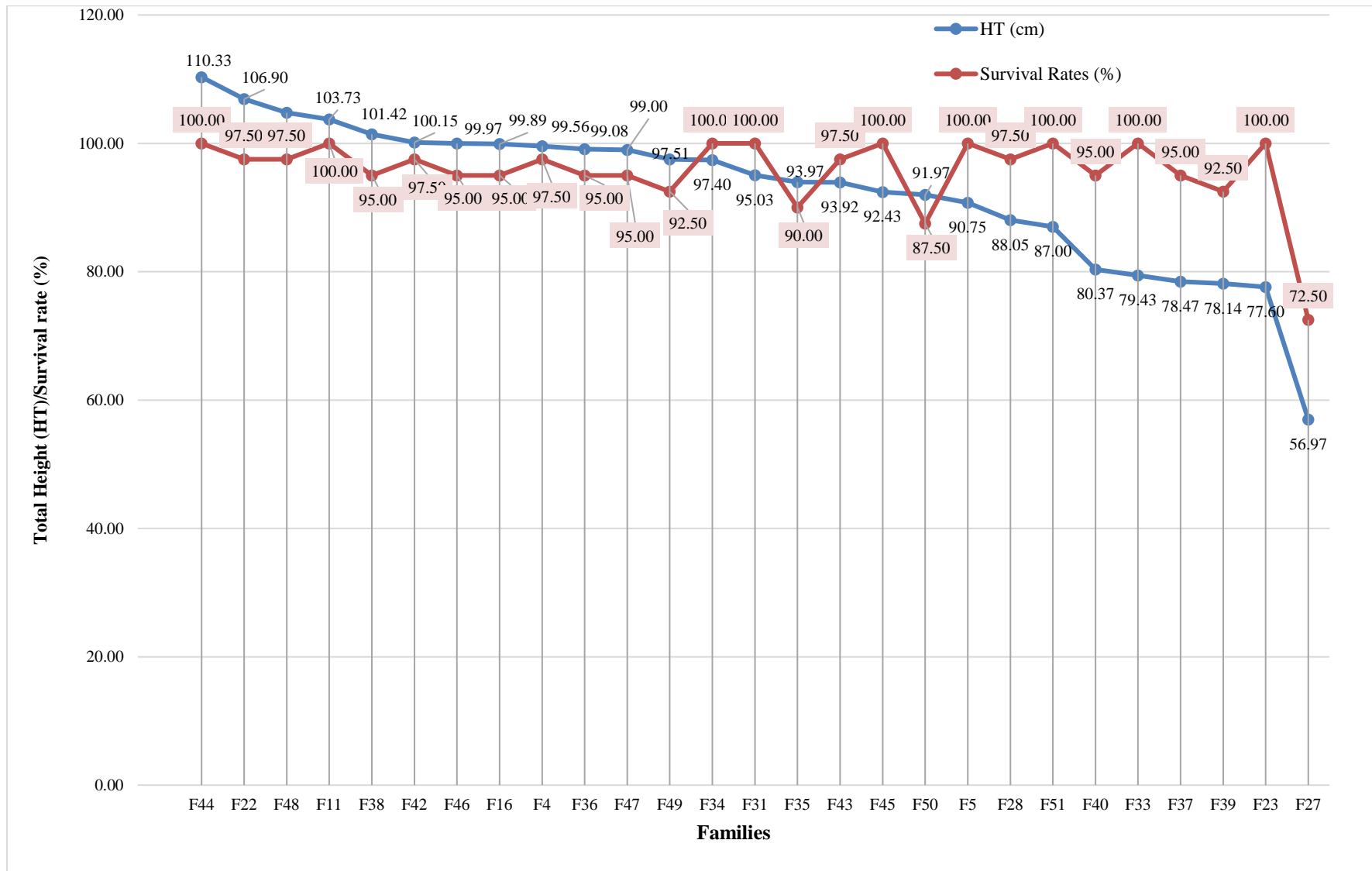
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	123509.799	26	4750.377	4.247	0.000
Within Groups	1126255.193	1007	1118.426		
Total	1249764.991	1033			

Table 10: Mean of Total Height (cm), SE, Tukey Post-hoc test and Survival Rate (%) of the 27 half-sib Families planted at SPF Setiu, Terengganu

Families	Mean HT (cm)	± SE	Tukey Post-hoc test	Survival Rates (%)
F44	110.33	4.78	a	100.0
F22	106.90	5.08	ab	97.5
F48	104.77	5.57	abc	97.5
F11	103.73	5.00	abc	100.0
F38	101.42	7.51	abc	95.0
F42	100.15	5.03	abc	97.5
F46	99.97	7.46	abc	95.0
F16	99.89	5.31	abc	95.0
F4	99.56	7.09	abc	97.5
F36	99.08	5.25	abc	95.0
F47	99.00	4.27	abc	95.0
F49	97.51	5.97	abc	92.5
F34	97.40	5.22	abc	100.0
F31	95.03	4.37	abc	100.0
F35	93.97	5.93	abc	90.0
F43	93.92	5.80	abc	97.5
F45	92.43	4.22	abc	100.0
F50	91.97	6.56	abc	87.5
F5	90.75	5.40	abc	100.0
F28	88.05	4.99	abc	97.5
F51	87.00	6.26	abc	100.0
F40	80.37	4.60	bcd	95.0
F33	79.43	4.03	bcd	100.0
F37	78.47	3.84	cd	95.0
F39	78.14	3.38	cd	92.5
F23	77.60	5.58	cd	100.0
F27	56.97	4.68	d	72.5

*Mean with the same alphabet showed no significant difference at 0.05

Figure 4: Mean of Total Height (cm) and Survival Rate (%) of the 27 half-sib Families planted at SPF Setiu



CONCLUSION

In general, the best growth performances at 16 months old were observed from F22, F38 and F48, whereas F27 consistently showed poor growth performances at SPF Mata Ayer and SPF Setiu. However, the variations observed among the progenies within a Family were very high, this might be due to the young age of the progenies. Second, the site's location affected the growth performances of the progenies significantly and showed that the seedlings planted at SPF Jeli have the best growth performance of the three trial locations.

This study will be able to provide important fundamental knowledge on the growth performance of *S. roxburghii* and the potential of the species to be introduced as forest plantation species in Malaysia and perhaps Southeast Asia. On the other hand, the progeny trial plots would also serve as an ex-situ conservation and in the long run, the plots could be converted into Seedlings Seed Orchards (SSO). SSO will have the capacity to provide improved planting materials as the mother trees in the stand are selected and the growth performances have been evaluated.

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