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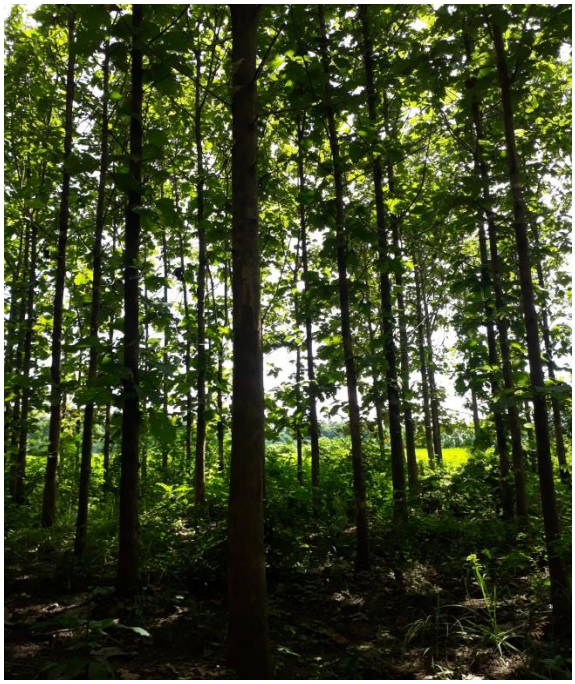
Assessing Growth Performance of a Teak Provenance Trial in Bago Yoma to Support Myanmar Reforestation and Rehabilitation Programme



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မြန်မာ့သစ်တောပြန်လည်တည်ထောင်ခြင်းစီမံကိန်း အထောက်အကူဖြစ်စေရန် အနယ်နယ်ကျွန်းစမ်းသပ်ကွက်မှ ကျွန်းမျိုးများ၏ကြီးထွားမှုလက္ခဏာများကို ဆန်းစစ်ခြင်း

တင်နှောင်းအေး၊တောအုပ်ကြီး
ဒေါက်တာရာဇာမင်း (Coalition Facilitator)၊ ဆုံစည်းပရိဂရမ်၊ဗြိတိသျှကောင်စီ
နွေးမွန်မွန်အောင်၊ဦးစီးအရာရှိ
ဝင်းဝင်းနွယ်၊တောအုပ်ကြီး

စာတမ်းအကျဉ်း

ယခုစာတမ်းသည် ပဲခူးရိုးမဒေသ တပ်ကုန်းမြို့နယ်၊ မိုးစွေကျေးရွာ၊ ငလိုက်ကြိုးဝိုင်း တွင် တည်ထောင်ထားသော ၁၁ နှစ်သားအရွယ်ရှိ အနယ်နယ်ကျွန်းစမ်းသပ်ကွက်မှ ကျွန်းမျိုးများ၏ ကြီးထွားမှု၊ အသက်ရှင်သန်မှုနိုင်နှုန်း ပင်စည်ဖြောင့်တန်းမှုအဆင့်များကို လေ့လာ ထားခြင်းဖြစ်ပါ သည်။ ယခုစာတမ်း၏ရလာဒ်များကို ယခင်လေ့လာမှု၏ ရလာဒ်များနှင့် နှိုင်းယှဉ်ထားပါသည်။ အနယ်နယ်ကျွန်းမျိုးများ၏ ပျမ်းမျှရှင်သန်မှုရာခိုင်နှုန်းမှာ ၈၀ ရာခိုင်နှုန်း ခန့်ရှိပါသည်။ ကျွန်းမျိုး များကြားတွင် ပင်စည်ဖြောင့်တန်းမှုအဆင့်၊ ပျမ်းမျှအချင်းနှင့် အမြင့် များသည် သိသာထင်ရှားစွာ ကွဲပြားခြားနားမှုရှိပါသည်။ ကန့်ဘလူကျွန်းသည် ရှင်ပင်ရာခိုင် နှုန်း(၈၂.၄%) ဖြင့် ရှင်သန်မှု အကောင်းဆုံးဖြစ်ပြီး နတ်တလင်းကျွန်းတွင် ပင်စည် ဖြောင့်တန်းသော ပင်ထောင်အရေအတွက် အများဆုံးပါဝင်ပါသည်။ ပဲခူးကျွန်းသည် ပျမ်းမျှ အချင်း (၁၉ စင်တီမီတာခန့်) ဖြင့် ကြီးထွားမှု အကောင်းဆုံးဖြစ်ပြီး ဖြူးကျွန်းသည် ပျမ်းမျှအမြင့် (၁၆.၉၈မီတာခန့်) ဖြင့် ကြီးထွားမှု အကောင်းဆုံး ဖြစ်ပါသည်။ ပဲခူး၊ ဖြူး နှင့် နတ်တလင်း ကျွန်းများသည် ယခုလေ့လာမှုတွင် ကြီးထွားမှုအကောင်းဆုံး ကျွန်းမျိုးများ ဖြစ်ပါသည်။ သို့ရာတွင် ကျွန်းမျိုးများ၏ ကြီးထွားမှု အခြေအနေများသည် အသက်နှင့်စိုက်ပျိုး ထားသည့်နေရာဒေသ၏ ရာသီဥတုအရ ဆက်လက်ပြောင်းလဲနိုင်ပါသဖြင့် နောင်အနာဂတ် ကာလများတွင်လည်း သုတေသန ဆက်လက်ပြုလုပ်သင့်ပါသည်။

Assessing Growth Performance of a Teak Provenance Trial in Bago Yoma to Support Myanmar Reforestation and Rehabilitation Programme

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Abstract

This study examines the growth, survival and stem straightness between teak (Tectona grandis L.f.) provenances in 11-year-old field trial in Moeswe, Bago Yoma region in Myanmar. The results are compared with earlier result. Field establishment was suitable with average mortality about 20%. The findings reveal that the significant differences ($p<0.001$) existed for stem straightness, dbh and height among eight provenances. Kantbalu provenance showed the highest survival rate (82.4%). Nattalin provenance is the best in terms of stem straightness. Bago and Phyu provenances are the best in terms of diameter and height. The best performing provenances are Bago, Phyu, Nattalin and Kantbalu provenances in terms of growth performance with suitable survival and stem straightness confirming in this evaluation at age 11 years. The comparative performance of provenances might change with age and place, the follow study is recommended in order to achieve consistent results in the future.

Keywords: Growth, Provenances, Survival, Stems straightness, *Tectona grandis*

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1. Introduction

Teak (*Tectona grandis* Linn.f.) is one of the most valuable timber tree species of the world. It has many favorable properties such as its color, texture, resistances to termites, fungi and weathering, and suitability for home construction and will continue to be one of the most admired and precious timber tree species in the world (Tint and Gyi, 1995). Teak is naturally distributed in India, Myanmar, Laos and Thailand. In Myanmar, teak occurs naturally all over the country except in the dry zone or tidal zone in delta regions or in the areas with the elevation more than 914 m (Tint and Gyi, 1995). As teak occurs on a great variety of soils and different environments, it can display geographic differences in one or more characteristics. Teak of the best quality timber which can be used for producing cylindrical and sound logs occurs in the Bago Yoma in which there are favorable soil and climatic conditions for best growth of teak (Kermode, 1964).

Due to the population pressure and increasing demand of timber for domestic uses and export, large teak plantations were formed in Myanmar starting from 1972. Teak is relatively easy to establish plantations where it generally shows high growth rates during the first twenty years (Pedersen et al., 2007). For achieving a high percentage of heart-wood, the rotation age can be as high as 120 years. However, the rotation age is typically shorter, for example, less than 40 to 60 years (Pandey and Brown, 2000). With regard to plantation programs, it is important that all the plantations should produce maximum volume of good quality timber in short rotations.

Earlier, most teak wood came from natural forests. However, the areas with teak have rapidly diminished and this had led to a greater dependence of plantation-grown teak. Although the growth and yield of plantations are largely influenced by site quality, other characteristics such as stem straightness, mode of branching, etc. are strongly controlled by genetic factors. Therefore, for large scale plantations, the seeds and seedlings used must be of higher genetic quality. This emphasizes the need to collect as much information as possible from existing field trials comparing different provenances of teak for improving the choice of seed sources for teak plantations and teak breeding programs. Several studies in Myanmar have shown differences between teak provenances in survival, growth, health and different stem quality such as stem form, crown form and mode of branching (Gyi, 1972; Min and Lwin, 2004; Naing, 2012; Khin and Lwin, 2015; Naing, 2015 and Lwin et al., 2010). This study aimed at examining the variation of growth and stem straightness between teak (*Tectona grandis* Linn.f.) provenances, and to examine the growth performance of 11-year-results with earlier results from Naing (2015) who studied at 8 years after planting.

2. Objectives

This research is aimed

1. to compare the growth performance of teak from various seed sources in the study site, and
2. to select suitable provenances for seed sources to support large scale teak plantations

3. Literature Review

Provenance is a synonym for "origin" or "source" and "ultimate natural origin" (Wright, 1976). Provenance testing is essential for species with naturally wide ecological ranges (Burley and Wood, 1976). Teak is expected to be numerous provenances because of its wide and discontinuous distribution (Gyi, 1972). Practical use of provenance data can be applied in planning breeding work, generalized planting recommendations, recommendations for seed from specific stands, and provenance tests as seed orchards.

Provenance differences for teak as well as many species have been investigated in as international network of provenance trials and these trials reveal important genetic variation between provenances tested at locations within and outside the natural distribution area (Kajaer et al., 1995), (Kaosa-ard et al., 1997). In Myanmar, several studies have examined the differences between teak provenances such as survival rate, growth, health and different stem quality such as stem form, crown form and mode of branching (Gyi, 1972; Naing, 2012; Khin and Lwin, 2015; Naing, 2015; Lwin et al., 2010; and Min and Lwin, 2004) and the existence of such differences within the species is still established. Gyi (1972) found that Java provenance gave the best germination followed by Taungoo in nursery stage and Myitkyina provenance was found to be the best in seedling development followed by Indian provenance in his test in compartment no. (57) in Taungnyo Reserved Forest in Pyinmana. Min and Lwin (2004) stated that significant differences of provenances for height and diameter at 5^{th} year were found in Phyu trial site in east of Bago Yoma. For this trial site in compartment no. (9) in Ngalike Reserved Forest in Pyinmana, Naing (2015) stated that Nattalin provenance is the best and followed by Taungoo provenance in terms of GBH at 8 years after planting.

Teak trees are genetically diverse organisms. Better growth, quality and adaptability of teak can be achieved by careful selection of the best sources when raising seedling for a given planting site (Kjaer, 2000). Kjaer (2000) and (Finkeldey, 2007) reported that seed source (provenance) testing and use of best seed sources is one of the important activities and starting point in the initial phase of most domestication programs, and leading to a tree improvement program. Considering the importance of provenance test in plantation program and being lack of much information in teak genetic variation in Myanmar, a future study on teak provenance is undoubtedly necessary to implement for teak as well as for other commercial species.

4. Materials and Methods

4.1 Study Area

This study was carried out in a teak provenance trial which was established in 2007 and having 11 years old now. The trial site is located in compartment No.(9), Ngalaik Reserved Forest, Tatkone Township. It includes 8 provenances namely Nattalin, Paukhaung, Kantbalu, Oatwin, Taungoo, Phyu, Bago and Thabeikyin where teak naturally occurs. The experimental design was a Randomized Complete Block Design (RCBD) with five replications. One replication was made up of 8 plots representing 8 provenances, which were assigned randomly. Within each plot, 25 seedlings of one provenance were planted in 5 rows and 5 columns with 3 m x 3 m (9 ft x 9 ft) spacing. The whole experimental area in this trial site included 1000 seedlings of 8 provenances, covering an area of 1.143 ha (2.82 Ac). The layout of the experiment design and name of provenances with respective code numbers are shown in Table 1.

Table 1. Layout and Design for Teak Provenance Trial in Compartment No. (9), Ngalaik Reserved Forest, Tatkone Township, Naypyitaw

17	18	14	16	15	11	13	12
22	21	23	28	27	24	25	26
36	35	37	34	33	32	38	31
48	43	41	42	46	46	44	45
54	57	56	55	51	58	52	53

Note

1st Digit	Block No. (Replication)
2nd Digit	Provenance No.
No. of provenances	8
	(1) Nattalin
	(2) Paukhaung
	(3) Kanbalu
	(4) Oaktwin
	(5) Taungoo
	(6) Phyu
	(7) Bago
	(8) Thabeikkyin
No. of Replications	5
No. of trees per plot	25 (5 rows and 5 columns)
Spacing	9 ft x 9 ft
Total Number of trees	1000
Area	1.143 ha (2.82 Ac)

4.2 Data Collection and Analysis

In this experiment, survival counting, stem form, height and diameter at breast height of all standing trees were conducted in order to evaluate the adaptability and growth performance of the trees to the environment of this site. The survival, stem form, height and diameter at breast height (dbh) of all provenances were completely enumerated during August, 2018. Diameter at breast height (dbh) is measured at 1.3 m above ground by using diameter tape. Total height of trees was measured with a Suunto dendro-clinometer. Regarding the quality of the tree, it is generally accepted that a long, straight bole with small knots is desirable from a utilization point of view. For the judgment of stem

form or stem straightness, the severity of bends, i.e. the tendency of crook-ness or straightness is evaluated. According to Kjaer et al. (1995), stem form was evaluated as scoring the stems on a 1-5 form scale in this study (Table 2). For data analysis, SPSS version 20 was used. Descriptive Statistics was used to analyze minimum, maximum and mean value of height and DBH among provenances in the study site. Analysis of Variance (ANOVA) was used to test the differences between provenances and the post hoc test was also conducted to compare the differences of the assessed parameters between any two provenances in the study site.

Table 2. Description of stem straightness scores

Score	Stem Form (Straightness)
1	Straight tree
2	Slightly wavering, few small bends
3	Wavering tree, many small bends
4	Crooked tree with 1-2 severe bends
5	Crooked tree with 3 or more severe bends

5. Results

5.1 Survival and Stem Form

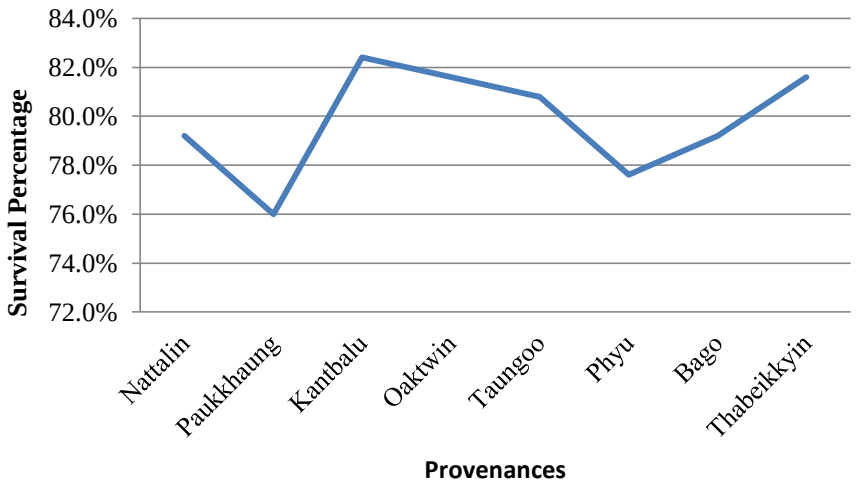

Figure 1. Survival percentage of provenances

The survival rates of the provenances were a little variable, ranging from 76% to 82.4% (figure 1). Kantbalu provenance showed the highest survival rate 82.4%, followed by Oaktwin and Thabeikkyin (81.6%), Taungoo (80.8%), and Bago (79.2%), respectively. Paukkhaung provenance showed the lowest survival rate (76%) among eight provenances in the trial site (Figure 1).

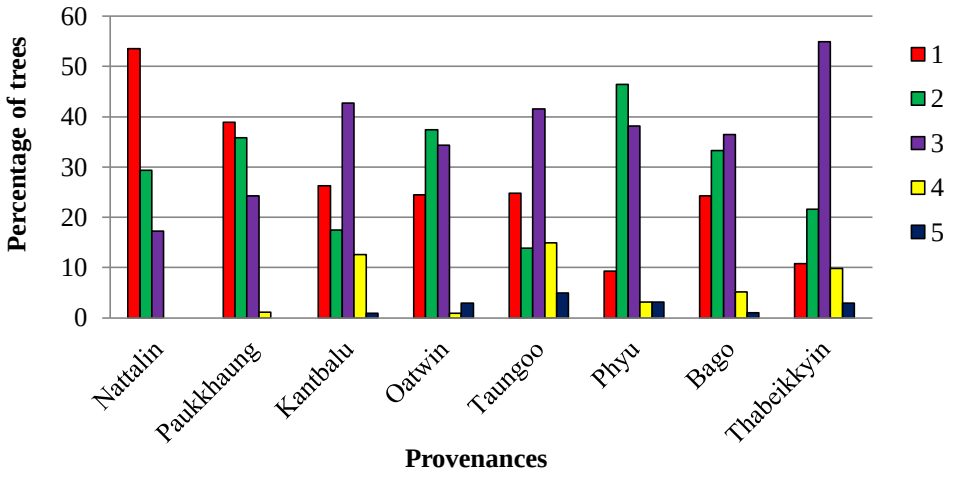

Figure 2: Description of stem straightness scores of provenances

Table 3. ANOVA results for stem straightness scores of provenances (N=798)

Provenances	N	Mean	Std.Error	df	F	P
Nattalin	99	1.64	0.08			
Paukkhaung	95	1.87	0.84			
Kantbalu	103	2.45	0.10			
Oaktwin	102	2.21	0.09	7	15.64	0.000***
Taungoo	101	2.61	0.12			
Phyu	97	2.44	0.08			
Bago	99	2.25	0.09			
Thabeikkyin	102	2.73	0.09			

The mean stem form for all provenances was 2.21 (Table 3). On average 56% of the trees scored 1 and 2, 36% of the trees scored 3, 6% of the trees scored 4, and 2% of the trees scored 5 in all provenances in this trial site (Figure 2). Only 26% of the trees had completely straight stems (Figure 2) and provenances were significantly different from each other ($p<0.001$) (Table 3).

5.2 Diameter at Breast Height (dbh) Measurement

According to the ANOVA of F test, the significant differences ($p<0.001$) were existed among provenances for five replications (Table 4). In order to detect the significant difference among mean dbh of provenances, LSD test was applied at 5% probability. The results of LSD test were presented in table 5.

In terms of dbh, Bago provenance was the largest followed by Nattalin, Taungnoo, Phyu and Paukkhaung provenances while Kantbalu, Oatwin and Thabeitkyin provenances were the smallest (Table 4). According to LSD test shown in table 5, Nattalin provenance is significantly different from Oatwin ($p<0.01$) and Thabeitkyin ($p<0.001$) provenances in terms of mean dbh (Table 5). Mean dbh of Paukkhaung and Kantbalu provenances are significantly different from Bago ($p<0.05$) and Thabeikkyin ($p<0.001$) provenances. Oatwin provenance is significantly different from Taungoo

($p<0.05$), Bago ($p<0.01$) and Thabeikkyin ($p<0.001$) provenances while detecting significant differences among mean dbh of provenances. Taungoo, Phyu and Bago provenances are significantly different from Thabeitkyin provenance ($p<0.001$) in terms of mean dbh (Table 5).

Table 4: ANOVA results for dbh measurements among provenances (N=798)

Code	Provenances	N	Minimum dbh(cm)	Maximum dbh(cm)	Mean±Std.Error dbh(cm)	Df	F	P
1	Nattalin	99	6.00	32.00	19.26±0.510			
2	Paukhaung	95	6.00	29.00	18.05±0.469			
3	Kantbalu	103	7.00	30.00	17.98±0.464			
4	Oatwin	102	4.00	30.00	17.40±0.451	7	7.113	***
5	Taungoo	101	8.00	36.00	18.98±0.427			
6	Phyu	97	4.70	34.00	18.63±0.532			
7	Bago	99	8.00	31.00	19.46±0.495			
8	Thabeikyin	102	6.00	24.00	15.67±0.367			

Table 5: Results of LSD test in terms of mean dbh (N=798)

Provenance	Nattalin	Paukkhaung	Kantbalu	Oatwin	Taungnoo	Phyu	Bago	Thabeikyin
Nattalin	-	0.063	0.050	**	0.668	0.340	0.760	***
Paukkhaung		-	0.951	0.351	0.149	0.365	*	***
Kantbalu			-	0.373	0.125	0.325	*	***
Oatwin				-	*	0.063	**	**
Taungnoo					-	0.595	0.461	***
Phyu						-	0.209	***
Bago							-	***
Thabeikkyin								-

5.3 Height Measurement

According to the ANOVA of F test, the significant differences ($p<0.001$) were existed among provenances for five replications (Table 6). In order to test the significant difference among mean height of provenances, LSD test was applied at 5% probability. The results of LSD test were presented in table 7.

In terms of mean height, Phyu provenance was the highest among eight provenances in the trial site (Table 6). Nattalin provenance was the second highest provenance followed by Oatwin, Taungoo, Paukkhaung, Bago, Kantbalu and Thabeitkyin provenances (Table 6). According to LSD test shown in table 7, Nattalin provenance was significantly different from Kantbalu ($p<0.01$) and Thabeitkyin ($p<0.001$) provenances. Paukkhaung provenance was significantly different from Phyu and Thabeitkyin provenances ($p<0.05$). Kantbalu provenance was significantly different from Oatwin ($p<0.01$), Taungoo ($p<0.05$) and Phyu ($p<0.001$) provenances in terms of mean height. Moreover, Oatwin provenance was significantly different from Thabeitkyin provenance ($p<0.001$) and Taungoo provenance was significantly different from Thabeitkyin provenance ($p<0.01$). And Phyu provenance was significantly different from Bago provenance ($p<0.01$) and Thabeitkyin provenance ($p<0.001$). Bago provenance was significantly different from Thabeitkyin provenance ($p<0.05$) (Table 7).

Table 6: ANOVA results for height measurements among provenances (N=798)

Code	Provenances	N	Minimum H (m)	Maximum H (m)	Mean±Std.Error H (m)	Df	F	Significance
1	Nattalin	99	4.57	19.81	16.54±0.331			
2	Paukhaung	95	4.27	20.73	15.74±0.352			
3	Kantbalu	103	6.09	21.95	14.99±0.379			
4	Oatwin	102	3.05	22.25	16.30±0.406	7	5.343	***
5	Taungoo	101	4.57	20.42	16.17±0.347			
6	Phyu	97	4.57	20.73	16.98±0.322			
7	Bago	99	4.57	19.81	15.58±0.314			
8	Thabeikyin	102	3.96	22.86	14.49±0.387			

Table 7: Results of LSD test in terms of mean height (N=798)

Provenance	Nattalin	Paukkhaung	Kantbalu	Oatwin	Taungnoo	Phyu	Bago	Thabeikyin
Nattalin	-	0.119	**	0.649	0.471	0.380	0.061	***
Paukkhaung		-	0.145	0.263	0.393	*	0.766	*
Kantbalu			-	**	*	***	0.242	0.306
Oatwin				-	0.789	0.181	0.152	***
Taungnoo					-	0.110	0.244	**
Phyu						-	**	***
Bago							-	*
Thabeikkyin								-

6. Discussion

Because of its economic importance, teak has been planted in large scales within and outside its natural range. Moreover, provenance or seed source trials have also been tested and/or established in order to attain good quality timber and superior genetic materials. For testing of these provenance trials, height, diameter at breast height, survival, stem form, crown characteristics, and branch habits are assessment parameters common to most trials (Min and Lwin, 2003). Teak can occur on a great variety of soil. Due to its wide and discontinuous distribution, the development of numerous provenances can be expected (White, 1991). Provenance variations in some characteristics such as wood quality, growth rate, stem form, stem morphology, germination, and other characteristics have also been reported in many studies (Nair and Mukerji, 1960; Hedegart, 1974; Keiding et al., 1986; Kaosa-ard, 1999 and Gyi, 1995).

In this provenance trial, eight provenances from various parts of Myanmar were tested in Moeswe, Bago Yoma region. Among the provenances, there were five local provenances from Bago Yoma area, namely Phyu, Bago, Oatwin, Taungoo and Paukkhaung. Survival, stem straightness, height and diameter were recorded in this study. And evaluation of this trial at the 11^{th} year of the establishment indicated that there was a variation among the tested provenances in terms of survival or adaptability to introduced site, stem straightness and growth performance (diameter and height). In terms of survival, Kantbalu provenance showed the highest survival rate followed by Oatwin and Thabeikkyin provenances but Paukkhaung provenance had the lowest survival rate in this study. There was significant differences in stem straightness among provenances ($p<0.001$) (Table 3) and the two best provenances which had more number of straight trees were Nattalin and Paukkhaung (Figure 2).

We can conclude that the differences in mortality and stem straightness have been found in this study. Similarly, there were many other provenance tests which found the differences in mortality, growth and stem straightness among the tested provenances (Keiding et al., 1986; Kajaer et al., 1995 and Kuang et al., 1996). However, a provenance by site interaction was not found for growth, stem straightness and mortality in this study. Therefore, the results of this study are probably only valid for this area.

In this trial site, Bago provenance was the largest in terms of dbh followed by Nattalin and Taungoo provenance. But Thabeikkyin provenance was the smallest in terms of dbh. In terms of mean height, it was observed that significant differences existed among eight provenances ($p<0.001$). Phyu provenance had the highest tree height, followed by Nattalin and Oatwin provenances. Thabeikkyin provenance was the lowest in terms of mean tree height. According to these results, it can be concluded that the local provenances for Bago Yoma region (Bago and Phyu) showed the best dbh and tree height. But Thabeikkyin provenance was the poorest in terms of dbh and tree height. It was consistent with some other reports (Persson, 1971 and Gyi, 1995). Persson (1971) who studied in Tanzania reported that the local provenance (Kihuwi) was superior to the others in volume production. Gyi (1995) who studied in Myanmar observed that the local provenance (pyinmana) tended to be the best in height and girth measurements in the 5^{th} and 8^{th} years, and concluded that local provenance was generally the best after he assessed the provenance trial established in Moeswe. In contrary, the local provenances were not always superior and in some cases, they were inferior to the imported provenances (Keiding et al., 1986).

In the assessment at 8^{th} year old in this trial site, it was observed that Nattalin provenance was the largest and Thabeikkyin provenance was the smallest in terms of gbh (Naing, 2015). There were many studies which indicated that the provenance variation of teak existed in many characteristics. The comparative performance of teak provenances might change with age and place (Mathauda, 1951 as quoted in Tint and Gyi, 1995). Hedegart (1971) observed that the differences among the provenances were highly significant in the 1^{st} year, but not very clearly defined in the 3^{rd}, 5^{th} and 8^{th} year. In Myanmar, Tint and Gyi (1995) assessed the provenance trial in Pyinmana at the 3^{rd}, 5^{th} and 8^{th} years after establishment and recommended that assessments of the provenance trials should be continued until more stable results were obtained.

The results from this trial site revealed that the local provenances (Bago and Phyu) were the best provenances in terms of dbh and tree height. Kantbalu provenance was the highest survival rate and Nattalin provenance was the best for stem straightness. Generally saying, Bago Yoma region provenances were suitable for this trial site located in Moeswe, Bago Yoma region. However, provenances from other regions could perform the best in terms of survival and stem straightness. So, it can be said that the differences in vegetation type, topography, macro and micro climatic conditions, soil condition and aspect of the region could determine the adaptability and growth performance of the tested provenances. Greaves and Hughes (1976) stated that three fundamental factors that should be examined in provenance species and provenance testing are rainfall distribution, mean annual precipitation and the temperature pattern. Climatic information for this trial site and selected provenances will be useful for further stages of tree improvement programs.

7. Conclusion

In this study, Bago and Phyu provenances emerged as the outstanding provenances for growth performance (dbh and height). Besides these provenances, Kantbalu and Nattalin provenances proved superior survival and stem straightness. Moreover, Nattalin provenance had superior dbh and height because of showing as the second largest and highest dbh and height at 11^{th} years old of this plantation. In this context, it is concluded that Bago, Nattalin and Phyu provenances should be selected

for Moeswe area to establish large-scale plantations. But Thabeikkyin provenances should not be chosen due to the poorest growth performance to Moeswe aera.

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