FURTHER INVESTIGATION INTO EFFECTIVE PLANTING TECHNIQUES FOR TEAK IN AREAS WITH DIFFERENT CLIMATIC CONDITIONS

Than Soe Oo[1]

ABSTRACT

For the successful establishment of extensive teak plantations, many techniques have been attempted in order obtain an optimum growth as well as the utmost economic outturn. Due to the selection of unsuitable sites, choice of inappropriate planting materials and lack of proper silvicultural management, failures have been reported from time to time. To provide some valuable information, an experiment was carried out in two townships with different climatic conditions where the special teak plantation programme is being intensively implemented. In this paper, planting materials suitable for such areas are recommended in line with the currently implemented plantation operations. Respective height growth and survival percent of different planting materials in two study areas with different climatic conditions are also included.

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1. INTRODUCTION

Owing to renowned reputation in quality, teak (*Tectona grandis* Linn. f.) is regarded as one of the most valuable timbers in the world. As natural teak forests are gradually dwindling and supply of natural teak becomes limited, teakwood fetches high prices in the international market, rendering attraction to many growers throughout the world. Across the tropics, the establishment of extensive plantations of this species goes beyond its home countries. Myanmar, one of the native countries of teak and a significant teak exporter, is also thriving to establish teak plantations for the economic development. In accord with the National Forest Policy adopted, special teak plantation programme has been initiated in 1998, and since then the departmental establishment of teak plantations has been significantly accelerated. Investigation on effective planting techniques well suited to different climatic situations is, therefore, an important task of the Forest Department.

Teak is commonly planted artificially using direct seeding, transplanting of potted seedlings, and planting of fresh or stored stumps, and planting techniques using different materials have been studied since the time large-scale plantation establishment of teak was started. Planting with potted seedlings is very attractive as it has proved to be the highest in survival rate. Alternatives, however, were also sought because of difficulty in transportation of seedlings to the planting site and high costs involved in planting with potted seedlings. Special attention was paid to the planting with stored stumps (OD;cifvdIif? 1982; Gyi et al., 1983). Maung et al. (2002) reviewed planting methods using seedlings, fresh stumps and especially stored stumps, and a preliminary study was carried out in Ngalaik Reserved Forest in Tatkone Township. The authors reported their findings and they received suggestion that such experiment be conducted in areas with different climatic conditions (e.g. high rainfall areas and low rainfall areas). This research, thus, is further investigation of the previous experiment in order to provide some useful information to special teak plantation programme being implemented in areas with different climatic conditions throughout the country.

2. OBJECTIVES

The overall objective of the study is to investigate effective planting techniques which are appropriate for climatic conditions of the plantation site. Specifically, the study aims:

- to evaluate planting techniques, and to study the variation in survival percent, growth rate and responses of teak planted using three different planting materials in two areas with different climatic conditions;
- to report some useful and applicable information for the special teak plantation programme; and
- to present some issues relating to raising successful establishment of teak plantations.

3. STUDY AREAS

3.1. Location

In order to compare growth responses and survival percentages of teak planted with different planting techniques in areas with different climatic conditions, two typical study areas were selected based on the rainfall regimes. They are Oktwin Township as a representative of high rainfall areas, and Tauntwingyi Township to stand for relatively low rainfall areas. Experimental sites in both study areas were selected within the teak plantations established in 2002.

The experiment in Oktwin Township was conducted in Compartment No. 197 of Khabaung Reserved Forest, which is situated in the eastern exposure of the Bago Yomas. The study area is located approximately at 18° 50' N and 96° 08' E with an elevation of 303 m a.s.l. The experiment plots were also established in Compartment No. 148 of Yanpe Reserved Forest in Taungtwingyi Township. The township, being situated at the eastern part of the Magway District, is included in the Dry Zone Greening Project area. The study area is located at 19° 43' N and 95° 42' E with an approximate altitude of 309 m a.s.l. The locations of the study sites are shown in Figure 1.

3.2. Forest Type

Climate and soil are the determining factors for the formations of different forest types. According to the classification of tropical forests based on temperature and rainfall (Lamprecht, 1989), the forests of the Oktwin study area are classified as moist deciduous to semi-evergreen types that appears to be moist evergreen forests in raining season. The classification is shown in Appendix 1.

Under the meteorological conditions which Taungtwingyi Township receives, dry deciduous and up to slightly moist deciduous forests normally occur, and dry forests usually predominate. The study site is situated on the western exposure of the Pegu Yomas, and the temperature is higher than that of the eastern side. In determining the local climatic condition, exposure plays a key role and occurring types of forest can be different when the exposures are not identical. Consequently, the vegetation forming in the area, i.e. Taungtwingyi Township on the western exposure, will be more or less drier than that of Oktwin Township on the eastern exposure.

It is reported that forests flourishing in the Taungtwingyi Township of Magway District are of mixed deciduous types in which teak and Pyinkado (*Xylia dolarbriformis*) grow abundantly and Thitya (*Shorea obtusa*), Ingyin (*Shorea siamensis*) and Tamalan (*Dalbergia oliveri*) are also found (OD;0if;jrifh? 1999). Kyathaung-wa (*Bambusa polymorpha*) and Hmyin-wa (*Dendrocalamus strictus*) are also abundantly found. These characteristics clearly indicate the fact that types of forest found under such climatic conditions are mostly dry forest and/or dry deciduous forest, and moist deciduous types may occasionally occur due to moister situation caused by microclimatic differences.

3.3. Climate

The study site in Oktwin Township lies within the area which is influenced by tropical savannah climate with a pronounced dry period between the monsoon rains. According to the climatic data of 1970-1999, the number of yearly rainy days is found to be around 90. The mountains of Myanmar, running in North-South direction, present effective barriers for South-West monsoon in the rainy season in order that the precipitation of the central part of the country is generally low. As the study area

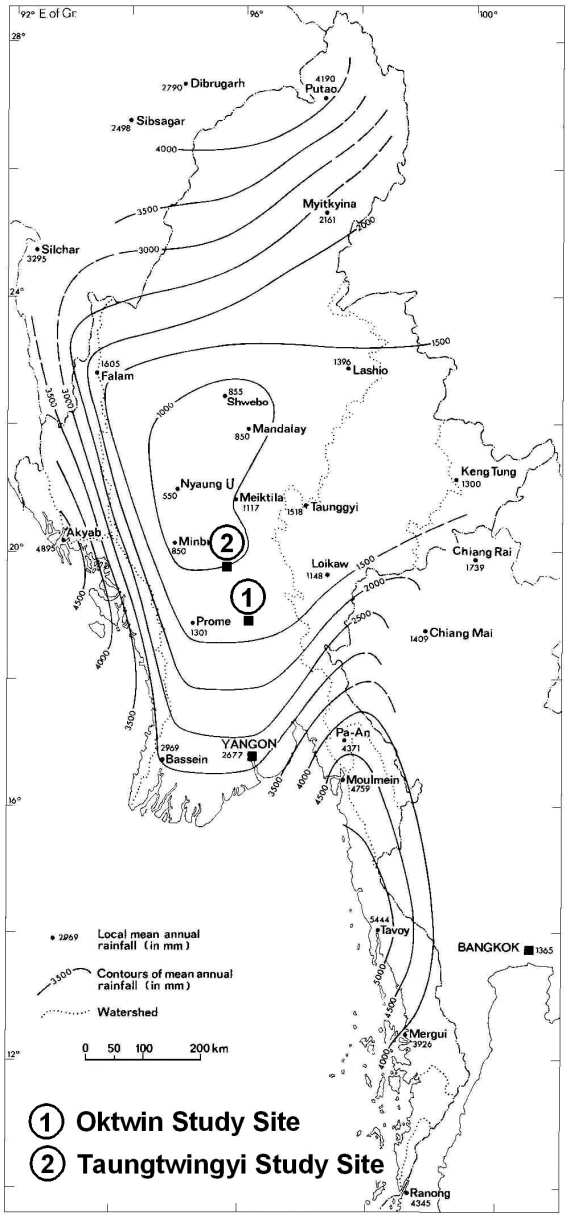
in Taungtwingyi Township lies on the fringe of the central dry zone area, it receives about 1040.4 mm (nearly 40 inches) rainfall and average temperature of 27.4° C. In Table 1 the climatic data (monthly means) of Toungoo Township that are applicable to the study site in Oktwin Township and of Taungtwingyi Township are compared.

Table (1) The climatic data (monthly means) for two study sites.

Month	Temperature (°C)		Rainfall (mm)	
	Oktwin	Taungtwingyi	Oktwin	Taungtwingyi
January	23.1	21.8	0.2	0.5
February	25.3	24.2.	8.8	2.3
March	28.5	28.5	19.6	0.4
April	30.9	31.6	36.0	2.6
May	29.9	31.9	284.5	139.3
June	27.6	28.9	328.4	169.7
July	27.0	29.2	416.1	172.2
August	27.0	28.4	441.6	186.9
September	27.7	28.4	272.9	200.2
October	28.2	28.3	116.0	110.1
November	26.1	25.3	39.8	56.2
December	23.8	22.4	2.4	0
Year	**27.0**	**27.4**	**1966.3**	**1040.4**

Source: The meteorological station, Toungoo and Taungtwingyi.

The climatograms of both Townships are compared in Figure 1. The diagrams clearly illustrate different climatic conditions, especially rainfall regimes that two study sites receive.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Shwebo
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Mandalay
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Keng Tung
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1 Oktwin Study Site
2 Taungtwingyi Study Site

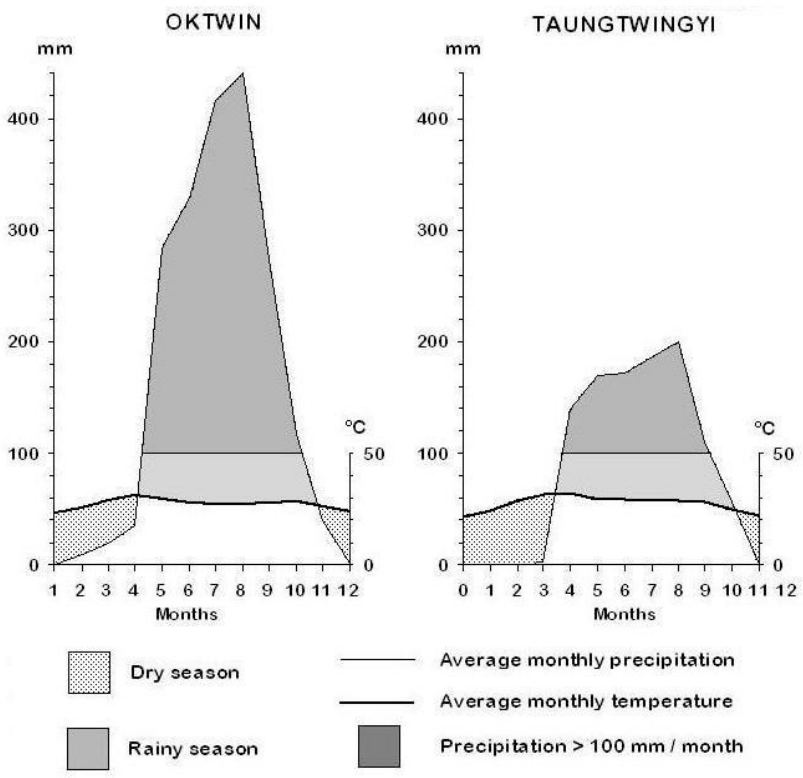

Figure 1: Locations of and Climatograms of study sites.

To express the aridity of the study sites in more precise terms, a quantitative measure called De Martonne's Index is used. The index is calculated by:

Yearly aridity index: $a_y = \frac{N}{T_y} + 10$

Monthly aridity index: $a_m = \frac{12 \cdot n}{T_m} + 10$

Where N = mean annual rainfall (mm)
n = mean monthly rainfall (mm)
T_y = mean annual temperature (°C)
T_m = mean monthly temperature (°C)

The value of index below 20 is considered as arid. The corresponding De Martonne's yearly and monthly aridity indices of two Townships are shown in Table 2. The dry period of Oktwin site is four months whereas the Taungtwingyi site has a longer period of five months.

Table (2) De Martonne's aridity index for two study sites.

Month	Jan.	Feb.	Mar.	Apr.	May	June
Oktwin	**10.1***	**14.2***	**18.3***	24.0	125.6	152.9
Taungtwingyi	**10.3***	**11.1***	**10.2***	**11.0***	62.4	80.5

Month	July	Aug.	Sep.	Oct.	Nov.	Dec.	**Year**
Oktwin	195.1	206.6	128.2	59.4	28.3	**11.2***	**82.7**
Taungtwingyi	80.8	89.0	94.6	56.7	36.6	**10.0***	**48.0**

Note: (*) Indicates the month with the aridity index below 20.

3.4. Soil

Soil samples of both experimental sites were collected and laboratory analyses were carried out at Forest Research Institute Yezin. The results obtained are given in the table 3a and 3b. Soil samples revealed acidic in Khabaung Reserved and showed alkaline in Yanpe Reserved of Tauntwingyi Township. Physical properties of both study sites range from sandy loam to sandy clay loam in texture. The pH values of Yanpe Reserved Forest of Taungtwingyi Township were found to be higher, and in consequence, the growth of teak in this area may be hindered by the alkaline soil. In Khabaung Reserved, on the other hand, acidic nature of soil may cause difficulties for the solubility of available phosphorus.

Table (3a) Physical properties of the soil samples of Compartment No. 148, Yanpe Reserved Forest, Taungtwingyi Township and Compartment No. 197 of Khabaung Reserved Forest of Oktwin Township (extractable nutrient in percentage of dry weight).

Soil Texture	Taungtwingyi			Oktwin		
	Depth (cm)			Depth (cm)		
	0-10	40-50	80-90	0-10	40-50	80-90
Sand % (Average)	40.6	27.4	27.8	55.4	46.4	40.9
Silt % (Average)	27.5	29.1	33.1	22.5	23.8	25.5
Clay % (Average)	28.3	43.1	38.6	20.2	29.1	31.6
Remark	Sandy Clay Loam	Clay Loam	Sandy Clay Loam	Sandy Loam	Sandy Clay Loam	Sandy Clay Loam

Table (3b) Chemical properties of the soil samples of Compartment No. 148 Yanpe Reserved Forest, Taungtwingyi and Compartment No. 197 of Khabaung Reserved Forest of Oktwin Township (extractable nutrient in percentage of dry weight).

Chemical Properties	Taungtwingyi			Oktwin		
	Depth (cm)			Depth (cm)		
	0-10	40-50	80-90	0-10	40-50	80-90
pH Ava	7.4	8.1	8.6	5.7	5.4	5.5
P %	0.000012	0.000008	0.000007	0.000020	0.000011	0.000016
Total N %	0.0873	0.0609	0.0401	0.0338	0.0255	0.0259
K %	n.a	n.a	n.a	n.a	n.a	n.a
Organic matter % (Av)	5.9	4.1	3.2	4.3	4.4	3.7

4. MATERIAL AND METHODS

4.1. Experimental Design

Split plot design with four replicates was adopted for the experiment. The following planting materials were used:

- Potted seedling (denoted by P);
- One year old fresh stump (denoted by F); and
- Stored stumps from one year old seedling (denoted by S).

As main plot factors four treatments, namely, normal planting as control, fertilization, site preparation (digging), and fertilization with digging were included in the experiment. One block (replicate) consists of four main plots for control and three treatments. Each main plot is composed of three subplots to which three different planting materials are randomly assigned.

Each subplot includes 25 trees (5 rows x 5 columns) with ~3 m x ~3 m spacing. The subplots were spaced ~6 m apart so as to avoid mixing and to differentiate one treatment plot from the other. The experimental plots in each study site have a total area of about 0.9 ha. Treatments and replicates of each plot were given unique identification numbers. Figure 2 depicts the layout of a block (replicate).

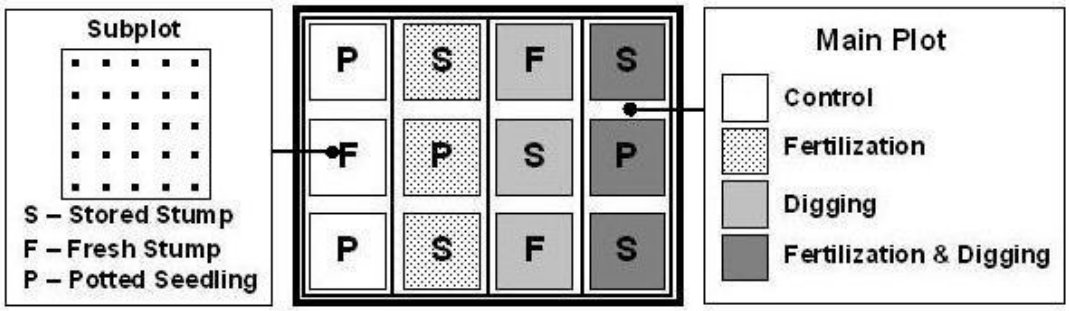

Figure 2: Layout of a replicate consisting of four main plots and twelve subplots.

4.2. Potted Seedlings

Seedlings required for the experiment were procured from the respective township forest department. To raise the potted seedlings, teak seeds of the same source were used.

4.3. Fresh Stumps

Seedlings were raised in the permanent nursery for one year to produce stumps for planting. After one year seedlings reached 60-90 cm height with the diameter of 1.0-1.3 cm, which is considered to be suitable size for preparation of stumps (Gyi, 1992). Stems were cut 3-5 cm above the root collar and around 10 cm below it. Stump preparation was carried out one day ahead of out-planting.

4.4. Stored Stumps

Seedlings were raised in the nursery for one year to produce fresh stumps for storage. Stump preparation for storage was made in February before leaves of the seedlings had been shed. The size of stored stumps was the same as that of fresh stumps. Methods suggested by Kaosa-ard (1979) and Gyi (1983) were used for the storage of stumps. The stumps were made in bundles of 45-50 pieces and stored in pits of (1.2 m x 1.2 m x 1.2 m) size. The bundles were placed layer by layer in the pit. Each layer of the bundles was separated by about 10 cm thick layer of river sand. The pits were put under shade to protect from the direct sunlight, and contact with water was strictly prevented so as to avoid the fungal infection. The temperature inside the pit was maintained below 35°C and daily temperature was recorded at 14:00 hours.

4.5. Establishment of Experimental Plots

After site preparation the experimental plots were laid down. Pillars were set up at every corner of each treatment plots. They were blazed at the upper part and treatment types and replicate numbers were marked on the blaze.

4.6. Planting, Weeding and Fertilization

Planting of seedlings, fresh stumps and stored stumps was completed on 21-6-2002 in Oktwin Township and on 5-7-2002 in Yanpe Reserved Forest of Taungtwingyi. Weeding was carried out in June and in August according to the

schedule prescribed for the special teak plantation programme. Fertilizer applications were carried out in June one week after planting and in October. Chemical fertilizer of N: P: K (8:16:9) was applied two times as suggested by Carter (1995).

4.7. Assessment of the Experiment and Data Analysis

First survival counting along with height measurement was undertaken in December, 2002 six months after planting. The assessment was planned to be continued in forthcoming years. Plot data sets were compiled from raw data and statistical analyses were performed. In split plot design, an observation (a plot mean) is considered as linear combination of seven components (Williams & Matheson, 1994), which can be symbolically expressed as:

$$Y_{ijk} = \mu + \rho_i + A_j + \eta_{ij} + B_k + A \cdot B_{jk} + \varepsilon_{ijk},$$

Where μ = overall mean,

ρ_i = replicate effect,

A_j = main plot treatments (fertilization, digging, etc.) effect,

η_{ij} = main plot residuals,

B_k = subplot treatments (planting materials) effect,

$A \cdot B_{jk}$ = interaction effect, and

ε_{ijk} = subplot residuals.

Based on the above model, analysis of variance tables were generated, and the significance of treatment differences were tested (see Appendix 2).

5. RESULTS AND DISCUSSION

5.1. Height Growth and Survival Percent of Planting Materials

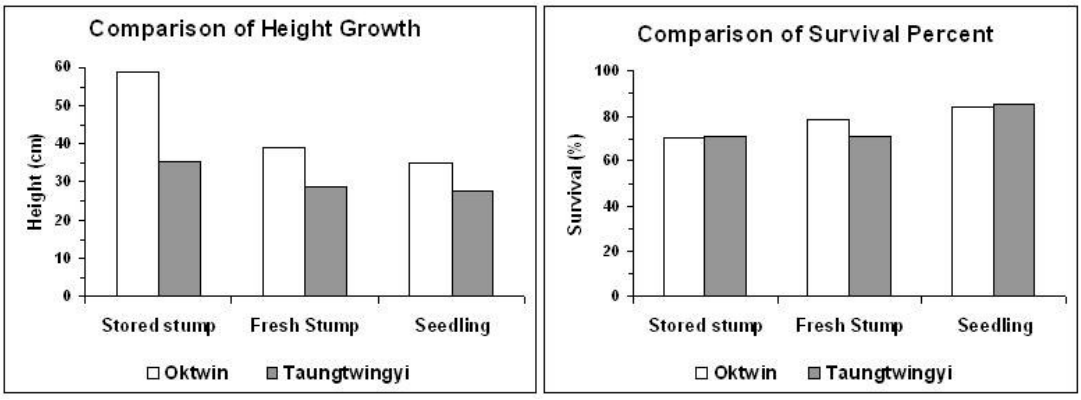

Figure 3: Comparison of height growth and survival percent for three different planting materials.

The growth performances and survival rates of three different planting materials are compared in Figure 3. Height growth at initial growing stage is usually considered important for teak to overcome the competition of weeds for light and soil moisture. Of three planting materials tested, the average growth rate of stored stumps is the highest in both study areas, and those of fresh stumps and potted seedlings are much lower. In Table 4 differences in mean height for three planting materials are shown. The statistical analyses confirmed the fact that the difference in height growth is highly significant.

Table (4) Differences in mean height (cm) for three planting materials.

	Oktwin		Taungtwingyi	
	Fresh stumps	Potted seedlings	Fresh stumps	Potted seedlings
Stored stumps	19.8**	23.6**	6.3**	7.8**
Fresh stumps	0.0	3.8	0.0	1.5

** Highly significant ($p < 0.01$)

In Taungtwingyi (low rainfall area), the height growth of all planting materials are lower than those of Oktwin area (high rainfall area). Student's t-test also indicates high significance of difference between average growth rates in two study sites. High rainfall areas or where the rainfall is reliable, stored stumps should be used for planting to obtain high performance of height growth.

The weakness of stored stump planting, however, is its lower survival percent as compared to the planting with potted seedlings. The figures shown above describe that fresh stump planting is also unsuitable for low rainfall areas. Its survival percent is approximately the same as of stored stumps. The other point that should be considered is time of planting. Out-planting was carried out in the last week of June and in the first week of July in which the rain is sparse or sometimes lacking in low rainfall areas. It should, therefore, be taken into account deliberately whether commercial teak plantations should be established in low rainfall areas like Taungtwingyi Township or not. Even if teak plantations have been successfully established, volume increment may be lower than those established in high rainfall areas. It may also lag behind the plantations of high rainfall areas in terms of economic return.

5.2. Effect of Fertilizer Application on Growth Responses and Survival Percent

Application of chemical fertilizer was included in the experiment to examine the effect of fertilization on the growth rates. In Oktwin study site, the average heights of fertilized plantlets are larger for all planting materials (Figure 4), although the differences are not statistically significant. Fertilizer application, however, does not improve the height growth in Taungtwingyi study area. The physical properties of soil (good sub-soil drainage, deep alluvium, etc.) play a key role for the establishment and good growth in height. For this reason, more attention should be paid to the physical properties of soil at the stage of site selection for plantation. Kaosa-ard (1995) also pointed that main factors limiting the success of teak plantation establishment are, among others, site quality, quality and quantity of planting materials, and silvicultural management.

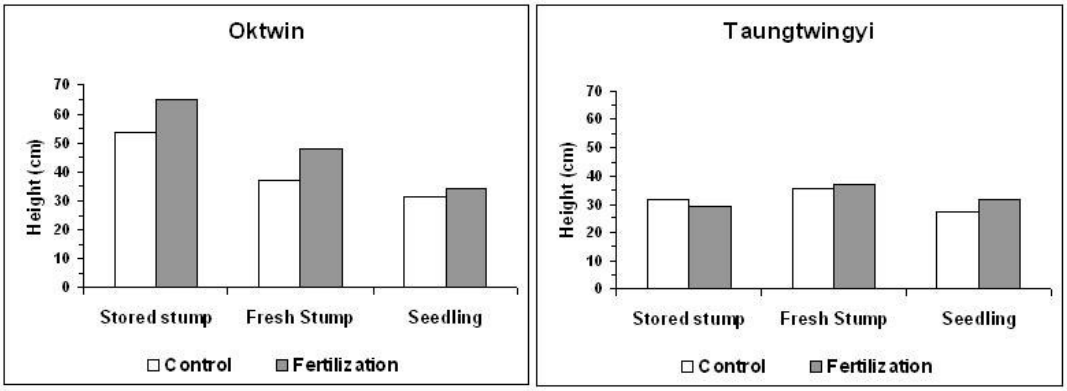

Figure 4: Comparison of height growth of planting materials with and without fertilizer application.

The experiment also shows the fact that the effect of fertilization on the survival percent of three planting materials is not significant (Figure 5). Since Teak is a calcareous species (Seth and Yadav, 1959; Kaosa-ard 1981; Tewari, 1992), it requires considerable quantity of calcium for its growth and development. Taken this point into consideration, higher growth may be achieved in higher rainfall areas with soil having pH > 5.5. In Oktwin study area calcium (lime) should be applied since its pH value lies between 5.7 and 5.5. In Taungtwingyi area, however, application of lime should not be carried out because the soil already shows alkaline nature (pH is 7.4 to 8.6). The site condition in terms of pH value in this area is not suitable for teak plantations as growth of teak suffers where pH value beyond 8.5 (Tewari, 1992). This may be one of the factors for the lower initial growth condition of teak planted in Taungtwingyi study area.

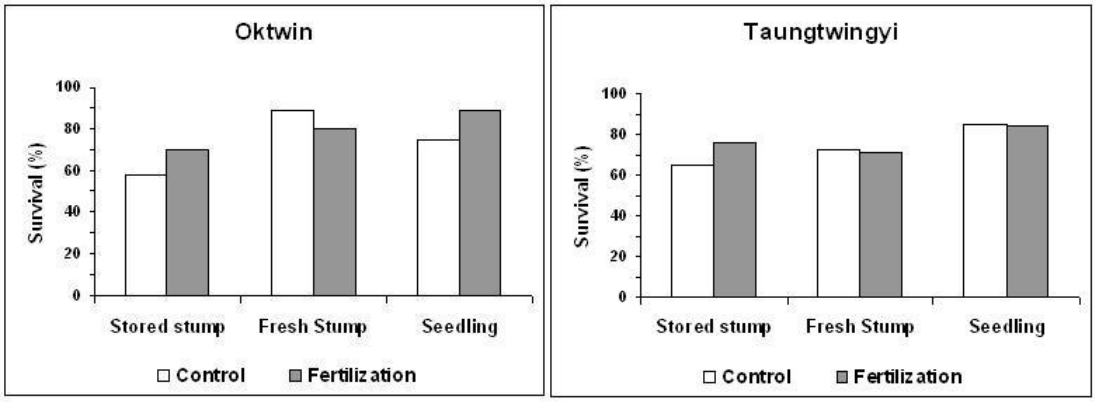

Figure 5: Comparison of survival percent between planting with and without fertilizer application.

5.3. Effect of Planting with Digging on Growth Responses and Survival Percent

As a main plot treatment factor, planting with digging was also taken into account in the experiment to study whether there are significant differences of height growth and survival rate affected by digging. The results for height growth and survival percentages in both study areas are given in Figure 6 and 7 respectively.

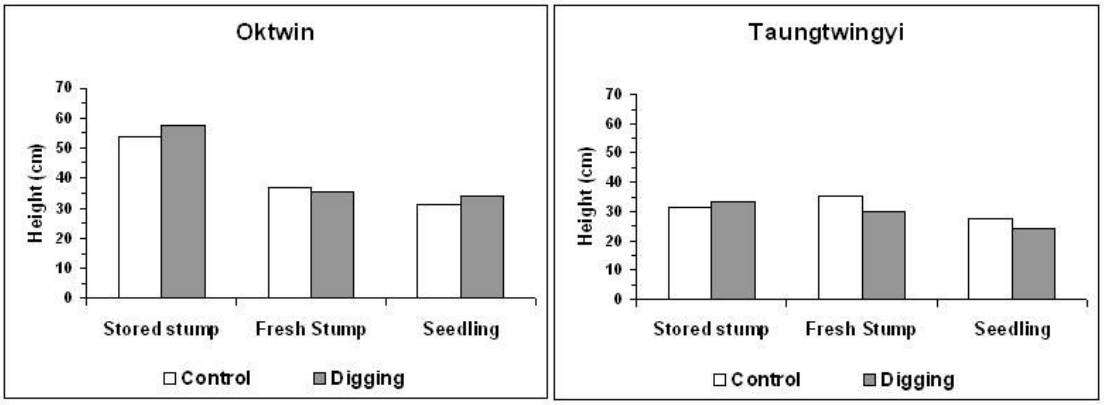

Figure 6: Comparison of height growth between planting with and without digging pits.

As Figure 6 shows, average height difference between with and without digging is not apparent. It should be generally noted that planting with digging pits could not offer significant height growth for teak. In both sites, on the other hand,

survival of stored stumps and potted seedling appeared to be improved by digging pits (Figure 7), although the differences were not statistically significant. Sufficient rainfall in regular pattern, physical soil properties such as sandy loam to sandy clay loam soil with good sub-soil drainage seem to be more important than soil preparation like digging pit or ploughing before planting. It might be on account of the natural growth habit of teak, since teak seedlings tend to rot in excessively moist or waterlogged conditions. In high rainfall areas, rainwater may be accumulated in pits in which seedlings are planted. Depending upon the amount of rainfall and soil porosity, the duration of waterlogged condition may exceed the tolerance of planted seedlings.

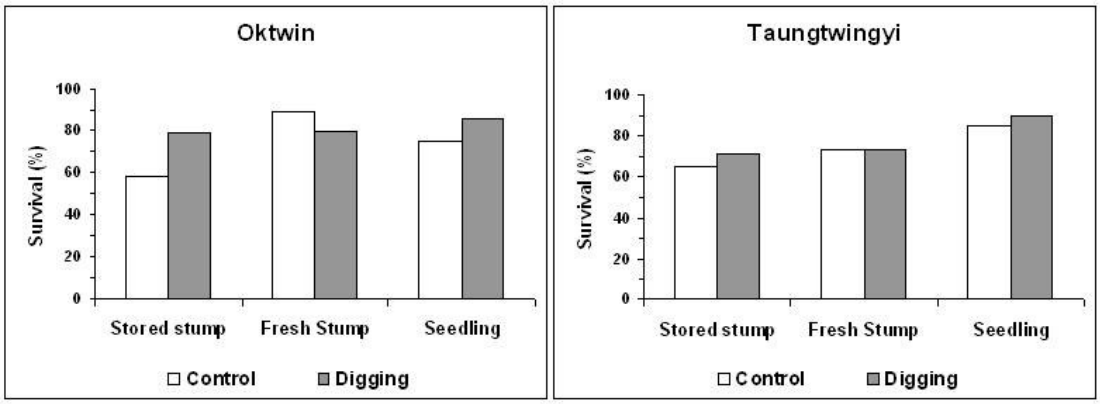

Figure 7: Comparison of survival percent between planting with and without digging pits.

However, in low rainfall areas like Tauntwingyi site, planting with digging pits seems to encourage the survival of the teak seedling. In such areas, especially in July, the rainfall may be sometimes low or even lacking, and rainwater can be stored by site preparation like digging. To avoid waterlogged condition at the base of the planted seedlings, and to collect sufficient rainwater to overcome the July drought, suitable size of pits is crucial for the survival of the seedlings. Planting should be completed immediately after the enough showers of monsoon (i.e., mid-June) and when the soil is sufficiently moist.

In the figures shown above, rainfall conditions play an important role in growth development of teak that leads to the success of plantation establishment. It is

because, although planting with digging pit does not show significant differences in height growth, average heights of different planting materials between two study areas show significant differences, particularly in stored stump planting.

Tewari (1992) stated that teak thrives well within an annual rainfall range of 1,000 to 1,500 mm. For the production of high quality wood with the optimum growth, moisture conditions (as expressed by annual rainfall) should be between 1,200 and 1,500 mm with a marked dry season of 3 to 5 months (Kaosa-ard, 1981; Keogh, 1987). According to the climatograms of the study areas, 4 months in Oktwin site and 5 months in Taungtwingyi area fall under the aridity index 20, and annual rainfalls being 1,966 mm and 1,041 mm respectively.

As the annual rainfall the Taungtwingyi site lies below the 1,200 mm limit, it may be, according to Tewari (1992), difficult to achieve optimum growth followed by high quality wood. In such areas, pre-sprout planting should be tried to achieve good survival percentage. Mishra (1958) stated that in very dry localities (annual rainfall 900 mm and below) “pre-sprouted planting” gives satisfactory results (Tewari, 1992). For this, stumps are prepared, 4 to 6 months in advance, i.e., in or around February and put in containers on a raised platform in shade and watered daily. These stumps after sprouting are then planted at the onset of monsoon. Although operating costs may be increased because of preparing stumps and nursery charges, this method can be a good alternative to obtain an optimum benefit under difficult circumstances for the establishment of teak.

Before establishing a teak plantation or reforestation in an area, it is critical to obtain knowledge of climatic and soil conditions, and also existing formation of forest types. By examining conditions of existing forests in which teak plantations programme is planned to be implemented by *Taungya* method, it can be determined whether teak can grow well under given circumstances or not, and if survive, the growth condition will be good or poor. Climatogram of a particular site is needed to obtain information about rainfall conditions and its pattern, and to envisage what types of forest can generally occur under existing climatic and edaphic conditions. Thereby appropriate choice of planting material can be made and out-planting can be carried out at right time.

6. RECOMMENDATIONS

Based on the findings of preliminary investigation by Maung et al. (2002) and of present study, the following recommendations can be derived. They fall into two broad categories:

Technical issues

- Although teak is a very hardy species, resistant to fire and to some extent to drought, intensive establishment of teak plantation should be avoided in the areas with the rainfall below 1,000 mm, if long-term economical benefits are expected from it.
- If it is inevitable to do so, potted seedlings or pre-sprout planting (one year old) should be applied for the certainty of survival percentage, and planting should be started only when the surface soil is sufficiently moist.
- As earlier studies indicated, the results of present study show potted seedlings offer the highest in survival rate with satisfactory height growth. Therefore, potted seedling is most appropriate if adequate funding is available.
- Fresh stump planting should be avoided in low rainfall areas with discontinuous rainfall pattern in rainy season. Its survival percent is unreliable and practically the same as that of stored stump whereas its height growth is lower than stored stump. In such areas it is extremely important to complete planting while the surface soil is sufficiently moist.
- Stored stumps showed the best height growth and lowest survival rate. In high rainfall areas, stored stumps should be planted followed by prompt patching where planted stored stumps do not survive. For certainty of survival potted seedlings, instead of stumps, should be used for patching. Rapid height growth enables the plantlets to suppress weeds and thus certain amount of weeding costs can be reduced, which may compensate the costs of patching.

Administration and management requirements

- If stump planting is planned to be used, availability of time need to be taken into account for a large-scale plantation programme. It would be a problem to prepare a large quantity of stumps from nursery bed within a limited time. After preparation, the stumps should be planted out as rapidly as possible. In high rainfall areas, this problem might be less serious because of the reliability in using stumps up to 15 days after cutting.
- As the establishment of teak plantation is a long-term task, selection of suitable site, choice of appropriate planting techniques and planting materials, and proper silvicultural management are indispensable prerequisites for the development of the plantation in the long run.
- Adequate fund is a fundamental requirement for the successful establishment of teak plantation. As Forest Department has already possessed a large amount of experiences on artificial regeneration of teak, the primary problem in large-scale establishment of plantations often is not technical one, but frequently inadequately allotted fund followed by weakness in subsequent tending operations.
- Regular assessment and monitoring are also necessary to achieve successful establishment of plantation accompanied with optimum.

7. CONCLUSION

It is not controversial that teak plantations have to be established not only to obtain economic benefits but also to compensate the depletion of marketable-sized trees in natural teak bearing forests. Though experiences and knowledge regarding artificial regeneration of this species have been accrued, many obstacles, sometimes formidable ones, are still being encountered in the implementation process. To make a plantation with a particular species on a particular site, it is important, first and foremost, to scrutinize the growth habit and silvicultural characteristics of that species. Prior to the implementation stage, information on climatic and soil conditions, and existing formation of forest types have to be collected in order to decide whether the species can adapt to that site and establish successfully. Lessons from past experiences need to be learnt so as to avoid selection of unsuitable sites, choice of inappropriate planting materials and planting techniques, to practice

necessary tending operations, and to adopt proper management for the plantation programme. Apart from these factors, adequate funds have to be assured not only for the establishment but also for long-term maintenance costs of the plantation.

Appendix 1

Simplified Classification of Tropical Forests According to Temperature and Precipitation

Precipitation regime	**Temperature regime – Mean annual temperature (°C)**		
	Approx. 22-28°C Hot tropics Elevation Approx. 0-800/ 1000 m a.s.l.	Approx. 22-14°C Temperate tropics Elevation Approx. 800-2100/2400 m a.s.l.	Approx. 14-10°C Cool tropics Elevation Approx. 2100-3200 m a.s.l.
Even distribution of Precipitation throughout the year $N_a \geq 5\ (T_a + 14)$ cm	Moist lowland evergreen forests	Moist montane evergreen forests	Moist evergreen forests at high elevations or cloud forest
	No more than 1 month with a < 20		
Altering wet and dry seasons Dry season(s) < 5 months; $N_a < 5\ (T_a + 14)$ cm > $2\ (T_a + 14)$ cm	Moist deciduous lowland forests	Moist deciduous montane forests	Moist deciduous forests at high elevations
	Max. 4 months with a < 20; min. 6 months with a > 40		
Altering wet and dry seasons Dry season(s) > 5 months; $N_a < 2\ (T_a + 14)$ cm	Dry deciduous lowland forests	Dry deciduous montane forests	Dry deciduous forests at high elevations
	6-8 months with a < 20; ca. 3 months with a > 40		

Note: T_a = mean annual temperature,
N_a = mean annual precipitation, and
a = De Martonne's aridity index.

Appendix 2

Summarized Results from Statistical Analysis

1. Oktwin Study Site

(i) Variate: Height (cm)

Analysis of Variance

Source of variation	d.f.	SS	MS	Computed F	p-Level
Replicate	3	1898.49	632.83	5.54	
Main plot	3	470.96	156.99	1.37	0.312
Residual	9	1027.72	114.19	1.17	
Subplot	2	5134.13	2567.07	26.32	<0.001
Main Plot · Subplot	6	417.79	69.63	0.71	0.642
Residual	24	2341.13	97.55		
Total	47	11290.24			

Standard errors and coefficient of variation

	Main plot	Subplot
Standard error	6.2	9.9
Coefficient of variation (%)	13.9	22.3

Standard errors of differences and least significant differences of means

	Main plot	Subplot	Subplot/ Main plot	Main plot/ Subplot
s.e.d.	4.36	3.49	6.98	7.18
l.s.d. (0.05)	9.87	6.60	13.20	13.90

(ii) Variate: Survival percent

Analysis of Variance

Source of variation	d.f.	SS	MS	Computed F	p-Level
Replicate	3	1912.0	637.3	2.05	
Main plot	3	466.7	155.6	0.50	0.692
Residual	9	2800.0	311.1	2.09	
Subplot	2	1520.7	760.3	5.11	0.014
Main Plot · Subplot	6	2303.3	383.9	2.58	0.045
Residual	24	3568.0	148.7		
Total	47	12570.7			

Standard errors and coefficient of variation

	Main plot	Subplot
Standard error	10.2	12.2
Coefficient of variation (%)	13.1	15.7

Standard errors of differences and Least significant differences of means

	Main plot	Subplot	Subplot/ Main plot	Main plot/ Subplot
s.e.d.	7.20	4.31	8.26	10.07
l.s.d. (0.05)	16.29	8.90	17.79	20.71

2. Taungtwingyi Study Site

(i) Variate: Height (cm)

Analysis of Variance

Source of variation	d.f.	SS	MS	Computed F	p-Level
Replicate	3	1481.74	493.91	16.3	
Main plot	3	161.03	53.68	1.77	0.222
Residual	9	272.65	30.29	1.07	
Subplot	2	549.69	274.84	9.67	<0.001
Main Plot · Subplot	6	128.07	21.34	0.75	0.615
Residual	24	682.26	28.43		
Total	47	3275.42			

Standard errors and coefficient of variation

	Main plot	Subplot
Standard error	3.2	5.3
Coefficient of variation (%)	10.5	17.6

Standard errors of differences and Least significant differences of means

	Main plot	Subplot	Subplot/ Main plot	Main plot/ Subplot
s.e.d.	2.25	1.89	3.77	3.81
l.s.d. (0.05)	5.08	3.89	7.78	7.76

(ii) Variate: Survival percent

Analysis of Variance

Source of variation	d.f.	SS	MS	Computed F	p-Level
Replicate	3	206.7	68.9	0.84	
Main plot	3	140.0	46.7	0.57	0.65
Residual	9	740.0	82.2	0.32	
Subplot	2	2128.7	1064.3	4.19	0.027
Main Plot · Subplot	6	354.0	59.0	0.23	0.962
Residual	24	6093.3	253.9		
Total	47	9662.7			

Standard errors and coefficient of variation

	Main plot	Subplot
Standard error	5.2	15.9
Coefficient of variation (%)	6.9	21.0

Standard errors of differences and Least significant differences of means

	Main plot	Subplot	Subplot/ Main plot	Main plot/ Subplot
s.e.d.	3.70	5.63	11.27	9.92
l.s.d. (0.05)	8.37	11.63	23.25	20.24

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14. ဦးခင်လှိုင်၊ ၁၉၈၂။ ကျွန်းငုတ်တက်များ သိုလှောင်မှုစနစ်နှင့် သိုလှောင်ငုတ်တက်၊ သာမန်ငုတ်တက် နှင့် ပင်ပေါက်ငယ်တို့ စိုက်ခင်းအတွင်း ရှင်သန်ကြီးထွားမှုကို လေ့လာခြင်း။ သစ်တောဦးစီးဌာန၊ ရန်ကုန်မြို့။
15. ဦးဝင်းမြင့်၊ ၁၉၉၉။ လုပ်ငန်းများဆောင်ရွက်မှုနှင့် တွေ့ကြုံရသည့် အခြေအနေများအပေါ် သုံးသပ်အကြံပြုတင်ပြချက်။ မကွေးခရိုင် အပူပိုင်းဒေသစိမ်းလန်းစိုပြည်ရေးဆိုင်ရာ အလုပ်ရုံ ဆွေးနွေးပွဲ (၂၀-၉-၉၉ မှ ၂၁-၉-၉၉ ထိ)။