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Growth Performance of teak plantation by Different Site Preparation

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Growth Performance of teak plantation by Different Site Preparation Methods

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Abstract

Site preparation is commonly used to increase survival and early growth of newly planted seedlings. However, the various site preparation methods should be implemented carefully to avoid negative side effects. Ideally, any early positive effects of site preparation should persist for a long time, but concerns have been raised as to whether site preparation might have a negative effect on the long-term productivity of a stand. The present study was therefore designed to investigate the long-term effects of different site-preparation treatments on growth performance of teak. In the 2019, an experiment plots were established. Five site-preparation methods were performed and seedlings from different nursery practice (polybag and pot-tube) were used. Growth variables such as height and diameter were measured every year. At the end of the fifth year growing season, teak growth responses showed significantly different among site preparation treatments. Over the five-year period, Treatment C (Slash & Burn) consistently shows higher mean annual increments of tree volume. Among different site preparation, tree growth was highest in slash & burn plots followed by Slash & burn with complete plowing plots, Strip burning plots, Strip plowing plots and clearing planting spot plots. The growth of teak raised by Polybag was higher than the growth of teak raised by pot-tube. This study evaluated the fifth-year growth performance of teak plantation. Continuous assessment needs to conduct in order to identify the long time effects of site preparation and nursery practices on teak growth.

Keyword: site-preparation, teak plantation, nursery practices, growth performance

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မြေနေရာပြုပြင်ခြင်းဖြင့် ကျွန်းစိုက်ခင်း ကြီးထွားမှုအား လေ့လာခြင်း

ဒေါက်တာယုယအေး၊ လက်ထောက်ညွှန်ကြားရေးမှူး
ဒေါ်ခိုင်ဝတ်မှုန်၊ ဦးစီးအရာရှိ
သစ်တောသုတေသနဌာန

စာတမ်းအကျဉ်း

စိုက်ခင်းစတင်တည်ထောင်သည့် အချိန်တွင် စိုက်ပင်များ ရှင်သန်မှုနှင့် ကြီးထွားမှု ကောင်းမွန်စေရန် အတွက် စိုက်ခင်းမြေနေရာပြုပြင်ခြင်းလုပ်ငန်းများ ဆောင်ရွက်လျက်ရှိပါသည်။ သို့ရာတွင် မလိုလားအပ်သော သက်ရောက်မှုများ မရှိစေရန်မြေနေရာ ပြုပြင်ခြင်း ကို ဂရုစိုက် ဆောင်ရွက်ရမည် ဖြစ်ပါသည်။ မြေနေရာပြုပြင်ခြင်းသည် အပင် ကြီးထွားမှု အပေါ် ကောင်းမွန်သော်လည်း မြေနေရာ ပြုပြင်ခြင်းကြောင့် စိုက်ခင်းအပေါ် ရေရှည်အကျိုး သက်ရောက်မှုများကို လေ့လာရန် လိုအပ်လျက်ရှိပါသည်။ စိုက်ခင်း မြေနေရာ ပြုပြင်ခြင်းနှင့် ပျိုးထောင်ခြင်း နည်းလမ်းများကြောင့် ကျွန်းစိုက်ပင်များအပေါ် အကျိုးသက်ရောက် မှုကို ရေရှည်လေ့လာရန် ရည်ရွယ်၍ ၂၀၁၉ ခုနှစ်တွင် မြေနေရာ ပြုပြင်နည်းအမျိုးမျိုးဖြင့် စမ်းသပ် ထားသော ကျွန်းသုတေသနစိုက်ခင်းကို တည်ထောင်ခဲ့ပါ သည်။ ပျိုးအိတ်ဖြင့်ပျိုးထောင်သော ကျွန်းပျိုးပင်နှင့် pot(tube)ဖြင့် ပျိုးထောင်ထားသော ကျွန်းပျိုးပင်တို့ကို မြေနေရာပြုပြင်ခြင်း နည်းလမ်း(၅)ခုဖြင့် စမ်းသပ်စိုက်ပျိုး၍ အပင်ကြီးထွားမှုကို နှစ်စဉ်တိုင်းတာခဲ့ပါသည်။ စိုက်ခင်းသက်တမ်း(၅)နှစ်အတွင်း တိုင်းတာချက် များအရ ယာခုတ်မီးရှို့သည့် စမ်းသပ်ကွက် သည် နှစ်စဉ် အပင်ကြီးထွားနှုန်း အကောင်းဆုံး ဖြစ်ကြောင်းတွေ့ရပါသည်။ မြေနေရာပြုပြင် ခြင်းများ နှိုင်းယှဉ်ပါကအပြောင်ရှင်းသည့်နည်းဖြင့် ဆောင်ရွက်သည့် ယာခုတ်မီးရှို့ နှင့် ယာခုတ်မီးရှို့ ထွန်ယက်သည့် စမ်းသပ်ကွက်များသည် လိုင်းအလိုက်ထွန်ယက်ခြင်း၊ လိုင်း အလိုက်မီးရှို့ခြင်း၊ စိုက်ပင်ပတ်လည် အပြောင်ရှင်းခြင်း ဆောင်ရွက်သည့် စမ်းသပ်ကွက် များထက် ကျွန်းပင်ကြီးထွားနှုန်း ပိုမိုကောင်းမွန်ကြောင်း တွေ့ရပါသည်။ စမ်းသပ်ကွက် များတွင် ပျိုးအိတ်ဖြင့် ပျိုးထောင်ခဲ့သည့် ကျွန်းပင်သည် pot-tube ဖြင့် ပျိုးထောင်ခဲ့သော ကျွန်းပင်ထက် ကြီးထွားနှုန်း ပိုမိုကောင်းမွန်ကြောင်း တွေ့ရပါသည်။ ဤစာတမ်းသည် သုတေ သနစမ်းသပ်ကွက်များ (၅)နှစ်တွင် တိုင်းတာရရှိသော အချက်အလက်များအား တင်ပြထား ခြင်းဖြစ်ပြီး စိုက်ခင်းမြေနေရာပြုပြင်ခြင်းနှင့် ပျိုးထောင်ခြင်းနည်းလမ်းများကြောင့် ကျွန်းပင် များ အပေါ် ရေရှည်အကျိုးသက်ရောက်မှုများကို ဆက်လက် လေ့လာသွားမည် ဖြစ်ပါသည်။

Growth Performance of teak plantation by Different Site Preparation Methods

1. Introduction

Globally, tropical rainforests are facing deforestation at an alarming rate, approximately one square mile of rainforest is destroyed every six minutes, with only one tree planted for every ten cut down. The United Nations Environment Programme (UNEP) projected that, at this rate, all remaining tropical forests could be destroyed by 2035 (Peace, 1994; *Myanmar Forestry Outlook Study).* Reforestation and afforestation have become essential strategies to combat deforestation, enhance biodiversity, and improve ecosystem services. Global frameworks like the Kyoto Protocol and the Intergovernmental Panel on Climate Change (IPCC) Report (2007) emphasize afforestation as an effective means to mitigate the rising concentration of atmospheric CO2 (Berthrong et al., 2012). Consequently, the global area of forest plantations has been expanding rapidly (Nouvellon et al., 2008).

Myanmar's Forest Department has practical experiences in program-based reforestation activities start from 1979. FD continued reforestation and afforestation activities by its national budget. Although Myanmar has already developed a significant extent of forest plantations, inspections conducted in 2010 has revealed that 55.98 % of the established plantation failed due to various reasons. Moreover, FRA (2020) has reported that Myanmar is the seventh-most deforested country in the world. In response to address deforestation and forest degradation issue, FD has developed and been implementing "Myanmar Reforestation and Rehabilitation Program (MRRP) (2017-18 to 2026-2027)". Plantation establishment is one of the main activities in MRRP program since forest department plan to establish 637,542 acres (state-owned plantation and private plantation) during the MRRP (10) years period. Mass production of forest tree seedlings is necessary to fulfill the targeted plantation establishment.

For ensuring plantation to be successful, appropriate silvicultural practices have to be applied such as selecting appropriate crop species, employing genetic sources, and optimizing nursery cultural practices for seedling development, and site preparation to modify the physical environment to enhance seedling performance after field planting (Gladstone and Ledig 1990; Grossnickle 2000). Site preparation, which is a necessary step in reforestation or afforestation, is an essential aspect of plantation success, influencing soil properties and seedling growth. It involves manipulating site conditions to increase the survival and growth of seedlings as well as to enhance the efficiency of tree planting or seeding. In Myanmar, establishment of plantations were normally carried out after removal and burning of slash (tops and branches) to facilitate subsequent management operations and reduce the risk of wildfires. Site preparation can favor the survival and growth of planted trees by reducing competition from understory vegetation (Karlsson, 2002). But on the other side, since these residues contain substantial nutrients (Cortez, 1996; Spangenberg et al., 1996; Jones et al., 1999), improper removal may deplete soil fertility and reduce productivity.

Appropriate nursery and tree planting technologies are vital for successful afforestation and reforestation. Nursery planting pots have been reported as one of the main factors affecting the successful development of seedlings (Dominguez-Lerena et al. 2006; Poorter et al. 2012).

Nursery practices have effect on the vigour of seedlings and accordingly on the success of their transplantation in the field (Oliet et al. 2009; Del Campo et al. 2010). Extensive research suggests that nursery operations play a significant role in seedlings quality and outplanting performance (liu *et al.* 2000, Gao *et al*. 2007, Li GL *et al.* 2012). Reforestation and restoration success in developing countries could be vastly improved with a readily available and cheap alternative to modern nursery containers (Khurram et al. 2017).

Now-a-day, polybags are more commonly used in nursery. Besides, there are different options to select for raising seedlings as modern nursery container, pot-tube become a substitute for plastic waste reduction. Start from 2017, modern nursery container, pot-tube, was initiated in Myanmar. Pot-tube seedlings offers several benefits such as being able to be transported considerable distance and being easy and quick to plant. Aung. et al (2018) recommended that pot-tube seedlings should be used instead of plastic bag seedlings to reduce plastic wastes in forests, transportation cost and planting cost. However limited study is conducted the growth performance of pot-tube seedlings after transplanting in the field. This study attempts to investigate the growth performance of pot-tube seedlings and poly bag seedlings after transplanting in the field.

Establishment of plantations requires some degree of site preparation and early maintenance to ensure high survival and rapid initial growth rate (Smith et al. 2012). Normally, tree plantation establish in degraded forest land. The sites were clear-felled during the winter. During the following summer, slash (tops and branches) was piled and burned. The slash and burn with subsequent replanting is used in establishment of plantation in Myanmar. This system is widely used in plantation establishment and produced good stand-establishment results for decades. But clear fell and burn may alters environmental conditions such as microclimate, soil hydrology, and soil fertility. Consequently, a clear cut, with its changing dynamics, is not always a friendly environment for newly planted seedlings (Grossnickle, 2000). Thus, concern has been raised as to whether different site preparation might have different growth performance of tree species. The present study was therefore designed to investigate the long-term effects of different site-preparation methods on growth performance of teak seedlings by pot-tube and poly bag.

2. Objectives

- To explore the effect of different site preparation practices on the growth of teak plantation
- To analyses the growth performance of pot-tube seedlings and poly bag seedlings after transplanting in the field

3. Materials and Methods

3.1.Study area and method

The present study was designed to investigate the long-term effects of different site-preparation treatments on productivity and determine any possible interactions with tree species and site fertility. In the 2019, Teak research plantation with a randomized block experiment was established at Ngalike Reserve Forest, Ottayathiri Township, Naypyitaw. Five site-preparation methods were performed and seedlings from different nursery practice (pot-tube and polybag) are used.

The pot-tube size was 5 inches x 1.5 inches. Pot tube media is mainly composed of Coir (up to 65%) and other ingredients such as peat, rice husks, carbonized rice husks, peat moss, gypsum, cow dunk, sphangum peat moss, *Hydrilla verticullata*. The polybag size was 7 inches x 3 inches. The soil media was composed of a mix of local soil, manure and sand with the proportion 3:2:1 with 3 parts local soil, 2 parts sand and 1 part manure.

The different site-preparation treatments were used in the experiment: (A) strip plowing (B) strip burning (C) control (i.e conventional slash and burn method) (D) slash and burn with complete plowing (E) clearing the planting spot. Treatment A, Strip plowing, was carried out in strips of 4 m, where treated 2 m and untreated 2 m strips alternated. Treatment B, Strip burning, was carried out in strips of 4 m, where treated 2 m and untreated 2 m strips alternated. Treatment C, Control plots (i.e conventional slash and burn method), the sites were clear-felled during the winter. During the following summer, slash (tops and branches) was pile and burn known as slash and burn method. Slash and burn method was used in plantation establishment in Myanmar. Treatment D, complete plowing plots were treated by plowing the whole plot area after slash and burn. Treatment E, zero burning and clearing 1 squared meter at the planting spot. Treatment A and treatment E are zero burning plot. All treatments were replicated three times. In strip-plowed plots seedlings were planted in the middle of the strip. In all treatment, the tree are planted with the spacing 4 m x 4 m.

Growth (DBH, height) will measure every year for a long term assessment on impact of site preparation. In this paper, the fifth year's growth response of two types of seedlings under five site preparation were analyzed. Tree growth were measured start from the first year teak plantation. Every year, tree growth were re-measured at the level of individual trees.

3.2.Statistical analysis

One way analysis of variance (ANOVA) was used to test the different among the site preparation. Post-hoc test was used to know the significant of one way ANOVA. Tukey's HSD test was performed for post-hoc comparisons between treatments mean at the 95% probability level ($P<0.05$). Differences in average tree height per container type (polybag and pot-tube) in each site preparation trial were assessed using independent sample t-test.

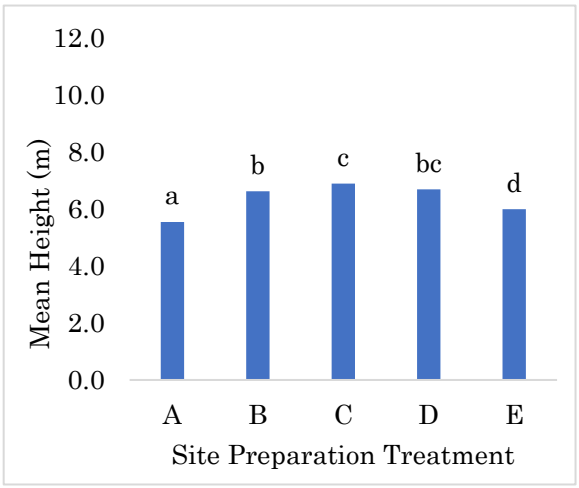
4. Results

The present study was designed to investigate the long-term effects of different site-preparation methods on productivity and determine any possible interactions with different planting stock. Besides, growth responses differ among different planting stocks and polybag seedlings are used in current reforestation program indicating a need for additional research for improved understanding alternative planting stock. Every year, tree growth were measured at the level of individual trees.

4.1.Effects of site preparation on tree growth

Growth of five-year-old teak plantation

The tree height growth in treatment C (6.89 m ± 0.06) was significantly higher than other treatments except treatment D. Based on the Tukey's HSD, treatment C is significantly higher than other treatment. After the fifth year growing season, tree growth was highest in slash & burn plots followed by Slash & burn with complete plowing plots, Strip burning plots, Strip plowing plots and clearing planting spot plots. This suggests that slash & burn (Treatment C) and slash & burn with complete plowing (Treatment D) provided the most favorable conditions for plant growth height. Diameter growth was not significantly different among site preparation treatments. When comparing the mean diameter (DBH), treatment A (strip plowing) showed the largest in diameter growth (10.58 ± 0.08 cm) followed by treatment B, treatment C. treatment E and treatment D (Figure 1). Basal area of teak plantation are not much different among different site preparation but volume was highest in slash & burn plots followed by Slash and burn with complete plowing plots (Figure 2).



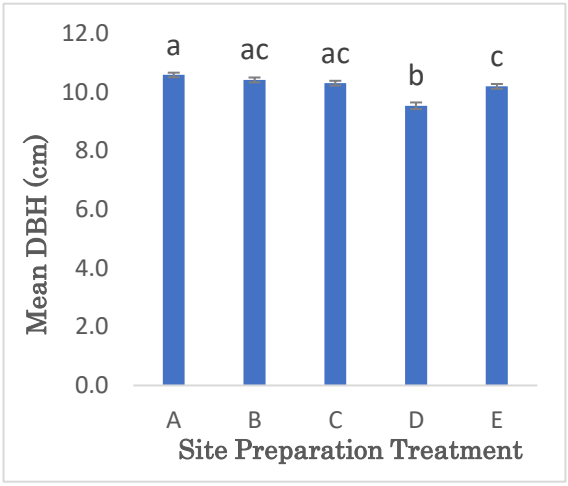
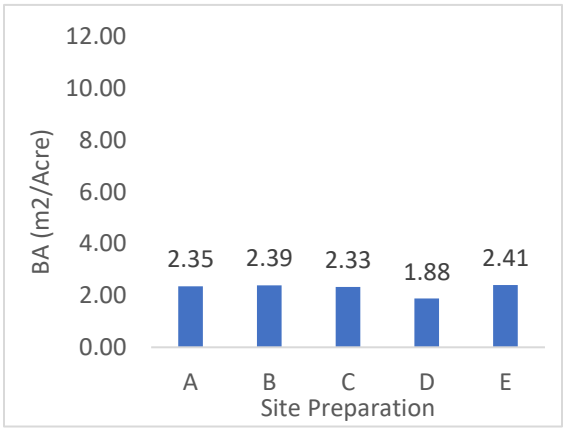


Figure 1.DBH (a) and Height (b) of five-year-old teak plantation under different site preparation



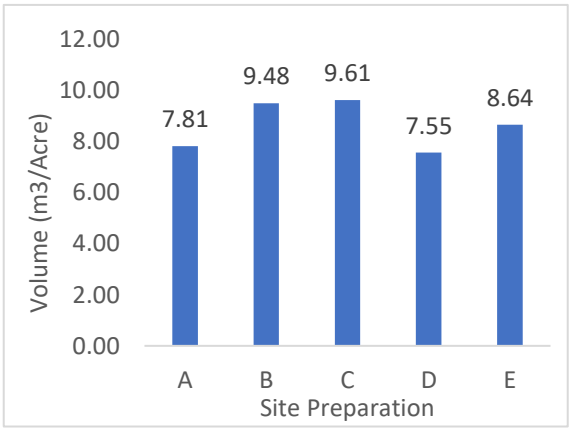


Figure 2. Basal Area (a) and Volume (b) of five-year-old teak plantation under different site preparation

Growth of teak plantation under different site preparation over years

Among different site preparation treatment, tree growth was highest in slash & burn plots followed by Slash & burn with complete plowing plots, Strip burning plots, Strip plowing plots and clearing planting spot plots. According to the five year measurement data, this suggests that slash & burn and slash & burn with complete plowing provided the most favorable conditions for plant growth.

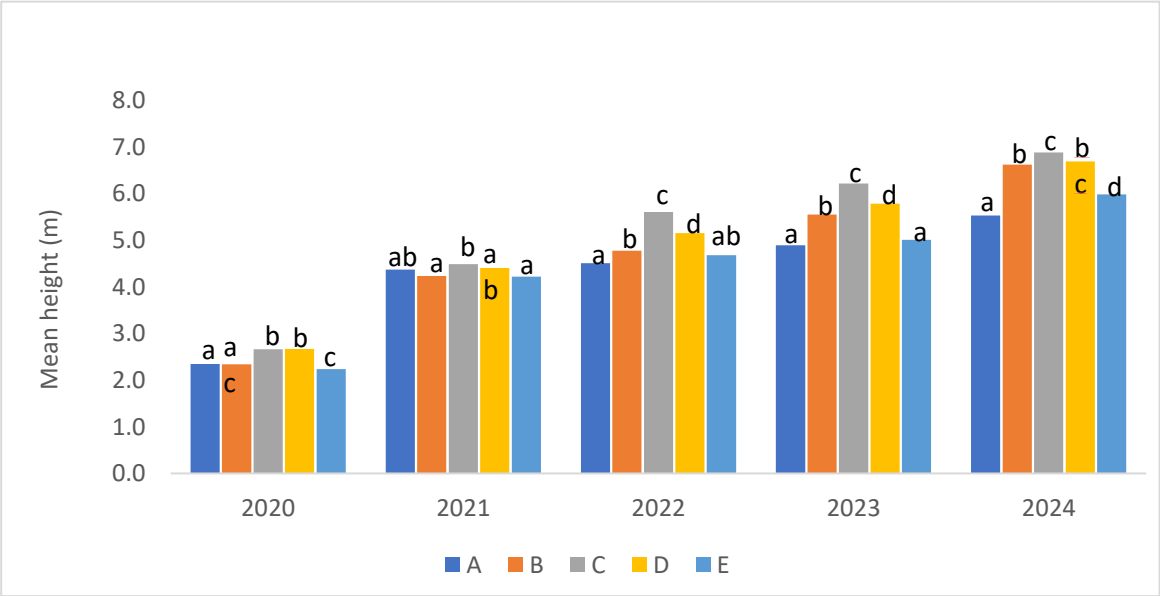


Figure 3. Growth (Height) of teak under different site preparation

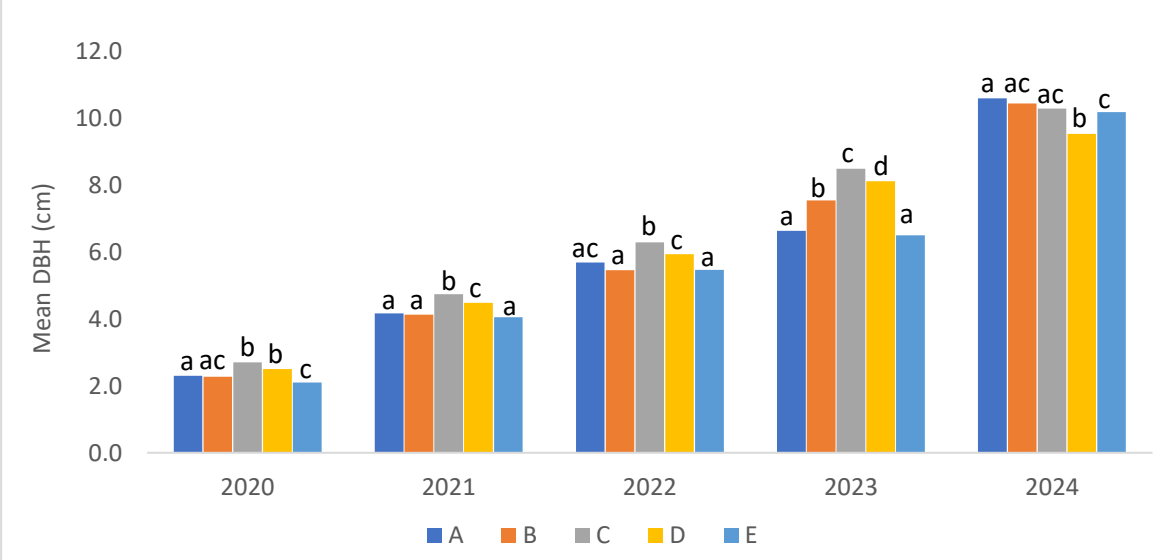


Figure 4. Growth (Height) of teak under different site preparation

Based on measurement data between 2020 and 2023, tree growth was significantly higher in slash & burn plots followed by Slash & burn with complete plowing plots (Figure 4). But in 2024, tree growth (DBH) of Strip burning plots, Strip plowing plots, slash & burn plots and clearing planting spot plots was not significantly different each other.

Table 1. Mean Annual Increment of teak under different site preparation

No.	Treatment	MAI Volume (m^3/tree)				
		2020	**2021**	**2022**	**2023**	**2024**
1.	A (strip plowing)	0.0006	0.0018	0.0023	0.0025	0.0058
2.	B (Strip Burning)	0.0006	0.0017	0.0022	0.0037	0.0068
3.	C (Slash & Burn)	0.0009	0.0024	0.0035	0.0053	0.0069
4.	D (Slash & burn with complete plowing)	0.0008	0.0021	0.0029	0.0045	0.0057
5.	E (clearing at planting spot)	0.0005	0.0016	0.0022	0.0025	0.0058

Table 2. Current Annual Increment of teak under different site preparation

No.	Treatment	CAI Volume (m^3/tree)				
		2020	**2021**	**2022**	**2023**	**2024**
1.	A (strip plowing)	0.0006	0.0030	0.0033	0.0033	0.0191
2.	B (Strip Burning)	0.0006	0.0028	0.0033	0.0082	0.0191
3.	C (Slash & Burn)	0.0009	0.0038	0.0057	0.0106	0.0133
4.	D (Slash & burn with complete plowing)	0.0008	0.0034	0.0044	0.0094	0.0106
5.	E (clearing at planting spot)	0.0005	0.0028	0.0033	0.0034	0.0193

Treatment C (Slash & Burn) consistently shows higher mean annual increments. The result suggest that Treatment C is the effective treatments for increasing tree volume (Table 1). By comparing the mean annual increasement over the years, treatment C (Slash & Burn) consistently shows higher mean annual increments followed by Treatment C (Slash & Burn with complete plowing).

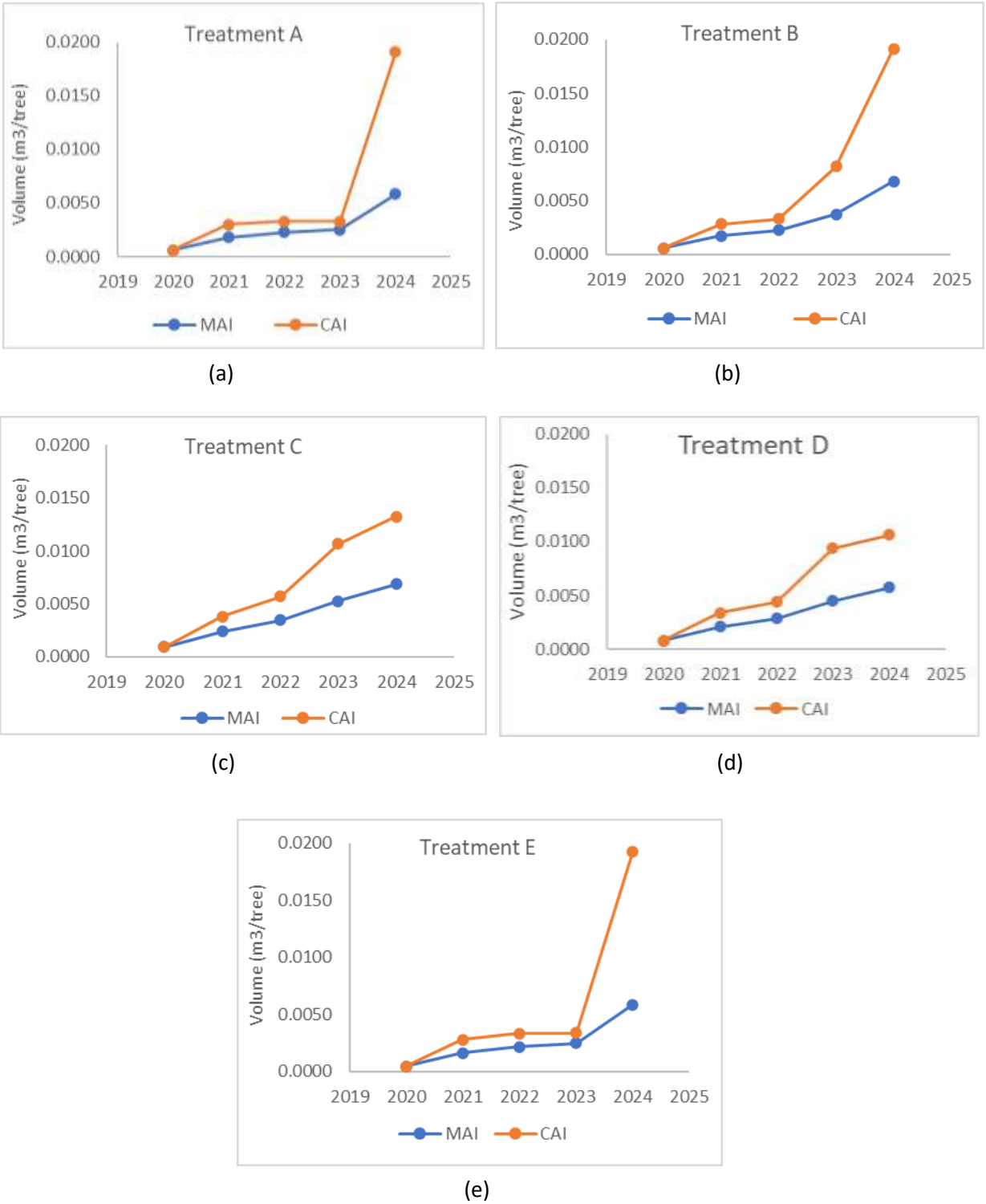


Figure 5. MAI and CAI of teak at each site preparation (a) Treatment A, (b) Treatment B (c) Treatment C (d) Treatment D (e) Treatment E

By analyzing the trends and values across the years for each treatment, Some treatments show steady increases, while others have fluctuations. At the individual tree level, CAI value was higher in Treatment C (Slash & Burn) and Treatment D (Slash & Burn with complete plowing) from 2020 to 2023 (the first year to fourth year of teak plantation) (Table 2). In 2024, CAI value of Treatment C and Treatment D are lower than Treatment A, B, E. It may be some environmental factors. So, long term assessment on tree growth are necessary in order to suggest effective site preparation treatment.

The MAI was a steady increase from 2020 to 2024, indicating that the average growth rate is accelerating over time (Figure 5). It was found that in 2024, the CAI is much higher than the MAI. This could indicate that the trees are reaching a peak growth phase or responding to optimal conditions. In 2024, CAI value was quite higher than the previous years. It may be many factors and annual rainfall might be one of the factor for increasing tree growth rate. In 2024, total precipitation days was 75 days/year and the mean annual rainfall was 69.56 inch. The mean annual rainfall was higher in 2024 (69.56 inch), in 2023 (46.18 inch), in 2022 (28.72 inch), in 2021 (34.89 inch) and in 2020 (27.08 inch). Because of the high mean annual rainfall in 2024, CAI value is much higher than the MAI value.

4.2.Growth performance of different planting stocks

Growth response of planting stocks under different site preparation treatments

Growth (height and DBH) were measured annually after plantation establishment. At polybag seedling plot, teak tree growth under treatment D (slash and burn with complete plowing) was highest 7.07 ± 0.11 meter, followed by treatment C (7.01 ± 0.08), treatment B (6.39 ± 0.07), treatment E (6.24 ± 0.07) and treatment A (5.47 ± 0.07). Based on the Tukey's HSD, treatment D is significantly higher than other treatments (A, B & E) but not significantly difference with treatment C (Figure 6 - a). Treatment C which is the conventional slash and burn method showed significantly better than other treatments (A, B & E).

The height growth of the pot-tube teak was within the ranges 5.60 ± 0.5 and 6.85 ± 0.06. At the pot-tube seedling experimental plot, tree growth was highest in treatment B (6.85 ± 0.06) followed by treatment C (6.76 ± 0.08), treatment D (6.30 ± 0.12), treatment E (5.73± 0.08) and treatment A (5.60 ± 0.05). As evaluated by Tukey's HSD, treatment B (Strip burning) showed significant difference and higher among other treatments except with treatment C. The height growth of other treatments (A, D & E) were significantly lower than treatment C (Figure 6 – b).

In polybag seedling plot, growth (DBH) of teak varied from 9.62± 0.12 cm to 10.74 ± 0.13 cm (Figure 7 - a). The maximum diameter growth was recorded in treatment A (strip plowing) followed by treatment E, treatment C, treatment D and treatment B. In pot-tube seedling, diameter growth was found maximum in treatment B (11.26 ± 0.10) followed by treatment A (10.44 ± 0.09), treatment C (9.96 ± 0.11), treatment E (9.68 ± 0.12) and treatment D (9.05 ± 0.16). As evaluated by Tukey's HSD test, treatment A showed significant difference ($P < 0.05$) with other treatments (Figure 7-b). Concerning the site preparation effect on growth (volume) of planting stock, Treatment C (Slash and burn) resulted in better performance of teak raised by polybag and treatment B (Strip Burning) showed better performance of teak raised by pot-tube (Figure 8).

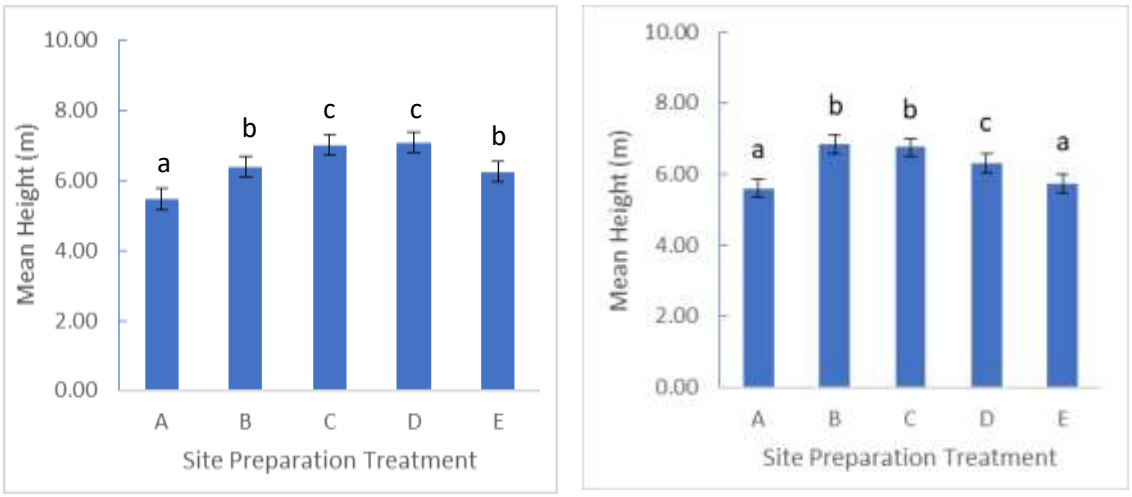


Figure 6. Growth (height) of teak raised by polybag (a) and Pot-tube (b)

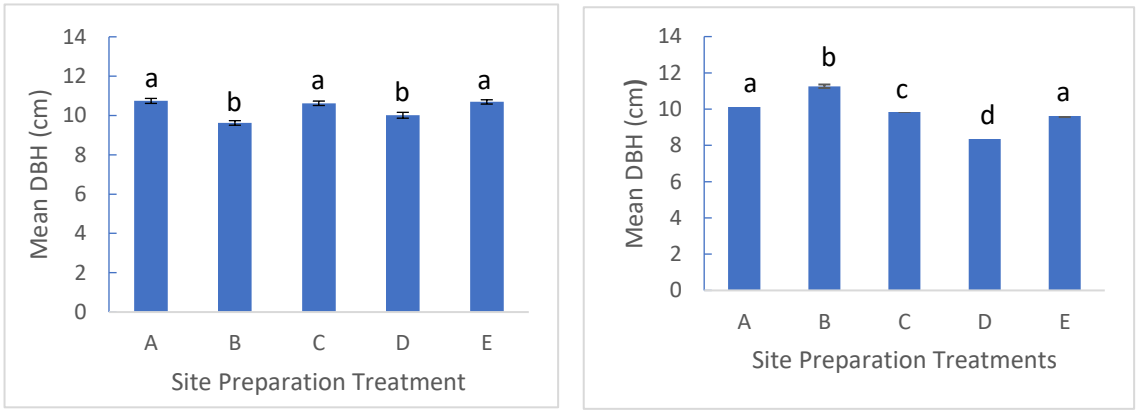


Figure 7. Growth (height) of teak raised by polybag (a) and Pot-tube (b)

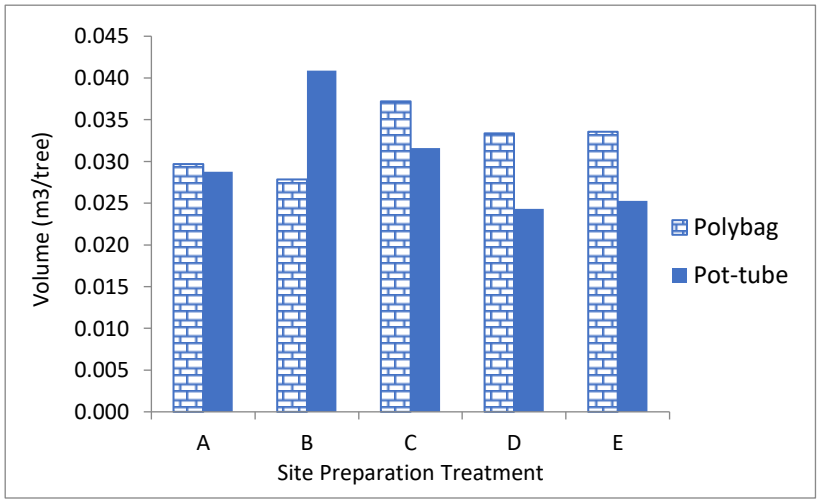


Figure 8. Volume of different planting stocks

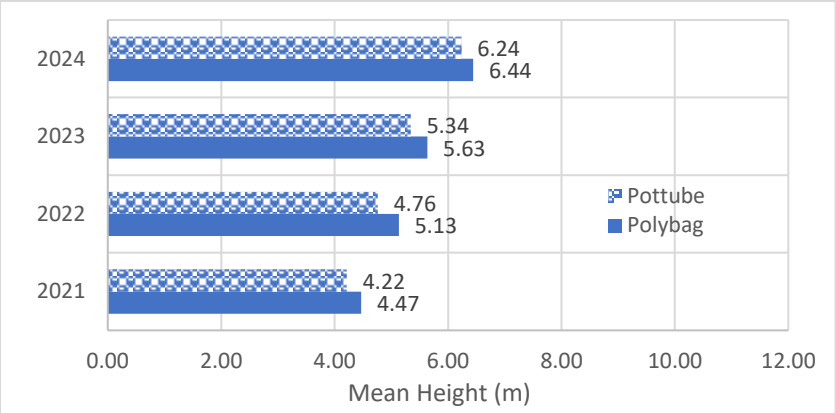
Based on measurement data, it was found that the planting stocks (polybag seedlings and pot-tube seedlings) effect on growth of tree in out planting stage. Based on measurement data, it was found that polybag seedlings were significantly higher than the pot-tube in all site preparation treatments except in treatment B (**Error! Reference source not found.**8)**.** It may be effects of d ifferent nursery practice such as different media and different pot size at the seedling stage. The pot-tube size was 5 inches x 1.5 inches while the polybag size was 7 inches x 3 inches. The positive effect of increasing planting pot size on seedling growth was reported for many plant species (e.g. Dominguez-Lerena *et al.* 2006; Dumroese *et al.* 2011). Our results confirm with Abera. *et al* 2018 statement. He stated that seedlings raised in large pots would be better developed and produced in a shorter time than seedlings raised in pots of smaller size. He also mentioned that better seedling performances in larger pots is due to the availability of more growing space, enabling the early development of root to escape drought, favorable condition for the success of transplantation in the field. Moreover the effect of media might be one of the factor the growth performance of tree. Some studies have reported significant growth differences under different soil mixes; for example, Fekadu et al. (2011) used different levels of manure, sand and local soil in a highland area but reported significant differences among the treatments. In this study, pot-tube media is mainly composed of Coir (up to 65%) and other ingredients but polybag media composed of local soil, manure and sand.

Growth response of different planting stocks over years

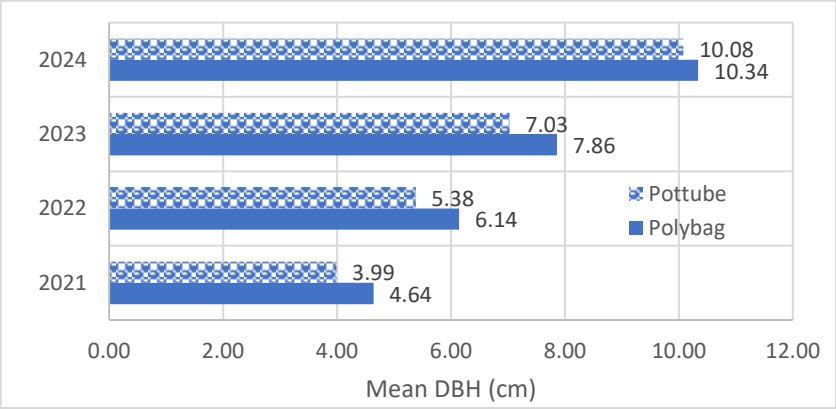
Based on measurement data, it was found that polybag seedlings were significantly higher and larger than the pot-tube both in height and DBH. This study observed that polybag seedling provided better height growth (4.47 m in 2021, 5.13 m in 2022, 5.63 m in 2023 and 6.44 in 2024) than pot (tube) seedling (4.22 m in 2021, 4.76 m in 2022, 5.34 m in 2023 and 6.24 in 2024). It was observed that the height of the polybag seedling was higher than the pot-tube seedlings at five years old. Likewise, the growth (volume) of teak raised by polybag seedling was higher than the pot-tube seedlings after the five years growing season (Figure 9). Starting from plantation establishment (2019), polybag seedling was observed about sixfold growth performance while pot-tube seedlings were almost tenfold growth performance within five years.

Diameter at breast height was measured and the growth increment varies significantly over the years for both seedling types. Although, mean annual increment of diameter was slightly better in polybag teak than pot-tube, the highest growth increment was found in pot-tube teak at the age of 5-years old. Mean annual increment (MAI) of teak raised by polybag was 2.07 cm/year and teak raised by pot (tube) was 2.02 cm/year (Table 3). This cumulative average shows that diameter increment was better in polybag teak than pot (tube) although the difference is relatively small, indicating that both methods are comparable in diameter increment.

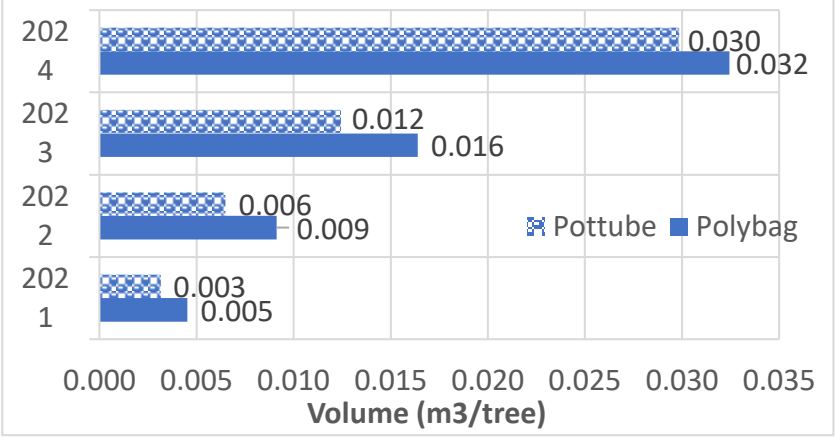
The highest growth increment was found in the first year (2020) for both planting stocks. Mean Annual Increment (MAI) of teak raised by polybag was 1.29 m/year and teak raised by pot-tube was 1.25 m/year (Table 3). Although pot (tube) teak showed better performance in individual years, the cumulative average shows that teak raised by polybag might offer more consistent or sustained growth over time.



(a)



(b)



(c)

Figure 9. Growth response of different planting stocks over years: mean height (a), mean DBH (b) and Volume (c)

Table 3. Mean Annual Increment of teak (DBH)

	Annual DBH Growth Rate (cm)					MAI (cm)
Seedling Type	2020	2021	2022	2023	2024	
Polybag	2.7	1.9	1.5	1.7	2.5	2.07
Pot (tube)	2.1	1.9	1.4	1.6	3.1	2.02

Table 4. Mean Annual Increment of teak (Height)

	Annual Growth Rate (Ht)					MAI (m)
Seedling Type	2020	2021	2022	2023	2024	
Polybag	1.60	1.83	0.66	0.50	0.81	1.29
Pot (tube)	1.67	1.95	0.54	0.58	0.89	1.25

The survival percentage is around 90 % in all site preparation treatment if the different planting stocks are not considered. This study consistent with other studies. Site preparation increases survival and that higher mortality occurs in the first years following planting (Johansson *et al.* 2013). And Wallertz *et al.* (2018) stated that the effect of site preparation was not only related to increase survival but it also positively affected individual trees. But Smith *et al.,* (2013) mentioned that based on trial research, the final survival, basal area and volume were not affected by land preparation. This study indicated that site preparation was not effect to survival percent of plantation.

5. Discussion

The silvicultural system of clear-felling with subsequent replanting is commonly used across the world. Although this system has produced good stand-establishment results for decades. A clearcut is not always a friendly environment for newly planted seedlings (Margolis and Brand 1990; Grossnickle 2000). Seedling stress is common, and both biotic and abiotic factors may reduce the regeneration success. One way to improve site conditions and thereby increase the survival and growth of planted seedlings at an early stage is by site preparation. However, the benefits of site preparation appear to be more obvious in the early years of growth, and they often decrease over time, with growth rates coinciding with non-prepared sites by the end of the rotation (Passauer, 2013 and Fox, 2005). Thus, this study designed to investigate the long term effect of site preparation on teak plantation. Different site preparation such as strip plowing, strip burning, slash & burn, slash & burn with complete plowing and clearing the planting spot were used. After second years growing season, teak growth (height) in slash and burn plots and slash and burn with complete plowing plots showed significantly higher than other plots. Thus, clear-felled treatments (slash & burn and slash & burn with complete plowing) were the effective method for stand establishment of teak. It may be due to the fact that cleared-fell and burning treatment reduce the ground vegetation. The result supports the statement of Karlsson (2002), he mentioned that site preparation promotes the early establishment and growth of crop trees by reducing competition from ground vegetation (Karlsson, A 2002). Moreover, the planted tree might less compete with weed and get sufficient light. It corresponds with Liu (2016) findings. He found that, in the clearing site, the trees growth well because they outcompeted other trees for light. Several studies indicated that tree growth releases mostly take place during the juvenile phase because of competition for light (Brienen, 2006 and De Ridder 2013).

When the site preparation methods categorized into burning and without burning, the burning plots (slash & burn, slash & burn with complete plowing) provided the better growth performance. Because slash & burn and slash & burn with complete plowing treatments cleared undesirable ground vegetation before plantation establishment and provide favorable condition for teak seedlings. This study result is comparable with Miller (2009) statement. He stated that various site preparation treatments should applied at stand initiation to reduce competing vegetation and improve crop tree growth. Mahmud's stated that zero burning is an environmentally friendly technique which helps safeguard the environment from air pollution. But in this study, teak growth in burning plots provide better than no burning plots. In case of survival rate, this study indicated that site preparation was not effect to survival percent of planted tree.

This study also examined the growth response of different planting stocks (polybag seedlings and pot-tube seedlings). In each site preparation treatment, different teak planting stocks were planted. After fifth years of transplanting in the field, it was found that the teak growth was affected by planting stocks**.** The growth of teak raised by polybag was higher than teak raised by pot-tube. Seedlings container type may be one of the factors that effect on tree growth in outplanting phase. The container size are different polybag seedlings (7 inches x 3inches) and pot-tube seedlings (5 inches x 1.5 inches). Jacobs (2017) found that the container types showed a few different the plant growth responses at both in nursery and one year after

outplanting. But Khurram S et al. (2017)'s report that in the outplanting phase, container type did not impact seedlings height and diameter growth of tree species. Although the first year following planting represents the critical establishment period, one or two year may have been insufficient to observe treatment effects, Grossnickle (2005).

At the time of planting, in June 2019, one year old seedlings raised by different nursery practice (polybag and pot-tube) were planted in all experimental plot. This study found that polybag seedlings growth was higher than pot-tube seedlings after transplanting in the field. In all site preparation treatment, the growth of teak raised by polybag was significantly higher than teak raised by pot-tube. It might be due to the seedlings height different at the time of plantation establishment. Even though this study used one year old seedlings, the height of poly bag seedlings was much higher than pot-tube seedlings at the time of planting. In term of annual growth increment, polybag seedlings resulted in almost sixfold height increment within five year while pot-tube seedlings resulted in almost tenfold height increment. The mean annual growth rate of different planting stocks are 1.29 m/year (height) and 2.07 cm/year (DBH) for polybag seedlings and 1.25 m/year (height) and 2.02 cm/year (DBH) for pot-tube seedlings. Hence the growth rate of pot-tube seedlings was comparable the polybag seedlings. If the annual growth rate of different planting stocks are similar, this result would suggest that use of pot-tube as an alternative container type in production nurseries for incorporation into reforestation and restoration programs. In terms of cost and practicality, Jabran et al. (2017) highlighted that polybag seedlings are typically more affordable and suitable for large-scale production due to their lower material cost and simpler design. Due to large quantities of seedlings could produce at a low cost, polybags are economically viable for large-scale planting in forestry projects.

6. Conclusion

Reforestation and afforestation have become essential strategies to combat deforestation, enhance biodiversity, and improve ecosystem services. Accordingly, the global area of forest plantations has been expanding rapidly. Forest restoration projects have become increasingly common around the world and planting trees is almost always a key component. Various site preparation practice are important tools used to help counteract this. Site preparation often results in improved seedlings survival and growth. Site preparation increases the availability of resources at a site by reducing competition from other species colonizing the regeneration area (Thiffault and Jobidon 2006; Wiensczyk et al. 2011; Johansson et al. 2013). Site preparation may lead to multiple interactions among soil physical and chemical properties that affect plant survival and growth. Limited research to date on site preparation and plantation performance has been conducted. Slash & burn are usually use in restoration program indicating a need for additional site preparation research to provide recommendation in reforestation program. Site preparation should be implemented carefully because they can have large impacts on the environment. Different site preparation may lead to multiple interactions among soil physical and chemical properties that affect plant survival and growth. In order to investigate the long term effect of site preparation on the growth of teak, the research plots were established in 2019. Five site preparation treatment were performed and seedlings from different planting stocks (pot-tube and polybag) are used. After fifth year growing season, slash

and burn resulted in better performance of teak raised by polybag and strip burning showed better performance of teak raised by pot-tube.

Based on five times measurement (2019 December to 2024 December), it was found that the growth of teak raised by polybag was significantly higher than teak raised by pot-tube. If compare teak height growth between 2019 Dec and in 2024 Dec, polybag seedlings resulted in almost threefold height increment within one year while pot-tube seedlings resulted in almost fourfold height increment. Mean annual growth (height) rate of teak raised by polybag was 1.29 m/year and teak raised by pot-tube was 1.25 m/year. This study provide the evidence to suggest that use of pot-tube as an alternative container type in production nurseries for incorporation into reforestation and restoration programs since pot-tube seedlings offers several benefits such as being able to transported considerable distance and being easy and quick to plant. Many developing countries are concurrently facing severe environmental problems that can be ameliorated by planting trees in restoration projects (Bewket W. et al 2005). In addition to providing an effective means to produce high quality seedlings for reforestation, use of pot-tube as nursery containers will reduce consumption of plastic and provide a commendable alternative for waste management. But seedlings producers should consider how pot-tube could be incorporated into their existing facilities, available resources, and seedlings handling and storage methods and it is recommended that further research on cost benefit analysis, forester's perception and long term effect on plantation should be conducted. Growth responses differ among different planting stocks and polybag seedlings are used in current reforestation program indicating a need for additional research for improved understanding alternative planting stock. Further comparative studies of different species in different region are needed for a deeper understanding of the effect of planting stocks after transplanting in the field. Reforestation and afforestation efforts, combined with good silvicultural practices, hold immense potential for reversing deforestation trends in Myanmar. By integrating sustainable site preparation, planting stock selection, and continuous monitoring, Myanmar can enhance the growth and resilience of its plantations while contributing to global climate mitigation efforts.

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