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Planting technique of Teli-garjan (*Dipterocarpus turbinatus* Gaertn.) and Dhaki-jam (*Syzygium firmum* Thw.) in degraded hills of Chittagong, Bangladesh

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ABSTRACT

Suitable plantation technique is important for establishing plantation of different species from better germination, growth performance, economic and environmental point of view. Two plantation techniques, polybag seedlings and thali (direct seeding on ring shaped cleared soil), were studied from 2005 to 2014 in order to find out the superior one for establishing plantations of Dipterocarpus turbinatus and Syzygium firmum. Results revealed that polybag seedlings of Dipterocarpus turbinatus and Syzygium firmum had little bit higher germination percentage, germination value and germination energy than thali. None of these values of polybag seedlings and thali are significantly different except germination value and germination energy of Dipterocarpus turbinatus. Cumulative germination percentage of both species was higher at the initial stage for polybag seedlings than thali. Growth performance up to 9.5 years of Dipterocarpus turbinatus showed that for polybag seedlings the average height, average diameter at breast height (DBH), mean annual increment (MAI) of height and MAI of DBH are comparatively higher, with no significant difference than thali. On the other hand, these growth parameters of Syzygium firmum are higher for polybag seedlings at 5% significant level than thali. The survival percentage of Dipterocarpus turbinatus was higher (78.67 ± 9.33%) in plantations raised from thali (direct seeding) than polybag raised seedlings (69.33 ± 9.61%). The financial analysis was very positive for thali since expenditure incureed for establishing plantations by thali was much lower (6.70 BDTk./individual) than polybag seedlings (15.60 BDTk./individual). Considering the germination potentiality, growth performances, financial invovement and environmental point of view, the study suggested that the thali technique or direct seeding may be suitable for teli-garjan (Dipterocarpus turbinatus) and dhaki-jam (Syzygium firmum) plantation.

Key Words: *Planting technique, Dipterocarpus turbinatus, Syzygium firmum, degraded hills, thali germination, germination value, energy and growth.*

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I. Introduction

Dipterocarpus turbinatus belongs to the family *Dipterocarpaceae*, a commercially important tree species distributed in Chittagong, Cox's Bazar, Chittagong Hill Tracts and Sylhet areas (Das and Alam 2001; Das, 1980). It attains a height of 35-50 m or more and a girth of 4 - 4.5 m in favorable conditions (Hossain, 2015; Troup, 1921; Zabala, 1990). Wood is heavy, fairly straight grained, used as railway sleeper and for making lorry, boat building and other construction purposes (Das and Alam, 2001; Das 1970). On the other hand *Syzygium firmum* belongs to the family Myrtaceae is another commercially important tree species distributed in the area of Cox's Bazar Chittagong Hill Tracts, Chittagong and Sylhet. It attains a height of 20-35 m and a girth of 1.5-2.0 m (Das and Alam, 2001; Hossain, 2015; Zabala, 1990). The wood is moderately hard. It is used as house building, furniture, boat and trawler pataton and beams, poles and other constructions (Das and Alam, 2001; Banik, 1980). Bangladesh is situated in north-eastern part of South Asia lies in between $20^{0}34'$-$26^{0}38'$ north latitude and $88^{0}01'$-$92^{0}41'$ east longitude (BBS, 2010). The country possesses 14.7 million ha of land area of which 2.57 million ha forest land that forms 17.5 percent of its total land area (Altrell *et al.*, 2007). The forest resources of the country depleted at an annual rate of 3.3 percent (Hossain, 2001). Consequently biodiversity of the country has been depleted heavily during the last four decades. That is due to ever increasing population and increased per capita consumption for food, fuel-wood, timber, homestead, aquaculture and other purposes resulting over exploitation of state managed forests and loss of biodiversity (Khan *et al.*, 2007). Rapid loss and degradation of forest resources in the country has created an alarming rate of forest biodiversity depletion (Rahman *et al.*, 2000; Hossain, 2001). To combat the situation and increase vegetation cover Bangladesh Government took different initiatives likes massive plantation programme in degraded hill forests, Social forestry programme, establishment of Protected Areas, National parks, Wildlife Sanctuaries, Game Reserves etc. Plantation programme was carried out through clear felling-cum artificial regeneration in degraded hill forests with long (20-40 years) and short rotation (12-15 years) working circles. Long rotation working circles includes the species like *Tectona grandis*, *Shorea robusta*, *Melina arborea*, *Artocarpus chama*, *Dipterocarpus turbinatus*, *Syzygium firmum*, *Lagerstroemia speciosa*, *Hopea odorata* etc. Plantation programme in Bangladesh usually run by using container raised seedlings in the nursery and in some cases bare rooted seedlings especially in mangrove species also used. Several problems like low germination rate, root coiling, slow growth, wilting and damping off due to lack of proper management (watering and shading) and also seed biology encounters and leads the low success rate of plantation. For successful plantation establishment, proper plantation technique is inevitable or pre-requisite. Seeds of *Dipterocarpus turbinatus* and *Syzygium firmum* are recalcitrant in nature which requires immediate sowing after collection. Moreover, it is very difficult to transport the container raised seedlings in the hilly areas due to poor communication facilities and it tolls high transportation cost. In that situation direct seed sowing may be one of the alternative options for plantation establishment of teli-garjan and dhaki-jam in the hilly areas and cost effective. Das (1980); Sengupta (1936) and Zabala (1990) indicated that direct seed sowing may be useful for plantation raising in case of tei-garjan and dhaki-jam in the degraded hilly areas. However, plantation raising through direct seed sowing for both the species related to timely commencement of rains. In that context there is a close coincidence between the commencement of rains and seed fall of teli-garjan and dhaki-jam in Bangladesh. Considering the fact the study was initiated to evaluate the plantation technique of these species through containerized seedlings and direct seed sowing (*thali*) process.

II. Materials and Methods

The study was initiated at Keochia Silviculture Research Station of Bangladesh Forest Research Institute under Satkania Upazilla of Chittagong district during June/May 2001 (Figure 01). The site is located between $22^{0}16'$ N latitude and $91^{0}49'$ E longitudes (Hossain *et al.*, 1989). Topography of the site is undulating hilly to flat, medium to gentle slopes. Deep soils with good drainage capacity, stoniness, small gravel present occasionally, sandy loam to sandy clay loam, pH ranges from 4.5 - 5.5, acidic in nature. Mean annual rainfall 2272 mm and mean annual temperature 25.5^{0} C (Zashimuddin, 2001).

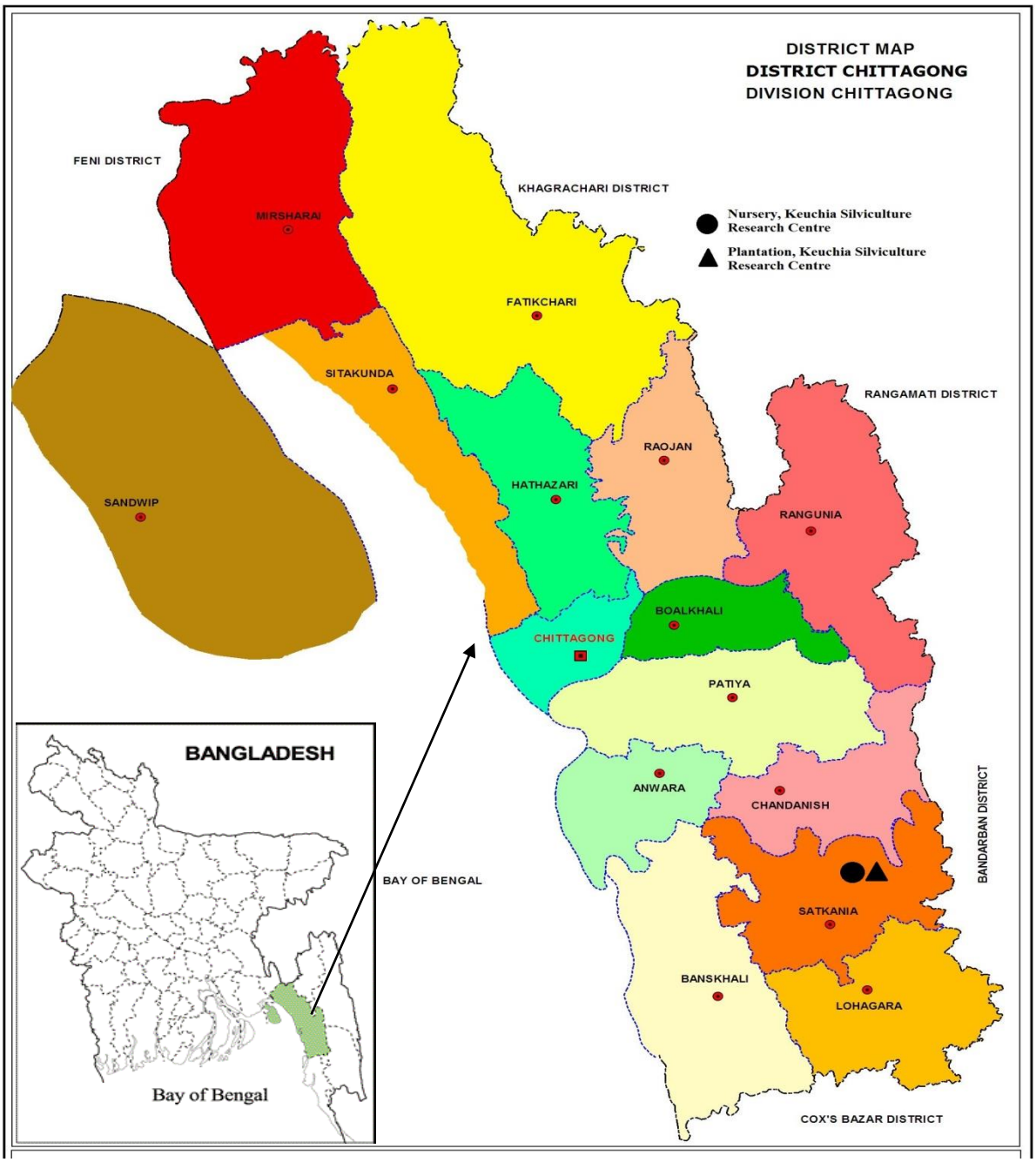

Figure 01. Map showing the location of the study area at Keocia Silviculture Research Station, Satkania on Chittagong district map, Bangladesh.

Experimental field was prepared through weeding during May 2005. Pits or *thali* prepared in the ring form with 30 cm radius at a distance of 2 m × 2 m. Total 75 *thali* were prepared in three replications (25 *thali* in each replication). Necessary cultural operations were also made in *thali*. Mature seeds were collected from selected mother trees of Dulahazara Seed Orchard Center of Bangladesh Forest Research Institute (BFRI), Chakaria, Cox's Bazzar during 2nd week of June 2005. Collected seeds were sown in the thali, following day. Three seeds were sown in each thali at a distance of 15 cm. So, in each replication 75 seeds (no. of *thali* was 25) were sown and total 225 seeds were sown in three replication. Similarly collected seeds were sown in poly bag arranged in the nursery. The polybag size was 12 cm × 18 cm. Medium used in the poly bag was mixture of soil and cow dung at a ratio of 3:1. One seed was sown in each poly bag, so 25 seeds were sown in each replication and total 75 seeds were sown in three replications. Germination was explored in both *thali* and nursery periodically through counting the germinating seeds. Cumulative germination was recorded every alternate day of sowing and continued up to end of the germination for *Dipterocarpus turbinatus*, on the other hand germination was recorded after 6 days interval for *Syzygium firmum*. In case of thali only one seedling

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kept for the assessment of growth performance after one year. Simultaneously one year old seedlings raised in polybag were planted in the same field side by side, where seeds were sown in thali. Polybag raised seedlings were planted at similar distance of thali (2 m × 2 m). In each replication 25 seedlings were sown, total 75 seedlings planted in three replications. Weeding was done at every six months. Germination data for calculating germination percentage, germination value and germination energy were collected. Germination value and germination energy (GE) was calculated following formula of Djavanshir and Pourbeik (1976) and Maguire (1962) respectively.

$$\text{Germination Value (GV)} = (\sum \text{DGS} / \text{N}) \times 10 \text{ GP}$$
$$\text{Germination Energy (GE)} = X_1 / Y_1 + (X_2 - X_1) / Y_2 + \ldots\ldots + (X_n - X_{n-1}) / Yn$$

Here,
DGS = Daily germination speed computed by dividing the cumulative germination percentage by the number of days since beginning the test
GP = germination percentage
N = frequency or number DGS that were calculated during the test,
X_n =is the number of germinant on the n^{th} counting date
Y_n, the number of days from sowing to the n^{th} count, and 10 in the first equation is constant

Initial growth performance of seedlings in the nursery and in the field don't include here due to some data inconsistency. Growth performance for seedlings raised by direct seed sowing (*thali*) and polybag raised seedlings were assessed in the field at the age of 9 years and 6 months.

Data were analyzed by MS Excel and IBM SPSS Ver. 2.1 software to get germination and growth performance parameters. Significant differences between the treatments were analyzed at $p < 0.05$ by ANOVA test.

III. Results and Discussion

Seed germination potentiality of *Dipterocarpus turbinatus* and *Syzygium firmum*

The study recorded highest (88 ± 4.0) germination percentage in poly bag and lowest (85.33 ± 3.52) percent in thali for *Dipterocarpus turbinatus*. The study found maximum (94.67 ± 2.67) germination percentage for *Syzygium firmum* while tried with polybags and minimum (92 ± 2.31) percent when it was tried in thali (Table 01). There was no significant difference between the values of germination percentage in polybag and thali treatment for both *Dipterocarpus turbinatus* and *Syzygium firmum* (at $p < 0.05$). In other experiments, *Pterocarpus santalinus* was represented by 79 – 81% germination when seeds soaked in water for six hours (Naidu and Mastan, 2001). *Rauwolfia serpenitna* showed 86% germination which was much better than control (Gupta, 2003). Haider *et al.* (2014) found 62 – 80 % germination for *Acacia catechu* under different treatments. So, it seems that the germination percentage for both polybag and thali was satisfactory. Germination Value (GV) was maximum (34.02 ± 2.14) for polybag treatment of *Dipterocarpus turbinatus* followed by thali treatment (22.34 ± 1.26) of the same species. The experiment revealed that thali treatment of *Syzygium firmum* showed minimum (7.17 ± 0.48) Germination value than polybag treatment (11.34^a ±1.53). Germination value of polybag and thali treatments for *Dipterocarpus turbinatus* were significantly different at $p < 0.05$, whereas no significant difference was found between germination value of polybag and thali treatments of *Syzygium firmum*. Germination of *Dipterocarpus turbinatus* seeds was initiated in polybag and thali at 5^{th} and 7^{th} days of seed sowing respectively. On the other hand, seeds of *Syzygium firmum* took 16 days to initiate germination in polybag and 18 days in thali. It is one of the important reasons of less germination value for thali than polybag. Swaminathan and Revathy (2013) reported germination value 16.95 and 10.22 for *Sapindus emarginatus* species treated by cold water and control respectively. The study revealed that germination energy (GE) of both *Dipterocarpus turbinatus* and *Syzygium firmum* species in *thali* were lower than polybag. In case of *Dipterocarpus turbinatus* the value is significantly lower (5.02 ± 0.16) in thali at $p < 0.05$ than polybag (6.68±0.38). But, no significant difference was found between germination energy recorded for polybag and *thali* treatments of Dhaki-jam (*Syzygium firmum*). Germination energy represents the speed of germination. As germination rate at the initial stage in polybag was higher than thali hence germination energy was found higher in polybag treatment. Swaminathan and Revathy (2013) in an experiment showed that

germination energy of *Sapindus emarginatus* was 2.5 for seeds treated by cold water which is lower than the germination energy of *Dipterocarpus turbinatus* in polybag and *thali*.

Table 01. Germination percentage, value and energy of *Dipterocarpus turbinatus* and *Syzygium firmum* in polybags and thali

Treatment	Garjan (*Dipterocarpus turbinatus*)			Dhaki-jam (*Syzygium firmum*)		
	Germination					
	%	Value (GV)	Energy (GE)	%	Value (GV)	Energy (GE)
Polybag	$88^{a} \pm 4.0$	$34.02^{a} \pm 2.14$	$6.68^{a} \pm 0.38$	$94.67^{a} \pm 2.67$	$11.34^{a} \pm 1.53$	$2.07^{a} \pm 0.16$
Thali	$85.33^{a} \pm 3.52$	$22.34^{b} \pm 1.26$	$5.02^{b} \pm 0.16$	$92^{a} \pm 2.31$	$7.17^{a} \pm 0.48$	$1.65^{a} \pm 0.10$

Similar letter indicates not significantly different column wise at $p<0.05$ significance level according to ANOVA, and ± indicates standard error of mean.

Cumulative germination

Experiments reveals that germination of *Dipterocarpus turbinatus* was started 5 days after sowing (DAS) and continued up to 21 days in both polybag and thali. After 21 days cumulative germination remained constant up to the end of the germination test. Maximum germination was found 88% in poly bag, while it was 85.33% in thali (Figure 02). During the germination process, the initial rate of increment in cumulative germination percentage in the polybags was higher than thali.

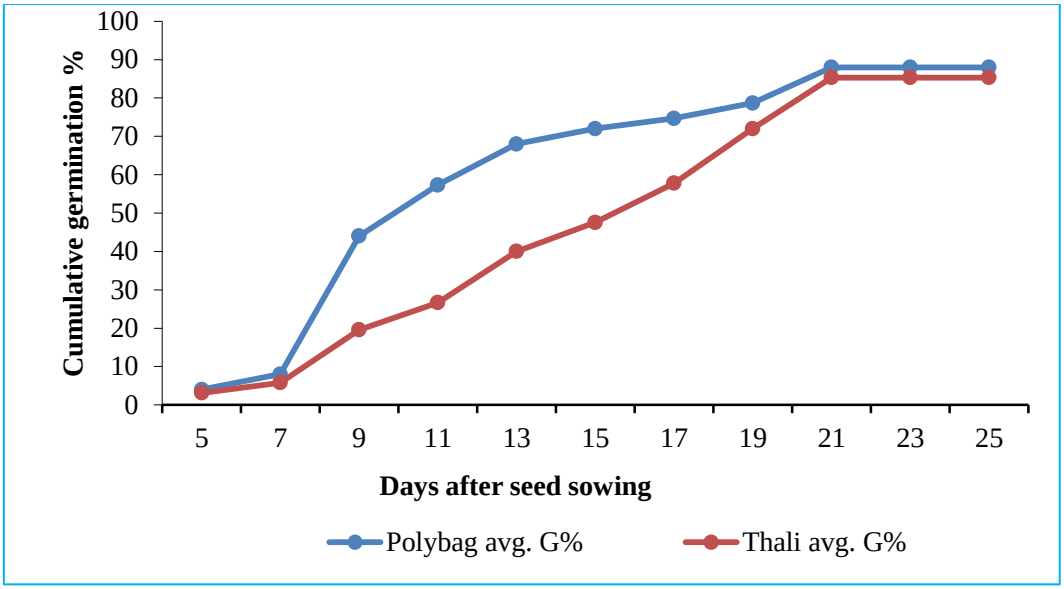

Figure 02. Progress of cumulative germination percentage of *Dipterocarpus turbinatus* seeds in both polybag and *thali*.

Greater time was required for germination initiation of *Syzygium firmum*. It was as long as 16 days after seed sowing to germination initiation. The germination of *Syzygium firmum* continuously rose from 16 to 76 days after sowing in both poly bag and thali and remained constant up to end of the germination test (88 days) (Figure 03). Maximum germination percentage (94.67%) was recorded for *Syzygium firmum* in polybag, whereas thali represented 92% germination. However, there was no significant difference between the germination percentage of thali and polybag at 5% level. Initial cumulative germination % was higher in polybag trial in comparison to thali trial. But, ultimately the germination percentage in both trials became almost equal. Hossain *et al.* (2011) investigated germination pattern for *Flacourtia jangomus* and found that germination was initiated 44-56 days for different pre-sowing treatments. In that experiment, the cumulative germination rose sharply from 48 to 66 days after sowing the seeds and remained constant up to end of the test. The germination process in thali may have been affected by the soil moisture and temperature at different points.

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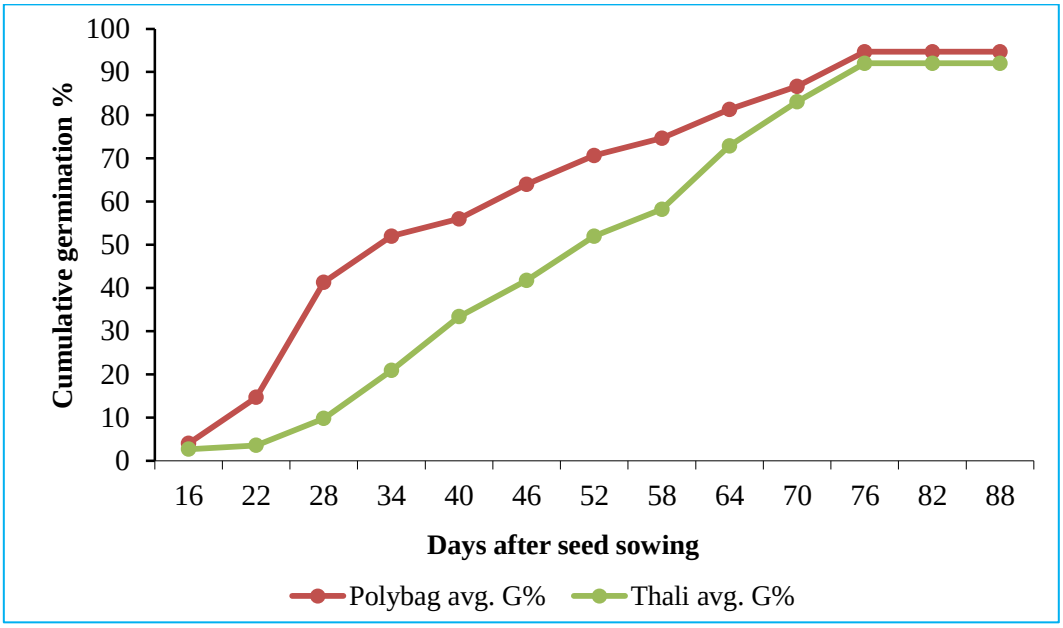

Figure 03. Progress of cumulative germination percentage of *Syzygium firmum* seeds in both polybag and *thali*.

Survival percentage

Survival percentage in the trial plantations of both Garjan (*Dipterocarpus turbinatus*) and Dhakijam (*Syzygium firmum*) was found between 60-80% which was satisfactory for plantations established from both polybad seedlings and direct sown seedlings (thali). For *Dipterocarpus turbinatus*, survival percentage was higher (78.67 ± 9.33%) in plantations raised from directly sown seeds than planation established from polybag raised seedlings (69.33 ± 9.61%). The values did not revealed any significant differenence at $p<0.05$ level between the survival percentage of the plantations raised from poly bag based seedlings and direct seeding (Figure 04). As a whole, survival percentage of the Dhaki-jam (*Syzygium firmum*) seedlings in the plantations at 9 years and 6 months age was found comparatively lower than the survival percentage of Garjan (*Dipterocarpus turbinatus*). Plantations established from polybag raised seedling showed higher survival percentage (69.33 ± 3.52%) than plantations established from directly sown seeds (58.67 ± 2.67%). There was no significant difference between the survival percentage of the plantations established from polybag seedlings and direct seeding (Figure 04). It may be due to climatic conditions of the study area.

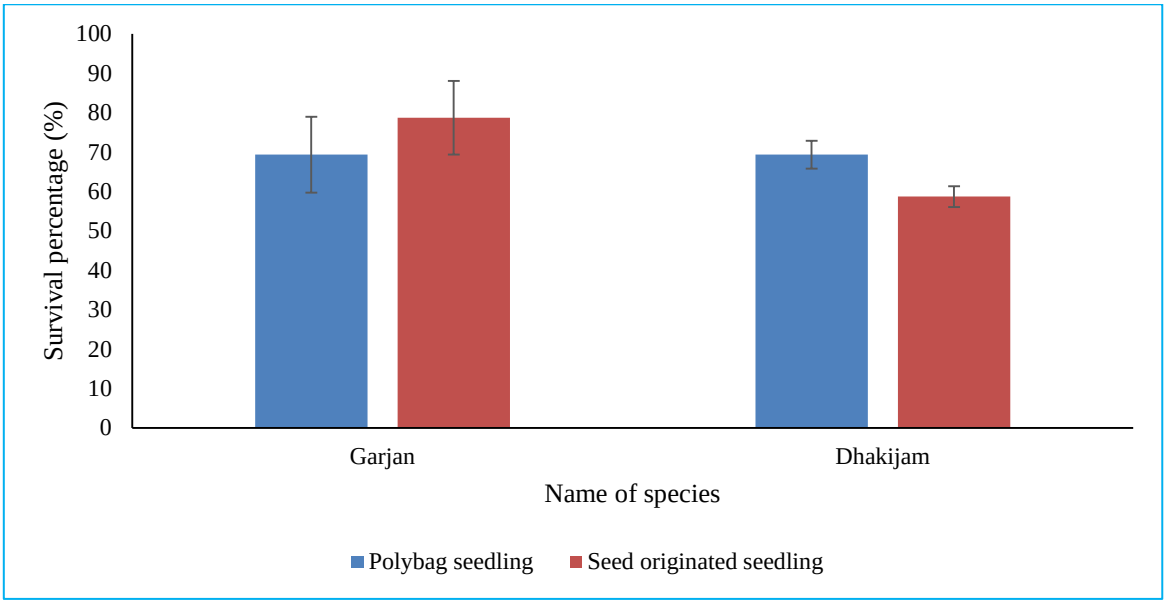

Figure 04. Survival percentages of both Garjan (*Dipterocarpus turbinatus*) and Dhaki-jam (*Syzygium firmum*) seedlings developed through polybags and seed originated seedlings.

Growth performance in the field

Different growth parameters like average height, average DBH, mean annual increment (MAI) of both height and DBH of *Dipterocarpus turbinatus* at 9 years and 6 months old seemed to be comparable between plantations of poly bag raised seedlings and *thali*. Average height (6.32± 0.26) and average DBH (20.24 ± 1.54) of *Dipterocarpus turbinatus* in plantations raised from polybag raised seedlings were found little bit higher than that's of plantations raised from *thali* (avg. height 6.21 ± 0.93 m and avg. DBH 16.17 ± 2.90 cm). But, there were no significant difference (at $p > 0.05$) between the average height and DBH recorded from *Dipterocarpus turbinatus* plantations raised from poly bag and thali (Table 02).On the other hand, average height (9.14 ± 0.57 m), average DBH (28.37 ± 1.11 cm), MAI of height (1.01 ± 0.06 m) and MAI of diameter (3.15 ± 0.12 cm) of *Syzygium firmum* plantations raised using poly bag raised seedlings were significantly higher (at 5% level) than plantations raised from thali (avg. height 5.75 ± 0.33 m, avg. DBH 17.82 ± 0.63, MAI of height 0.64 ± 0.04 m, MAI of DBH 1.98 ± 0.07 cm) (Table 02).

Table 02. Growth performance of *Dipterocarpus turbinatus* and *Syzygium firmum* plantations raised from poly bag seedlings and directly sown seeds (thali) at the age of 9 years 6 months

Treatment	*Dipterocarpus turbinatus*				*Syzygium firmum*			
	Height (m)	DBH (cm)	Height MAI (m)	DBH MAI (cm)	Height (m)	DBH (cm)	Height MAI (m)	DBH MAI (cm)
Polybag	6.32 ± 0.26[a]	20.24 ± 1.54[a]	0.70 ± 0.03[a]	2.25 ± 0.17[a]	9.14 ± 0.57[a]	28.37 ± 1.11[a]	1.01 ± 0.06[a]	3.15 ± 0.12[a]
Thali	6.21 ± 0.93[a]	16.17 ± 2.90[a]	0.69 ± 0.10[a]	1.8 ± 0.33[a]	5.75 ± 0.33[b]	17.82 ± 0.63[b]	0.64 ± 0.04[b]	1.98 ± 0.07[b]

Similar letter indicates not significantly different column wise at $p<0.05$ significance level according to ANOVA, and ± indicates standard error of mean

Table 03. Expense incurred under different cost categories for establishing Dhakijam and Garjan plantations from both polybag raised seedlings and direct seed sowing (BDT.)

Cost category	Average expenses for raising and establishing individual seedling of both *Dipterocarpus turbinatus* and *Syzygium firmum* (BDT.)	
	Seedlings raised in polybags	Direct seed sowing (*Thali*)
Single seed (Propagule)	0.55	0.55
Container, sowing, weeding, watering in the nursery	2.45	0
Plantation establishment (site preparation, sowing or transplanting, staking, *thali* preparation or digging hole, seedling transportation, plantation maintenance)	12.60	6.15
Total cost	15.60	6.70

Financial analysis

Plantation establishment involves substantial amount of money expenditure. Some people say it's a cost activity. However, money expenditure under different cost categories for seed collection, seedling raising, and plantation establishment of both *Dipterocarpus turbinatus* and *Syzygium firmum* was recorded. The expenditure incurred for plantations raised from polybag seedlings and direct sowing (thali) were then compared to find out the cost effective method of plantation establishment (Table 03). The table revealed average cost required for both *Dipterocarpus turbinatus* and *Syzygium firmum* under different cost activities. The results showed that, raising individual seedling in the polybags involved expenditure of BDT. 2.45. It includes cost for buying container, seed sowing, weeding and watering at the nursery stage. Whereas, direct seed sowing involved no such costs since seeds are directly sowed in the plantation site and container as well as nursery based activities are not needed

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for that. Plantations establishment involves different activities i.e. site preparation, sowing or transplanting, staking, thali preparation or digging hole, seedling transportation, and plantation maintenance. A total of BDT. 12.60 was incurred for each polybag seedling to establish it in the plantation whereas establishing each seedling raised by direct seed sowing needed much lower amount (BDT. 6.70). It is mainly because of the staking, labor needed for seedling transportation and digging hole needed to plant the polybag raised seedlings. An important environmental consideration is that in polybag based seedling raising process the polythene used during the test were left to the environment where thali process did not cause such environmental pollution.

IV. Conclusion

Polybag raised seedlings of *Dipterocarpus turbinatus* and *Syzygium firmum* had little bit higher germination percentage, germination value and germination energy than *thali* with no significantly difference except germination value and germination energy of *Dipterocarpus turbinatus*. Survival percentage of *Dipterocarpus turbinatus* was higher in plantations raised from *thali* (direct seeding) than polybag raised seedlings. Growth performance at 9.5 years of *Dipterocarpus turbinatus* for polybag seedlings is comparatively higher than *thali* with no significant difference. On the other hand; growth performance of of *Syzygium firmum* is higher for polybag seedlings at 5% significant level than *thali*. The financial analysis was very positive in favour of *thali* planting. The money incureed for establishing plantations by *thali* was less than half in compasrison to polybag seedlings. Seemingly polybag seedlings are little bit superior considering germination parameters and growth performance but financially *thali* technique is more feasible. Another important aspect is that polybag used for seedling raising are left to the environment which caused serious pollution like land degradation, whereas *thali* process is absolutely free of it. Considering the above mentions aspect the study favor's *thali* technique for raising plantation of *Dipterocarpus turbinatus* and *Syzygium firmum*.

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