

CONCLUSSION AND RECOMMENDATIONS

Study on growth and development of teak growing outside the natural ranges in Thailand was conducted in threes localities including Teak International Provenance Trials in Lampang, Clone Bank and Seed Orchard in PCT Seed Center, Uthai Thani and Ladkrating Plantation in Chachoengsoa and Cha-am Teak Farm, Phetchaburi. Results can be summarized as follows:-

1. Teak International Provenance Trials, Lampang

Teak International Provenance Trails established in Lampang, comprising of 8 provenances from India, Indonesia and Thailand. In the present study, the survival percentage varied from 64% (3002/108-Maharashtra, India) to 84% (SPA/133, Lampang-Thailand) with the total average value of 80.87%. The total average height growth was 19.90 m ranging from 16.20 m (3002/108-Maharashtra, India) to 22.03 m (3041/130-Chiangmai, Thailand). The D_{10} performance ranged from 23.89 cm (3002/108-Maharashtra, India) to 32.43 cm (3049/100-Ngliron, Indonesia) with the overall average value of 31.27 cm. DBH varied from 19.96 cm (3002/108-Maharashtra, India) to 25.85 cm (3041/130-Chiangmai, Thailand) with the total average value of 23.75 cm. Large variation among provenances on growth of height, D_{10} and DBH were found among provenances ($F=10.915^{**}$, $F=14.481^{**}$ and $F=13.376^{**}$) while variation among blocks was significant only on D_{10} and DBH growth. Concerning the stem form, the percentage of straight stem character was between 50.75% (3008/113-Haliyal, India) and 87.99% (3041/130-Chiangmai, Thailand) with the average value of 69.73%. The result indicated that national provenance performed the best as good as provenance from Indonesia whereas the Indian race showed the poorest growth in all cases. More research works should be concentrated on the local races.

2. Clone Bank, Uthai Thani

2.1 Growth Performances

71 clones were planted in Clone Bank at TPC Seed Center, Uthai Thani. The Clone Bank was presently investigated when the clonal materials were 19 years old. The survival percentage varied from 0% to 100%, 47 out of 71 clones had 100% of survival with the average value of 87.85%. The clone V78 and V95 had low survival percentage (25%) while all ramets of clone V79 and V97 had died out. Superior clones based on height performance were V34, V127, V36, V100 and V74. The average height growth was found to be 19.64 m. ranging from 8.75 m (clone V110) to 24.55 m (clone V34). D_{10} growth ranged from 11.26 cm (clone V86) to 38.15 cm (clone V100) with the overall average of 27.87 cm. The dominant clones in D_{10} were clone V100, V34, V118, V111 and V124 with the average value of 38.15cm, 38.05cm, 35.99cm and 35.80 cm respectively. DBH of these clones ranged from less than 10 cm (clone V85, V86, V97 and V99) to more than 25 cm. Clone V100, V34, V84, V124 and V130 showed the good performance on DBH with the

value of 34.24, 32.70, 31.85, 31.24 and 31.13 cm respectively. The results indicated that inferior clones (clones V78, V79, V95 and V97) should be detected from any reforestation program. It is not only they can not tolerance to biotic and abiotic enemies but they also can not adapted and fitted well to this planting site. Moreover, it is better to justify superior clones selection in the maturity stage or at least it reached half of rotation. However, the evaluation at the early stages can be used temporary in determining suitable clones. Priority list was changed with ages and at the age closed to 20 years, the accuracy in determining suitable clones was found. Concerning to crown diameter development of teak in the present study, average crown diameter after 19 years of clone bank was 5.19 m ranging from 3.05 m (clone V95) to 7.74 m (clone V130)

2.2 Annual Ring Growth

Clonal variation in ring growth of 71 clones in TPC Clone Bank, Uthaihani was studied. The total average ring growth was 6.46 mm, ranging from 5.12 mm to 8.39 mm. The superior clones with the widest ring width per year were clones V100 (8.39 mm year⁻¹), V118 (7.84 mm year⁻¹), V124 (7.71 mm year⁻¹), V111 (7.63 mm year⁻¹), V30 (7.56 mm year⁻¹), V49 (7.57 mm year⁻¹), V34 (7.49 mm year⁻¹), V84 (7.14 mm year⁻¹) and V45 (7.12 mm year⁻¹) and clone with poor annual growth were V99 (5.12 mm year⁻¹), V85 (5.26 mm year⁻¹) V73 (5.37 mm year⁻¹)

The calculation of ring growth was determined in each clone by the equation for each clone. The R² value ranged from 0.367 (clones V123) to 0.872 (clone V120). Result indicated that annual ring growth in each clone responded very differently to changeable climatic conditions. In most case the inverse relationship between ring width and age was found.

2.3 Heartwood Formation

The result showed that the average sapwood area ranged from 34.68 cm² (clone V86) to 366.42 cm² (clone V124) with the total sapwood area mean of 196.66 cm² (39.08%). The overall average heartwood area was 303.56 cm² (60.92%) ranging from 94.31 cm² (clone V85) to 524.81 cm² (clone V100). The top five clones with the high percentage of heartwood area were clone V119 (75.58%), V86 (74.43%), V85 (71.60%), V46 (71.01%) and V7 (70.67%). However, when considering to average of heartwood volume, it ranged from 0.05 m³ (clone V86) to 1.22 m³ (clone V100) with the total heartwood volume average of 0.52 m³. Clones with high value in heartwood volume were V100 (1.22 m³), V130 (1.03 m³), V118 (0.95 m³), V7 (0.92 m³), V111 (87 m³), V34 (0.85 m³), V4 (0.81 m³) and V39 (0.80 m³). Moreover heartwood content within a tree decrease with height.

2.4 Coppicing Ability

Number of sprouts in all clones ranged from 3 (clone V72) to 41 (clone V100) with the overall average value of 18.86 sprouts per coppice. The top five

clones showed high potential in coppice were clones V100, V34, V126, V49 and V118. Beside, most clones expressed the excellence in coppicing and coppicing percentage, only clone V129 had no sprouts in the first record. Moreover, growth of height of all sprouts was measured and found that the overall average was 0.85 m.

2.5 Sprout Growth

Height growth of all sprouts was measured. At the age of 1 month after coppicing, the total average of height growth of sprouts was 2.25 m, ranging from 1.50 m (clone V78 and V84) to 2.85 m (clone V45). At the 6 months old, the total average height had increased to 5.22 m and ranged from 1.81 m (clone V84) to 6.98 m (clone V100). After coppicing 12 months, the overall average height had reached to 5.33 m, varying from 2.94 m (clone V78) to 7.27 m (clone V100). Finally at 18 months old, the average height ranged from 3.72 m (clone V78) to 8.40 m (clone V45) with mean of 6.33 m. and clones V45, V100, V118, V46, V27, V34, V42, V41, V49, V80 had the excellent value height growth in this age. More than half of sprouts showed the good height performance during early growth period. Moreover, in view of height increment, it had increased greatly in the first record and slightly increased afterward.

Growth in D_0 of teak sprouts after coppicing was measured at 1, 2, 3, 4, 6, 12 and 18 months old. At the first months, the total average D_0 of sprout was 3.55 cm, varying between 2.50 cm (clone V95) to 5.07 cm (clone V118). At 6 months old, the overall average D_{10} was 6.37 cm, ranged from 3.18 cm (clone V84) to 8.35 cm (clone V118). At the age of 12 months, overall average D_{10} was 6.40 cm, varying from 3.51 cm (clone V39) to 8.33 cm (clone V100). At 18 months old, average D_{10} was between 3.60 cm (clone V36) and 12.48 cm (clone V81) with the mean of 8.80 cm and the top ten sprouts coppiced from clones V81, V22, V49, V100, V34, V41, V121, V120, V69 and V 110 respectively.

DBH of teak sprouts at the age of 1 month, the overall average DBH was 2.22 cm, varying from 1.44 cm (clone V78) to 2.96 cm (clone V118). At 12 months old, the total average DBH was 4.58 cm, ranged from 2.55 cm (clone V84) to 6.38 cm (clone V100). And finally at the 18 months old, the average DBH ranged from 2.30 cm (clone V36) to 10.25 cm (clone V81) with the total average of 6.67 cm.

In some period of measurement, some teak sprouts showed less value in height and DBH that cause by top cut when strong storm occurred. Jaijing (1994) commented that it was poor decision to select *Eucalyptus deglupta* for the shelterbelt in this site except narrow spacing issued. The trend of growth increment in height, D_{10} and DBH increased slightly after the first month of coppicing.

According to the previous study, the average height growth of all grafts at the ages of 3, 6, 12 and 18 months were 1.41, 2.07, 3.33 and 4.99 m respectively. When comparing the mean of height growth at the ages of 3, 6, 12 and 18 months between sprouts and ramets which all originated from the same clone set, the result

showed that highly significant difference in height growth between sprouts and ramets was found ($P < 0.01$). From the present study, the height growth rate between sprout and ramet was smaller when teaks grow older. Moreover, no data was available in this issue it thus is very interesting to research in long term so that it might be taken into consideration as a better alternative in teak productivity management in the future.

As many references, indicated that in coppicing system, tree always had the rapidly growth in the early period. Besides, in some species, coppicing system will enhance the short rotation and productivity of plantation

Certainly, the variation among clones allow tree breeder to concentrate to the planting of these superior clones. Superior clones may change with ages. As Teak Improvement Center and ASEAN Tree Seed Center has studied on the flowering and seed ontogeny of teak. In the future, research on synchronization among selected clones has to taken into consideration.

3. Clonal Seed Orchard

3.1 Clonal Seed Orchard in Uthai Thani

This study was conducted in clonal seed orchard comprising of 25 superior clones derived from clone bank priority list.

As regards 15 years old clonal seed orchard, the survival percentage ranged from 50 % (clone V130) to 90 % (clone V49) with the average value of 75.2 %. 11 clones out of 25 clones had the survival value higher than the mean value while 14 clones was poor survival rate in this planting site.

The height growth of 15 years old varied between 17.112 m (clone V3) and 21.586 m (clone V34) with the average value of 19.104 m. There were 14 clones (clone V26, V34, V35, V36, V37, V43, V45, V49, V72, V83, V100, V112, V127 and V130) showed better height growth above the average value.

Diameter at 10 cm above ground level (D_{10}) varied between 41.67 cm (clone V32) and 55.30 cm (clone V36) with the average value of 47.87 cm.

DBH growth varied from 33.40 cm (clone V32) to 43.45 cm (clone V34) and range between 35.15 cm and 46.18 cm. Besides, Clone V34 manifested the outstanding performance in DBH growth whereas clone V32 was the poorest one for this assessment.

The Analysis of variance showed the high significant differences among blocks on survival percentage ($F=6.941^{**}$), height ($F=6.660^{**}$), D_{10} ($F=2.046^{**}$) and DBH ($F=2.335^{**}$).

Evaluation of fruit production showed good fruit production with the mean score of 2.51 ± 1.343 by which 16 out of 25 clones have high fruit produced. Clone V36 was superior in fruiting potential (average score = 3.69) and the inferior clone was clone V3 (average score = 1.06). Moreover the level of excellent, good, moderate poor and none fruit production were 27.25, 30.62, 18.81, 8.43 and 14.89 per cent respectively. Largely significant differences on teak fruit production was found among blocks and clones but clonal variation showed highly statistically significant ($F= 4.794^{**}$).

Research on estimation of teak fruit have to rely on the method of estimation, either from standing trees or from the ground. Counting the number of fruits per branch and the number of branches per ramet would give the fruit production estimation more accurately.

Result of stem form showed that clone V26 expressed the highest value (86%) in straight stem while clone V3 showed the poorest performance in stem form (27%). More than half of all clones performed better stem form than average value (64%). In practices, good stem form is the target for superior clone as the stumpage price is higher as the stem form is good.

Numbers of the damaged trees were also investigated. It was found that the total average value of damaged ramets was low only 17% ranging from 0-37%. It is necessary to study the damaged trees whether it is damaged by biotic or abiotic factors.

As the results on growth characteristic of teak clonal seed orchard at the age of 15 years old, it was indicated that the site quality influenced very much on growth character of all selected clones. The present study indicated clearly that site condition has more effected on tree growth characteristics than the genetic background. Proper seed orchard establishment has therefore relied on site selection. Intensive management practices during the course of development id needed if good tree characters and good seed crops are expected.

3.2 Clonal Seed Orchard in Ladkrating Plantation, Chachoengsao

The survival percentage of 1, 6, 9, 12, 15 and 18 months old teak were ranged between 77.77-100, 61.11-88.88, 52.77-88.88, 50.00-86.11, 50.00-86.11 and 47.22-83.33 per cent respectively. And the average value of survival percentage of these clones in each ages were 93.77, 76.00, 74.55, 71.33, 70.55 and 66.44%.

Height growth of all ramets was evaluated and recorded. The total average height of 1,6,9,12,15 and 18 months were 0.175, 0.708, 1.332, 1.749, 1.802 and 2.256 cm respectively. Clone V3 showed the best growth on height. However, other clones expressed the good height performance. Difference on height character was slightly only 0.1-0.6 m. Concerning the Analysis of variance on height growth, it

was found that difference among clones was insignificant. In contrast, high variation on height growth was found among blocks since 6 months old to 18 months old.

D_{10} performance was studied on 1,6,9,12,15 and 18 months old teak in clonal seed orchard to be 0.854, 1.582, 2.474, 2.900, 3.154 and 3.318 cm respectively. Clone V40 expressed the highest value on D_{10} growth. The Analysis of variance showed that clonal variation was insignificant but the highly significantly differences among blocks was observed

At the age of 12 months, the overall average DBH was 1.80 cm, ranging from 1.46 cm (clone V45) to 2.05 cm (clone V34). At 18 months, the overall average DBH had increased slightly to 1.94 cm and varied from 1.59 cm (clone V45) to 2.26 cm (clone V40). Analysis of variance on this performance of 12 and 18 months old teak was analyzed. It was found that insignificant variation occurred in both block and clone. Exceptionally, the age of 18 months, variation among blocks was found ($F=5.536^*$)

Though only superior clones were selected, the results indicated that the survival percentage in this site varies from clone to clone. In the first period, all clones had high survival rate and decreased in the next time as caused by the differences in adaptation to site and resistance to biotic injuries. Moreover, the long drought period than the previous years have effected the water deficit and drought condition occurred and affected rather severely to clone survival.

4. Cha-am Teak Farm, Phetchaburi

4.1 Growth Performance

The plantation was established with different kind of planting materials including tissue culture (V3), tissue culture (V33), stump generated from seed production area and stump from teak natural forest.

The survival percentages of tissue culture (V3), tissue culture (V33), stump from Mea Tip Seed Production Area and stump from natural forest were 96.50, 95.75, 98.75 and 96 respectively with the total average of 96.75. Teak generated from stump, Mea Tip SPA showed the highest value while tissue culture (V33) showed the lowest survival rate in this site.

The result of average height growth at the age of 9 years teak was found that it varied from 6.18 m to 8.41 m with the overall mean value of 7.64 m. Both tissue culture (v3) and stump from Mae Tip SPA showed the high value of height growth. In contrast, tissue culture (v33) had lower growth rate in height than other planting sources.

D_{10} of various planting materials ranged from 10.55 cm to 15.21 cm with the total average of 13.85 cm. Tissue culture (V3) showed superior performance in

D_{10} than stump materials but on the contrary, tissue culture (V33) expressed the lowest growth performance.

As the result, teak raised from stump, natural forest showed remarkably the highest value in diameter growth with the value of 10.25 cm. The inferior planting source was tissue culture (V33) (6.38 cm). The DBH growth ranged from 6.39 cm to 10.25cm with the total average of 9.11 cm.

Significant differences in survival percentage, height, D_{10} and DBH were not found.

Concerning to the present study, the slightly growth performances differences occurred in all planting materials when compared with teak grown in native range. This difference might not cause by differences in planting materials but might be site condition as well. It is important to select good site to grow teak for maximum yield. Deep soil and good drainage system are the perform choice.

4.2 Total Biomass

The total biomass of 9 year-old teak derived from four planting stock types was between 12.15 kg tree⁻¹ (tissue culture (v3) in DBH class 5-9 cm) and 114.18 kg tree⁻¹ (stump, Mae Tip SPA in DBH class 13-17 cm). The average total biomass of tissue culture (v3), (v33), stump-Mae Tip SPA and stump-NF were 50.73, 45.48, 59.39 and 53.64 kg tree⁻¹ with the overall mean of 52.31 by tree⁻¹.

It was concluded that stump from Mae Tip seed production area and tissue culture (V33) produced remarkably high in stem biomass while unimproved material such as stump from natural forest had low potential in stem biomass production.

Based on available data, it was expected that the above ground biomass ranged from 53.98 ton ha⁻¹ (tissue culture (V33)) to 76.58 ton ha⁻¹ (stump, Mae Tip SPA) with the total average of 64.05 ton ha⁻¹. Stump, Mae Tip SPA showed the better value in growth and biomass than other materials in this planting site. That is why genetically improved materials are essential for all plantation programs.

Root biomass was also studied and the result showed that average values of tissue culture (V3), tissue culture (V33), stump, Mae Tip SPA and stump from natural forest in root dry weight were 12.87, 13.09, 13.45, 16.11 kg tree⁻¹ respectively, with the total average of 13.88 kg tree⁻¹.

The ratio of above ground /below ground biomass of 9 year-old teak generated from tissue culture (v3), tissue culture v33, stump- Mae Tip seed production area and stump from natural forest are 2.94, 2.47, 3.42 and 2.33 times of root biomass respectively. The overall average of shoot/root ratio is 2.79.

4.3 Root system

The average diameter of root system of teak raised from tissue culture (V3), tissue culture (V33), stump-Mae Tip-SPA and stump-natural forest were 3.13, 2.27, 3.22 and 2.62 m. respectively. The overall average was 2.81 m and stump-Mae Tip-SPA showed the large root system diameter while tissue culture (V33) showed the lowest value.

Root depth of all planting sources ranged from 0.46 m to 0.86 m with the total average of 0.71 m. Tap root depth of teak raised from stumps showed the differences in each DBH classes and planting sources. It may be caused by several environmental factor especially soil depth, soil nutrient, soil moisture and soil property where tree grow. Teak raised from tissue culture (V33) had the longest vertical root (0.86 m) while tissue culture (V3) had a low value in root depth. In contrast, tissue culture (V3) had the highest value in average root length (33.19 m). This is quite an extraordinary phenomenon as the teak tissue culture materials can developed root length better than those raised from stumps. Additionally, average root length was between 18.50 m (tissue culture (v33)) and 33.19 m (tissue culture (v3)) with the mean of 25.88 m.