Cha-am Teak Farm

The teak experimental site under tree farming condition at Cha-am Teak Farm is under the private enterprise. The plantation was established in 1994 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. Moreover Randomized Complete Block Design (RCBD) was used which consists of 4 blocks and 4 plots each with 100 trees per plot and water dipping system was applied during the first 2 years to guarantee the sufficient water supply during the development. Moreover, this site was previously used in cassava planting for a number of years.

As for teak tree farm under intensive cultivation practices, variation in the teak growth performances in seedling stage was studied and insignificant. However, after the termination of water dipping system, differences in height growth and DBH at 32 months was found to be significant among blocks (Thueksathit, 1999). Although the research in seedling stage had been done but there is only a little needful information for making a decision in tree farming investment. It is important reason to do continuously more research to detect the growth in advance stages. Thus this site was carried out to answer the inquisitively existing problem in growth and development when the different planting materials were used particularly outside its natural habitat. Therefore the study on variation in growth, biomass and root development was conducted in this area.

1. Survival percentage

Historically, teak stump planting has been used practically throughout the country because of less germination success in direct seeding of teak. Generally the survival percentage of this plating method in the FIO plantation in the north is about 78-96 percent (FIO, 1982). However, even after stump planting, the survival percentage of each teak plantation varied considerably. Universally the survival percentages depend much on planting material quality, planting time, environmental conditions at the time of planting, biotic and abiotic factors and management practices.

For a number of years, the tree planting program has been seriously promoted by collaboration between agencies especially Royal Forest Department. From this active action, the planting of teak has steadily expanded to large scale plantation in national wide. It was not only more investment in teak planting but also more alternative in planting sources and tissue culture is the one interesting choice for tree planters in this task.

In Cha-am teak farm, the survival percentage at the age of 9 year-old teak planted with different planting sources was determined and no variation from source to source was found. 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 as shown in Table 50 and Figure 29.

However, from the result, all planting materials expressed the high efficiency in adaptation due to survive in unsuitable environment condition and also analysis of variance showed statistically insignificant difference among planting materials used (F=1.306ns) (Table 51).

Teak can either be raised using seed or vegetative propagation. Teaks raised from seed collected at random tend to show fairly wide variability in its growth. However, seeds are very important to maintain a broad genetic base. On the other hand, vegetative propagation using cutting and tissue culture techniques will ensure production of uniform planting materials of desired traits.

2. Height growth

At the same experimental site, Thueksathit (1999) studied growth performances under water dipping system for one year. It was found that all teak seedlings raised from different planting materials increased slightly on height growth and variation in height performance was insignificant. This means that water treatment stimulated height growth of various materials similarly.

In the present study, 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 (Table 52).

Variation in height growth was found only among blocks (Table 53). This result indicated that environmental factors influence to height growth of all planting materials.

3. Diameter growth at 10 cm above ground level (D_{10})

The rate of diameter growth varies greatly with species, age and site. Species that have a long life span usually grow less in a giving period than do species with a short life span.

Diameter growth apparently proceeds largely at the expense of current photosynthesis and is sensitive to environmental conditions, especially water supply. Decreases in diameter caused by dehydration especially during period of drought. MacDougal (1938) emphasized the close relationship between available moisture and diameter increase. In general, trees usually grow in diameter for a longer period of time than they grow in height.

In the present study, it was found that 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 (Table 54).

Table 50 The average survival percentage of 9 years old teak in Cha-am Teak Farm, established in 1994

Planting materials	Average survival percentage
1. Tissue culture (V3)	96.50±2.380
2. Tissue culture (V33)	95.75±2.630
3. Stump, Mae Tip SPA	98.75±0.957
4. Stump, Natural Forest	96.00±1.155
Total average	96.75±2.113
CV(%)	2.18

Table 51 Analysis of Variance on survival percentage of 9 years old teak in Cha-am Teak Farm, Phetchaburi, established in 1994

SOV	df	SS	MS	F
Block	3	22.500	7.500	2.177^{ns}
Treatments	3	13.500	4.500	1.306^{ns}
Error	9	31.000	3.444	

Table 52 The average height of 9 years old teak in Cha-am Teak Farm, established in 1994

Planting materials	Average height (m)
1. Tissue culture (V3)	8.41±1.067
2. Tissue culture (V33)	6.18±1.978
3. Stump, Mae Tip SPA	7.78±0.574
4. Stump, Natural Forest	8.17±2.449
Total average	7.64±1.756
CV(%)	22.98

Table 53 Analysis of Variance on height growth of 9 years old teak in Cha-am Teak Farm, Petrchaburi, established in 1994

SOV	df	SS	MS	F
Block	3	21.432	7.144	5.055*
Treatment	3	12.139	4.046	2.863^{ns}
Error	9	12.720	1.413	

* = Significant at 95%
^{ns} = Non-significant

Treatments : 1. Tissue culture (V3)
2. Tissue culture (V33)
3. Stump, Mae Tip SPA
4. Stump, Natural Forest

Analysis of variance showed insignificant variation on D_{10} among these planting materials and blocks (Table 55).

4. Diameter at Breast Height (DBH)

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 as shown in Table 56. Besides, planting sources variation on DBH was insignificant (F=3.088ns) (Table 57). Gupta *et al.* (1991) described the tree from tissue culture grew significantly faster than those from seedlings, but by fifth year there was no significant difference in height increment and DBH of the two stock types.

Chanpaisaeng (1993) reported that growth potential of 10 years old teak plantation under poor and good site qualities was 7.2 cm and 15.0 cm in DBH respectively. When comparing to this site, the average DBH of teak growing here was a little higher than teak grown in bad site quality. It indicated that this area must be improved rapidly by means of fertilizer application so that good productivity in the future can be expected.

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. Better growth and diameter growth depend very much on site quality and sufficient management practices to maintain the growth in good condition. It is important to select good site to grow teak for maximum yield. In general, teak trees do not prefer dry site and sandy soil where drought may affect to growth increment. Kaosa-ard (1981) and Bunyavejchewin (1987) reported that on dry sandy soil, shallow or hard pan soil, dry and acidic soil and on waterlogged soil derived from and sandstone, granite, teak always perform very poor in growth and form. Results in this study indicated that quality of planting material planted outside natural range did not influence remarkably to growth performances so far. However, lesson learnt from teak growing within and outside distribution range exhibited variation in growth and certain characteristics varied till the age of tree passed at least its half life span. That is why long term study in variation is necessary and needed particularly in wood quality. Furthermore, teak growing in unsuitable area, proper silviculture operations and fertilization must be implemented intensively, if good productivity is expected.

Table 54 The average D_{10} of 9 years old teak in Cha-am Teak Farm, established in 1994

Planting materials	Average D_{10} (cm)
1. Tissue culture (V3)	15.21±2.292
2. Tissue culture (V33)	10.55±2.945
3. Stump, Mae Tip, SPA	14.89±1.710
4. Stump, Natural Forest	13.85±3.431
Total average	13.85±3.431
CV(%)	24.77

Table 55 Analysis of Variance on D_{10} of 9 years old teak in Cha-am Teak Farm, Phetchaburi, established in 1994

SOV	df	SS	MS	F
Block	3	59.390	19.797	3.031^{ns}
Treatments	3	58.463	19.488	2.984^{ns}
Error	9	58.786	6.532	

Table 56 The average DBH of 9 years old teak in Cha-am Teak Farm, established in 1994

Planting materials	Average DBH (cm)
1. Tissue culture (V3)	9.92±1.289
2. Tissue culture (V33)	6.38±2.360
3. Stump, Mae Tip SPA	9.87±1.517
4. Stump, Natural Forest	10.25±4.242
Total average	9.11±2.858
CV(%)	31.37

Table 57 Analysis of Variance on DBH of 9 years old teak in Cha-am Teak Farm, Phetchaburi, established in 1994

SOV	df	SS	MS	F
Block	3	43.763	14.588	3.381^{ns}
Treatments	3	39.966	13.322	3.088^{ns}
Error	9	38.829	4.314	

* Significant at 95%
ns Non-significant

Treatments : 1. Tissue culture (V3)
2. Tissue culture (V33)
3. Stump, Mae Tip SPA
4. Stump, Natural Forest

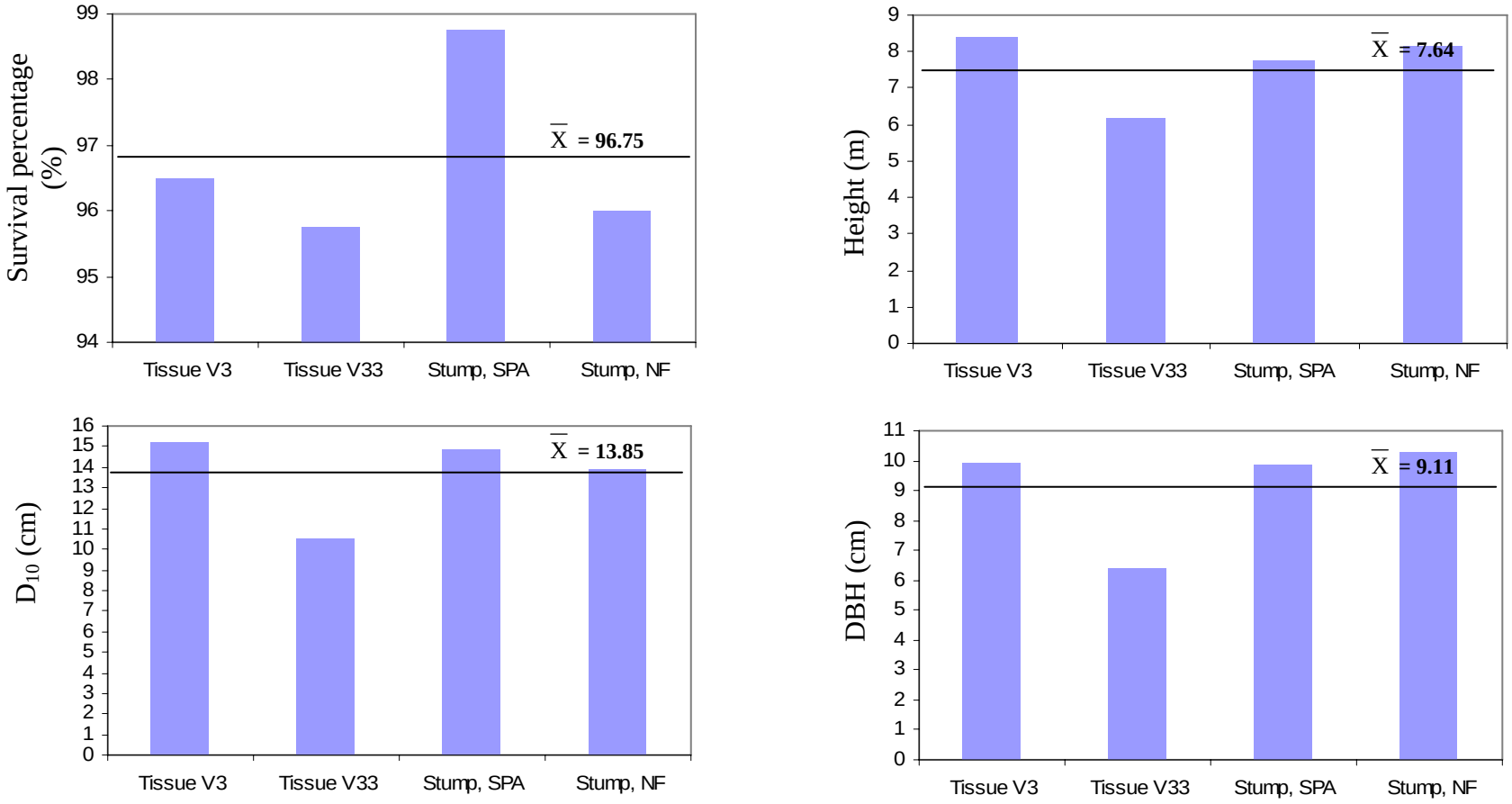

Figure 30 Average survival percentage, height, D_{10} and DBH of various planting materials at Cha-am Teak Farm, Phetchaburi.

5. Total Biomass

In this study, 12 trees (three in each planting materials) were selected as samplings for biomass study. Table 58 and Figure 31showed the results of the total biomass production consisting of stem, branches, leave and root.

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 was 50.73, 45.48, 59.39 and 53.64 kg tree-1 with the overall mean of 52.31. Stump from SPA had the highest value in total biomass particularly higher than others in stem dry weight but the lowest value was teak originated from tissue culture (V33). However, the main objective of teak planting is teakwood or timber thus related to stem biomass production, which tissue culture (V33) could produce the excellent dry weight in part of stem. In contrast, teak raised by stump from natural forest showed very high production in branches and root component but showed the lowest value in stem biomass.

The results could be concluded that stump from Mae Tip seed production area and tissue culture (V33) produced remarkably in stem biomass while unimproved material such as stump from natural forest had low potential in stem biomass production. Moreover, percentage of biomass production of each component of all planting materials was calculated and shown in Figure 32.

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}. Results in Table 58, 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 $tree^{-1}$.

From Figure 33 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.

The value of BGB:AGB is known to range from less than 0.1 to more than 1 depending on a range of factors including nutrient and water availability, spacing, age, species, climatic zone (Jackson *et al*., 1996: Werner and Murphy, 2001).

Table 58 Total biomass of 9 years old teak planted with different planting materials grown outside the natural habitat, Cha-am, Phetchaburi

Planting materials	DBH Class	Total biomass (kg)				Total
		Stem	Branch	leave	root	
Tissue culture (V3)	5-9	6.75	1.16	1.24	4.97	*14.12*
	9-13	21.66	9.66	3.18	13.77	*48.27*
	13-17	41.73	18.59	9.60	19.88	*89.80*
Total		70.14	29.41	14.02	38.62	**152.19**
Average		*23.38*	*9.80*	*4.67*	*12.87*	***50.73***
Tissue culture (V33)	5-9	5.03	0.61	1.21	5.30	*12.15*
	9-13	18.47	3.80	2.54	9.92	*34.73*
	13-17	52.19	10.53	2.78	24.05	*89.55*
Total		75.69	14.94	6.53	39.27	**136.43**
Average		*25.23*	*4.98*	*2.18*	*13.09*	***45.48***
Stump, Mae Tip, SPA	5-9	5.99	1.04	1.16	5.39	*13.58*
	9-13	28.32	7.12	2.73	12.24	*50.41*
	13-17	50.01	30.23	11.23	22.71	*114.18*
Total		84.32	38.39	15.12	40.34	**178.17**
Average		*28.11*	*12.80*	*5.04*	*13.45*	***59.39***
Stump, Natural Forest	5-9	8.79	1.29	2.13	5.60	*17.81*
	9-13	23.10	9.65	3.66	20.30	*56.71*
	13-17	36.32	20.96	6.68	22.44	*86.40*
Total		68.21	31.90	12.47	48.34	**160.92**
Average		*22.74*	*10.63*	*4.16*	*16.11*	***53.64***
Overall average		24.86	9.55	4.01	13.88	52.31

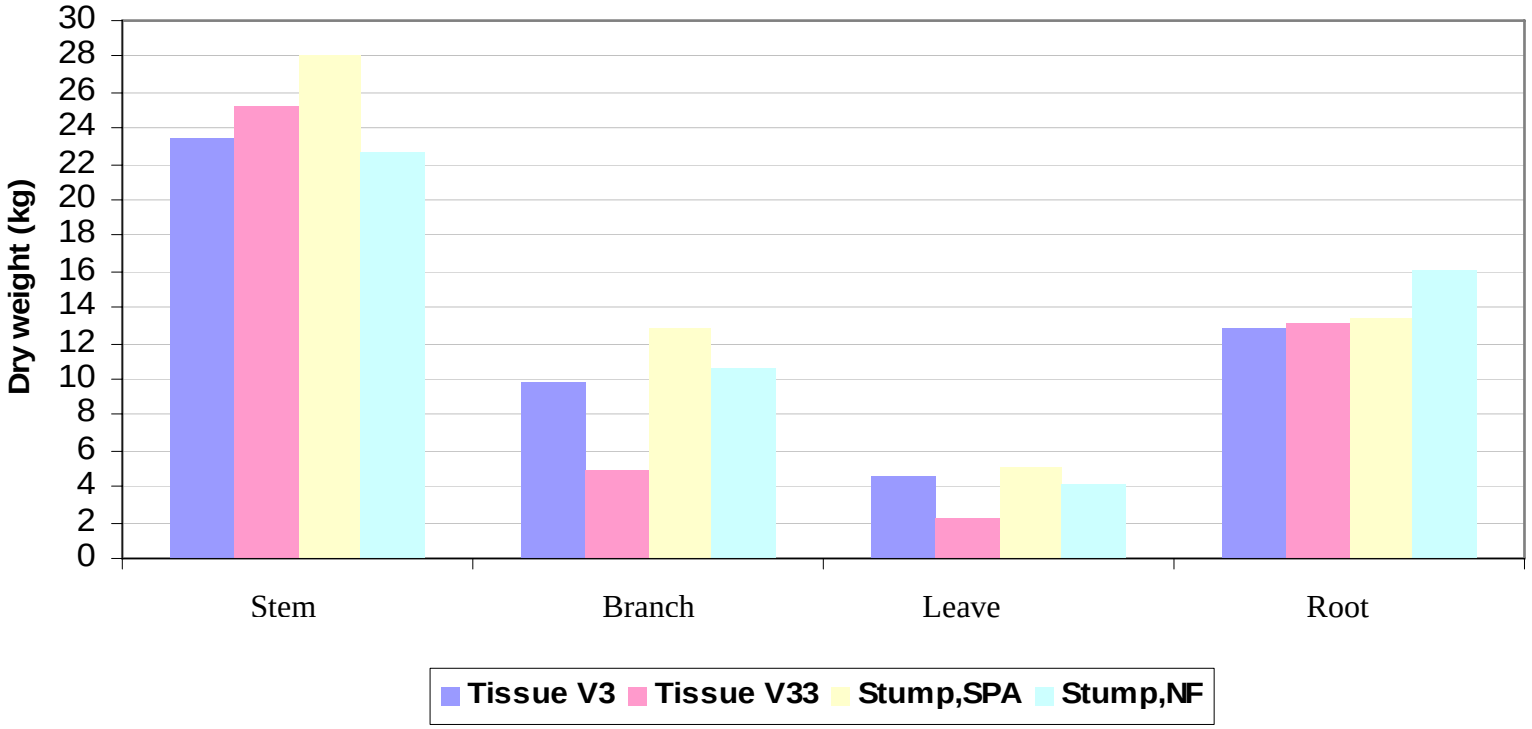

Figure 31 Average dry mass of root, stem, branch and leave biomass of teak from various planting stock types at Cha-am Teak Farm, Phetchaburi.

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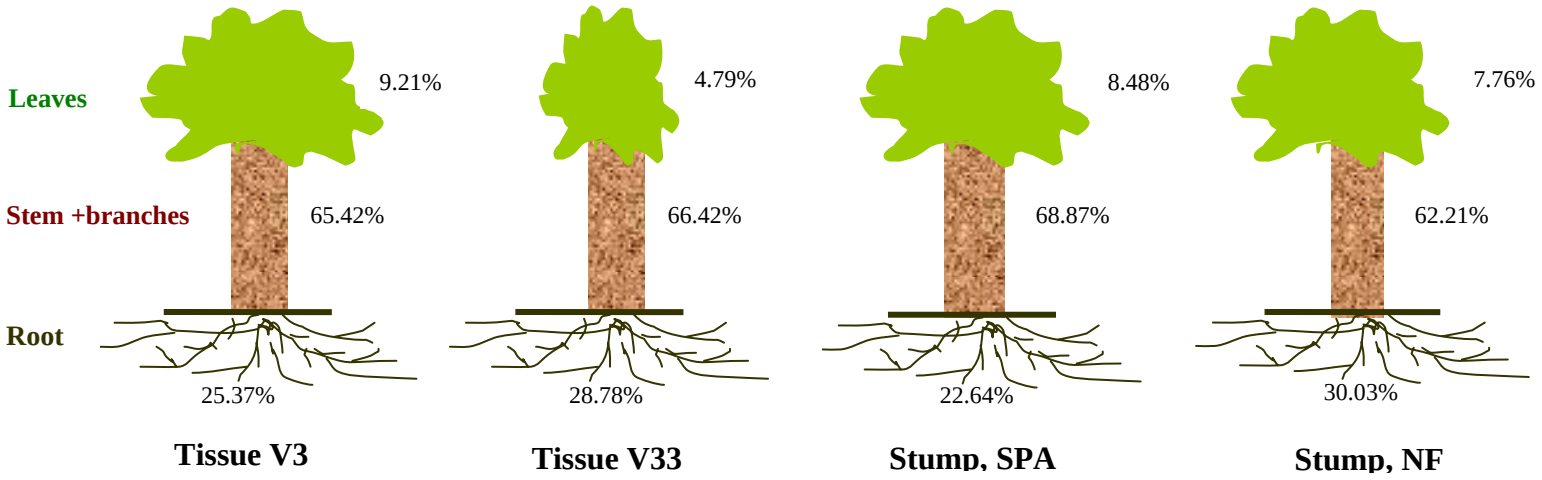

Figure 32 Biomass percentage of leaves, stem, branches and root of teak from various planting stocks at Cha-am Tree Farm, Phetchaburi.

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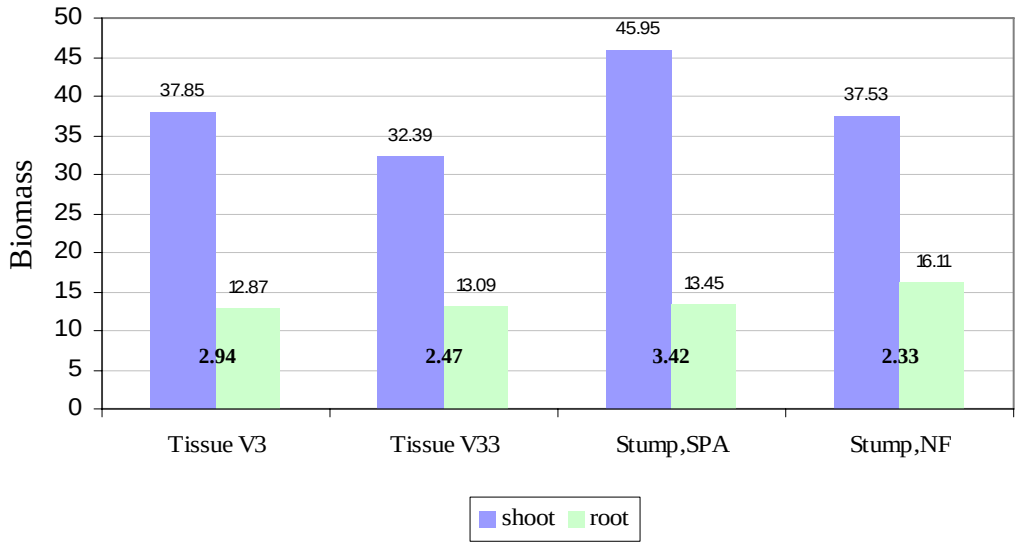

Figure 33 Shoot:Root ratio of 9 year-old teaks from various planting stocks at Cha-am Tree Farm, Phetchaburi.

6. Root System

The characteristics of the root system depend partly on its heredity and partly on the environment in which it develops. The depth and extent of root systems of mature trees often are dominant factor in drought resistance. It is well known that orchard, shade and forest trees on shallow soil are more subject to drought injury than those growing on deep soils, and during the great drought of past few years. The roots are mainly confined to the upper 30 cm of soil surface. Tap root losses its ability to penetrate when the tree becomes older and always attacked by insects or fungus. Lateral and vertical roots are developed profusely after the cessation of tap root penetration. The lateral roots grow parallel to the soil surface in various depths. However most of root study had been done in seedling period while in mature stage have not enough information so far. There are only few supporting experimental data are available. More research of the effects of dry soil on growth, structure and functioning of teak roots is needed.

Root system of 10 years old teak generated from various planting sources such as tissue culture from plus tree V3 and V33, stump from seed production area and natural forest are studied. Materials are planted under farm condition and located outside teak natural range in which. Besides, the soil type of this experimental site is loamy sand and was previously used for cassava planting for amount of year.

From Table 59,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)

Table 59 Growth and development of teak root at the age of 10 years planted in Cha-am teak Farm, Phetchaburi

Planting Sources	DBH interval (cm)	Root system diameter (m)	Root depth (m)	Number of coarse root	Average Root collar diameter (cm)	Total root length (m)
Tissue culture (V3)	5-9	2.70	0.60	6	3.98	14.25
	9-13	2.50	0.30	9	6.36	39.13
	13-17	4.20	0.47	10	6.08	46.20
		(3.13)	(0.46)	(8.33)	(5.51)	(33.19)
Tissue culture (V33)	5-9	2.00	0.98	8	2.95	24.73
	9-13	2.45	0.41	6	6.16	15.99
	13-17	2.35	1.20	7	7.91	14.77
		(2.27)	(0.86)	(7)	(5.67)	(18.50)
Stump, Mae Tip, SPA	5-9	2.65	0.71	5	5.16	19.03
	9-13	2.20	0.65	9	11.25	21.29
	13-17	4.80	0.90	10	7.80	54.83
		(3.22)	(0.75)	(8)	(8.07)	(31.72)
Stump, Natural Forest	5-9	2.20	0.90	6	4.40	18.15
	9-13	2.50	0.60	11	5.62	20.31
	13-17	3.15	0.76	6	6.58	21.87
		(2.62)	(0.75)	(7.67)	(5.54)	(20.11)
Total average		2.81	0.71	7.50	6.20	25.88

showed the lowest value. Considerably, Root system distribution did not depend on tree size. However, most of tree samples that having low value in root system diameter always showed the high value in root depth.

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 class and planting sources. It may cause by environmental factor especially soil depth, soil nutrient, soil moisture and soil property that 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.

Ngampongsai (1967) studied the distribution of teak root system in various ages and reported that root growth and distribution of teak seem to increase with ages, but the rate of increasing is declined when teak get older. Teak roots at the age of 10 years were found approximately 55.6 percent in 30 cm of soil depth and 44.4 percent in deeper soil level. Similarly, Sterett (1920) concluded that in the fertile soil, lateral root of young trees always grow and distribute in around 6-12 inch of soil depth.

If teak was planted in hard soil, tap root and vertical root will be stunted and also could not penetrate easily. However trees will adapt themselves by increase more lateral root in the top soil for their existence.

Development of a deep root system is very important for survival of seedling, tree growth and productivity. And differences in root habit are a cause of differences in survival of various species. Some species can become established only in moist areas because their shallow roots do not enable them to live in summer drought, whereas some have deep taproots which enable them to survive droughts, even the first year or two. Satoo (1956) observed that the extent of root system is an important factor in survival of conifer seedling in Japan.

Root habit is one of the most important factors determining the drought resistance of trees, deep rooted species surviving much better than shallow rooted species. The relatively lower shoot/root ratios of hardwoods also enable them to survive droughts better than do pines (Kozlowski, 1949).

Furthermore, number of coarse root was also counted. Tissue culture (V3) showed the highest value in number of root (8.33) but tissue culture (V33) showed the lowest value (7). The total average of root coarse number was 7.50.