

## RESULTS AND DISCUSSION

### Provenance Trials

There are several sets of International Provenance Trials have been established in Thailand. Among them, teak is the pioneer in this kind of research. Standard methodologies in raising seedling, planting methods, lay out design management practices, as well as data collection were developed by experts and member of the network.

As early as 1970, an International Teak Provenance Trials was established as a part of an action program formulated by the FAO Panel of Experts on Forest Gene Resources conservation. The ultimate goal was aimed to assess variation on certain important characteristics among provenances and land races of teak. The results would direct to the proper choice of selection of suitable materials for plantation establishment. The studies would also obtain estimates of gene-ecological variations between populations for gene resource conservation (Keiding *et al*, 1986). additionally, the main objectives of provenance trails are to seek the best seed sources for the further improvement program, plus tree selection, as well as *in situ* and *ex situ* gene conservation.

#### 1. Survival Percentage

In most provenance trials, the survival percentage of selected provenance of any species is the most important indicator to determine the proper choice of tree provenance to grow on a large scale in that particular area. The high survival percentage of any provenance could be indicated the adaptation ability of such provenance have in the new environment where they are growing, including biotic and abiotic factors that trees faced during the development period.

In the present study, the survival percentage observation in the Teak International Provenance Trails, in Lampang, which was established in 1974 varied from 64-84% (Table 6 and Figure 14). Study showed remarkably difference in survival percentage from provenance to provenance. Provenance SPA/133 from Lampang showed the prominent survival percentage (84%) and the lowest were the provenance from Maharashtra (3002/108), India and from Chiangmai (3041/130) (64%). Low survival percentage was partly caused by poor adaptation to the planting site and fire in dry season (RFD, 1981). The average survival percentage was 70.87%. However, no significant differences in survival percentage among provenances were found ( $F= 0.129^{ns}$ ) as shown in Table 7.

Generally, the survival percentage of teak under plantation conditions is above 80% in the first year and decrease gradually in the later stages. Jaijing (1994) reported that average survival percentage of 20 years old teak in this trial was 78.1 and Anderson (1997) also recorded that the average survival rate was down slightly to 75% in the next three years.

**Table 6** The average survival percentage of 29 years old teak, established in 1974, at Teak International Provenance Trials, Teak Improvement Center, Ngao, Lampang

Provenances	Survival percentage
3049/100 Ngliron Indonesia	70
3002/108 Maharashtra India	64
3008/113 Haliyal, Karnataka India	72
3013/116 Arbail, Karnataka India	76
3039/129 Tak Thailand	71
3041/130 Chiangmai Thailand	64
3043/132 Phayao Thailand	66
-SPA/133 Lampang Thailand	84
Average	70.87

**Table 7** Analysis of variance on survival percentage of 29 years old teak at Teak International Provenance Trials, Ngao, Lampang, established in 1974.

SOV	df	SS	MS	F
Block	3	285.50	95.16	0.969 <sup>ns</sup>
Provenance	7	1275.50	182.21	1.855 <sup>ns</sup>
Error	21	2062.50	98.21	

<sup>ns</sup> = Non-significant differences

## **2. Height Growth**

In the early stages, trees generally develop better height growth than diameter growth. Trees of various ages attained height growth differently, and differences in growth performance were also found in trees of the same age (Wenger, 1955).

Concerning the International Provenance Trials which was established in 1974, early observations showed that the average height of 5 years old provenances originated from TIC seed source area (No.133) was 9.7 m. Additionally, the Indian provenance showed susceptible to pests. It was also found that the provenance from Indonesia was the second to the Thai provenance in height growth, with an average height of 9.1 m (BIOTROP, 1980).

In contrast, provenances from dry sites in India performed better in height growth than local provenances when established in Sukhothai. The observations were similar to the trials established in Chiangmai, although variation on height growth between provenances was insignificant. Exotic provenance from India also showed better height growth than those of local sources (RFD, 1981).

In the present study, results from the performance on height growth of 29 years old in the Teak International Provenance Trials, comprising of 8 provenances show that all provenances from Thailand and Indonesia have better performance than all provenances originated from India. Large variation on height growth among provenances was found (10.915\*\*), as shown in Table 9. The average height growth of 29 years old teak planted in this trial was 19.90 m. ranging from 16.20 m (3002/108-Maharashtra, India) to 22.03 m. (3041/130-Chiangmai, Thailand) (Table 8 and Figure 15) .

## **3. Diameter at 10 cm above ground level (D<sub>10</sub>)**

Variation in D<sub>10</sub> between provenances showed high significantly difference. Provenance 3002 from India was the poorest performing on D<sub>10</sub> with the average value of 23.89 m below the trial average (29.48 m). And provenance 3049 from Ngliron, Indonesia had the superior performance with the average value of 32.42 m and followed by the provenance from Lampang, Thailand (31.72 m) and the provenance from Chiangmai, Thailand (31.46 m). (Table 10 and Figure 16)

In Table 11, Analysis of variance showed highly significant differences among provenances, the variation in diameter at 10 cm above ground level was 18.10\*\* but variation among blocks was insignificant.

Kaosa-ard (1992) studied the diameter at ground level in form of semi quantitative character as buttress using scoring system. It was found that teak originated from India has no buttress tree (99%) and teaks originated from Thailand have most buttress than trees originated from other provenances.

**Table 8** The average height of 29 years old teak in Teak International Provenance Trials, Teak Improvement Center, Ngao, Lampung

Provenances	Average height (m)	SD
3049/100 Ngliron Indonesia	21.526 <sup>a</sup>	0.882
3002/108 Maharashtra India	16.205 <sup>c</sup>	2.431
3008/113 Haliyal, Karnataka India	16.926 <sup>±c</sup>	0.963
3013/116 Arbail, Karnataka India	19.225 <sup>b</sup>	1.786
3039/129 Tak Thailand	21.010 <sup>ab</sup>	1.281
3041/130 Chiangmai Thailand	22.037 <sup>a</sup>	1.471
3043/132 Phayao Thailand	20.491 <sup>ab</sup>	1.320
-SPA/133 Lampung Thailand	21.827 <sup>a</sup>	1.365
Average	19.906	2.517
CV(%)	12.64	

<sup>abc</sup> means that, by DNMRT, significant at 99% level

**Table 9** Analysis of variance on height of 29 years old teak in Teak International Provenance Trials, Ngao, Lampung

SOV	df	SS	MS	F
Block	3	15.685	5.228	2.817 <sup>ns</sup>
Provenance	7	141.824	20.261	10.915 <sup>**</sup>
Error	21	38.980	1.856	

<sup>ns</sup> = Non-significant differences

<sup>\*\*</sup> = Highly significant differences at 99% confident limit

**Table 10** The average diameter at 10 cm above ground level ( $D_{10}$ ) of 29 years old teak in Teak International Provenance Trials, Teak Improvement Center, Ngao, Lampang

Provenances	Diameter at 10 cm above ground level (cm)	SD
3049/100 Ngliron Indonesia	32.424 <sup>a</sup>	1.056
3002/108 Maharashtra India	23.895 <sup>c</sup>	2.825
3008/113 Haliyal, Karnataka India	26.039 <sup>c</sup>	1.194
3013/116 Arbail, Karnataka India	28.945 <sup>b</sup>	3.389
3039/129 Tak Thailand	30.917 <sup>ab</sup>	0.941
3041/130 Chiangmai Thailand	31.462 <sup>ab</sup>	0.888
3043/132 Phayao Thailand	30.450 <sup>ab</sup>	1.602
-SPA/133 Lampang Thailand	31.721 <sup>a</sup>	0.754
Average	29.481	3.293
CV(%)	11.17	

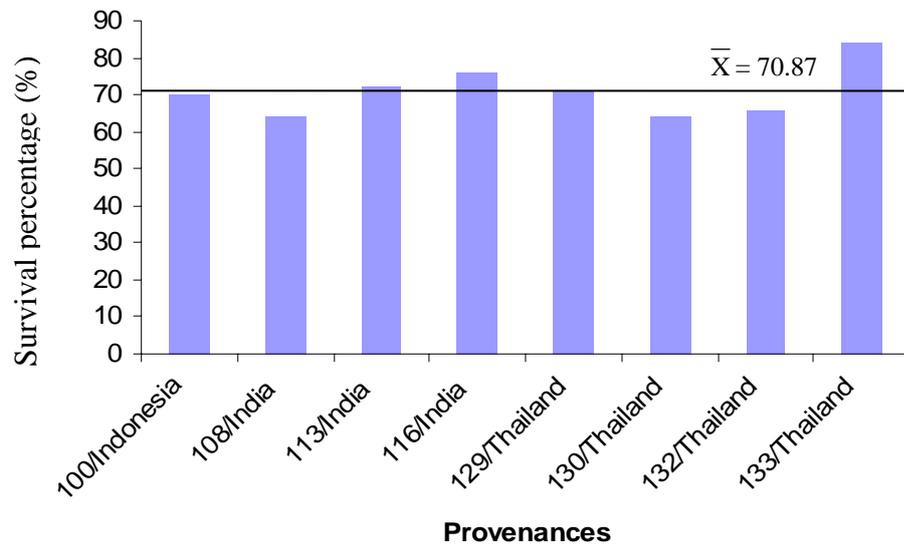
<sup>abc</sup> means that, by DNMRT, significant at 99% level

**Table 11** Analysis of variance on diameter at 10 cm above ground level ( $D_{10}$ ) of 29 years old teak in Teak International Provenance Trials, Lampang

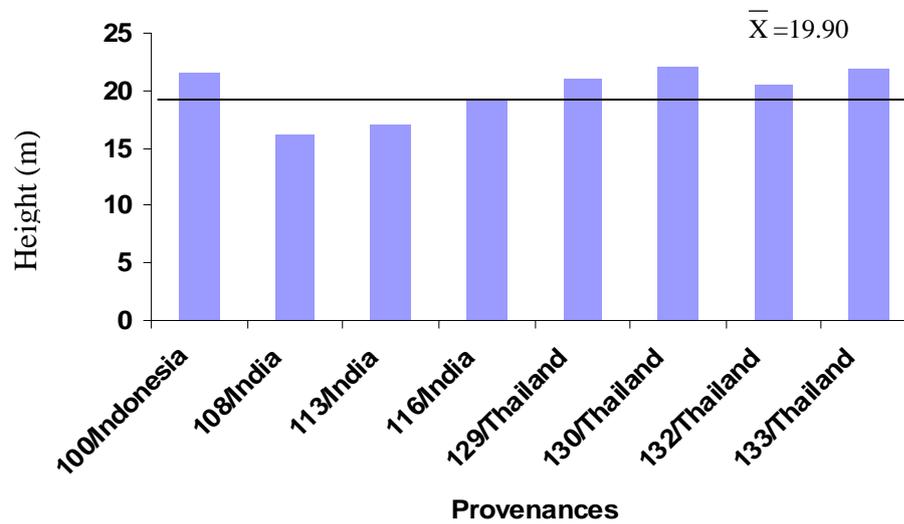
SOV	df	SS	MS	F
Block	3	27.503	9.168	3.633*
Provenance	7	255.799	36.543	14.481**
Error	21	52.994	2.524	

\* = Significant differences at 95% confident limit

\*\* = Highly significant differences at 99% confident limit



**Figure 14** Average survival percentage of 29 years old teak in International Provenance Trials at Ngao, Lampang.



**Figure 15** Average height growth of 29 years old teak in International Provenance Trials at Ngao, Lampang.

The study showed that it would take many years to prove the races better than those originated from India and Indonesia. Successive management and evaluation is thus importance in teak improvement program.

The buttress characteristic of 8 provenances was studied by Jaijing (1994) showed statistically significant. The present study recorded the larger size of buttress of local teaks.

#### **4. Diameter at Breast Height (DBH)**

Diameter at Breast Height (DBH) is the important tree characteristics used to determine tree growth and tree volume. With the exception of *Pinus merkusii* which having long grass stage for better adaptation to fire problems under the natural conditions, most tropical trees promote height growth first and DBH thereafter.

Diameter at Breast Height (DBH) varied considerably between provenances with average value ranging from 19.962 m (3002-India) to 25.857 m (3041-Thailand) as shown in Table 12 and Figure 17. Under Lampang condition, the teak provenances could be classified into 4 groups by based on DBH. The source 3041/132-Chiangmai/Thailand, 3049/100-Central Java/Indonesia and SPA/133-Lampang/Thailand were superior provenances.

Table 13 showed the Analysis of Variance identified the highly significant differences in DBH among provenances (13.376\*\*) and blocks (6.650\*\*). This means that provenances selection is necessary to evaluate at the future assessment.

The differences among blocks indicated the strong species and site interaction. Variation among blocks recommended to plant superior clones on suitable site otherwise the DBH performance of teak would be varied considerably and economic gain would be limited.

At the age of 23 years old teak, The Indian provenances (3002, 3008 and 3013) were segregated at the lower end of the average diameter values in the trial, possibly attribute to the presence of geographical region variation. Average diameter performances across the 4 assessments at ages 7, 14, 23, 26 have consistently shown the Thailand and Indonesian provenances to perform better than Indian Provenance (Anderson, 1997).

According to the reassessment of trial IP001 in the International Teak Provenance Trials, Anderson (1997) resulted that in the performance of eight provenances tested has identified differently. The assessment conducted at the age of 23 indicated that the provenance from Thailand and Indonesia have superior performance in average height and diameter values when comparison to those of the Indian origin. Kaosa-ard (1992) and Kjaer *et al* (1995) in their study on provenance variation in teak growth, the high rating performance of the improved seed source of provenance-SPA across the assessment indicates the benefits obtainable from the tree improvement program.

**Table 12** The average diameter at breast height (DBH) of 29 years old teak in Teak International Provenance Trials, Teak Improvement Center, Ngao, Lampang

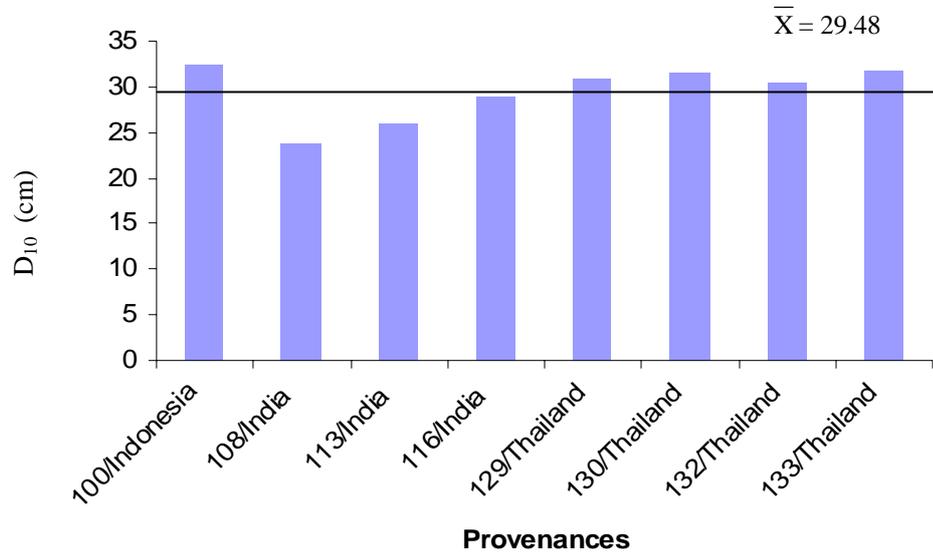
Provenances	Diameter at Breast Height (cm)	SD
3049/100 Ngliron Indonesia	25.599 <sup>a</sup>	0.881
3002/108 Maharashtra India	19.962 <sup>c</sup>	2.751
3008/113 Haliyal, Karnataka India	21.059 <sup>c</sup>	0.776
3013/116 Arbail, Karnataka India	23.209 <sup>b</sup>	2.473
3039/129 Tak Thailand	24.912 <sup>ab</sup>	0.934
3041/130 Chiangmai Thailand	25.857 <sup>a</sup>	1.363
3043/132 Phayao Thailand	23.970 <sup>ab</sup>	1.109
-SPA/133 Lampang Thailand	25.494 <sup>a</sup>	1.014
Average	23.758	2.517
CV(%)	10.59	

<sup>abc</sup> means that, by DNMRT, significant at 99% level

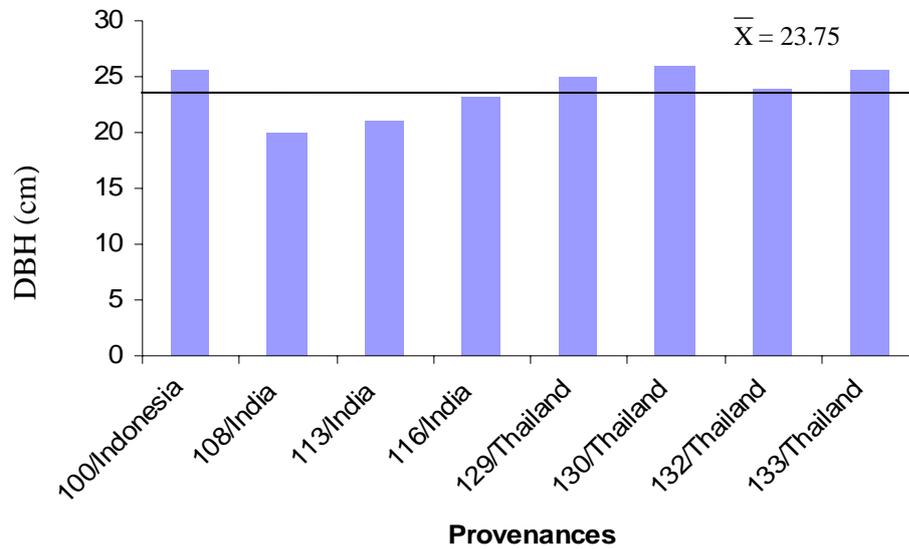
**Table 13** Analysis of variance on diameter at breast height (DBH) of 29 years old teak in Teak International Provenance Trials, Lampang

SOV	df	SS	MS	F
Block	3	29.129	9.710	6.650**
Provenance	7	136.724	19.532	13.376**
Error	21	30.664	1.460	

\*\* = Highly significant differences at 99% confident limit



**Figure 16** Average diameter at 10 cm above ground level (D<sub>10</sub>) of 29 years old teak in International Provenance Trials at Ngao, Lampang.



**Figure 17** Average diameter at breast height (DBH) of 29 years old teak in International Provenance Trials at Ngao, Lampang.

## **5. Stem form**

One of the easiest ways to alter wood properties is to manipulate tree form. Tree form refers mainly to the straightness of the tree stem. Bole straightness has a major effect on both the quality and yield of solid wood products. Moreover, It is commonly known that the variability in wood between poor and well-formed trees also affects different product wood products. Poor tree form can be the result of crooked or leaning stems, any time when the tree does not grow straight or vertically, it forms reaction wood, which is undesirable for most final products (Zobel and van Buijtenen, 1989).

The investigation of this trial, several types of stem form and damaging were found. There were straight, leaned, curved, two stems and damaged as caused provenance trials by broken stem can shown. The study of tree form and damaging in each provenance was recorded by counting the number of tree in each plot.

Concerning the stem form of teak in the international provenance 3041/130 from Chiangmai, Thailand showed the excellent forms and had highest percentage of straight stem character (87.99%) while teak source from Haliyal, India (3008/113) had the poorest stem form (50.75%). The average distribution of straight, leaning, curved, two stems and broken stem was 69.73%, 3.09%, 12.65%, 13.13% and 1.40% respectively (Table 14).

In the same way, Indian teak from Maharashtra and Arbail sources expressed the high value of inferior stem such as curved stem, leaned stem and two stems as shown in Table 14.

All provenances from Thailand showed the better stem form as compared to teak originated from India and Indonesia. As teak with better stem quality will provide more benefits. Characteristic of stem was the one of the crucial criteria for provenance selection that should be practically recommended.

Through field observation, other damaging in each teak provenance was also studied and found that percentage of damaging was high in almost provenances as Table 14. The main evident cause of damaging was termites more than any enemies. However, from observation, termites always destroyed teak bark only not to other part of trees.

It's important to note that the use of proper provenance is one key to having a successful tree improvement program. The results of reassessment in growth performances in teak international provenance trials consisting of 8 seed sources established in 1986 at Lampang showed that Thai provenance was the dominant source and most suitable use in large scale teak planting as shown in Table 15. Better genetic materials can be obtained from teak improvement program rely on teak clone materials and using improved seed from seed orchard.

**Table 14** Tree forms and termite damage of 8 provenances of 29 years old in Teak International Provenance Trials, Lampang

International provenances	Stem forms (%)				Damaging by termites (%)	Remarks
	Straight	Curved	Leaned	Two stems		
3049/100 Ngliron Indonesia	69.67	2.72	16.23	10.13	84.08	Broken stem = 1.25%
3002/108 Maharashtra India	56.17	5.88	25.74	12.21	58.42	
3008/113 Haliyal, Karnataka India	50.75	8.63	21.71	18.91	61.57	
3013/116 Arbail, Karnatak India	61.43	2.44	14.74	25.23	46.19	
3039/129 Tak Thailand	76.05	3.82	5.38	13.19	80.36	Broken stem = 1.56%
3041/130 Chiangmai Thailand	87.99	0.00	5.36	6.65	81.25	
3043/132 Phayao Thailand	74.80	0.00	6.08	13.24	71.08	Broken stem = 5.88%
-SPA/133 Lampang Thailand	80.98	1.19	5.96	9.37	71.11	Broken stem = 2.50%
Average	69.73	3.09	12.65	13.13	69.26	1.40

Table 15 Ranking of 8 International Provenances in Lampung

International provenances	Growth parameter for ranking				Stem form	Total score/Rank
	Survival percentage	Height	D <sub>10</sub>	DBH		
3049/100 Ngliron Indonesia	5	3	1	2	5	16 (3)
3002/108 Maharashtra India	7	8	8	8	7	38 (8)
3008/113 Haliyal, Karnataka India	3	7	7	7	8	32 (7)
3013/116 Arbail, Karnataka India	2	6	6	6	6	26 (6)
3039/129 Tak Thailand	4	4	5	4	3	20 (4)
3041/130 Chiangmai Thailand	7	1	3	1	1	13 (2)
3043/132 Phayao Thailand	6	5	4	5	4	24 (5)
-SPA/133 Lampung Thailand	1	2	2	3	2	10 (1)