Clonal Seed Orchard

1. Clonal Seed Orchard in Uthai Thani

In practice of modern industrial plantation, superior clones are selected for mass production by using cuttings or tissue cultures for preparation of the planting stocks. However, the propagation techniques are commonly known but the problems related to monoculture plantation have indicated the failure of using single clone over years. If the clones are susceptible to diseases and pests, the plantation will face with the high rate of mortality. Therefore, seed orchard is established so as to produce better quality of seed uses at cheaper price and heterogeneous genetic materials for plantation activities.

In Thailand, most established seed orchards of teak are first generation clonal seed orchards, including the TPC clonal seed orchard. In the present study, 25 superior clones from the teak clone bank in Uthai Thani have proved the superiority at the planting site of Uthai Thani and these clones were used in clonal seed orchard establishment in the adjacent site in 1989.

1.1 Survival percentage

Even though the clone selection of teak was based on the good survival percentage and the better overall growth performances in the clone bank, the previous study showed that not all clones could survive 100 per cent. It was found that the survival percentage under seed orchard conditions in the early days of development required the replanting of few clones. The problem was mainly related to the budding technique.

At the age of 15 years old teak clones were planted in form of clonal seed orchard comprising of 25 screened clones from Clone Bank, set in 1989 at Uthai Thani. The present study showed that the survival percentage ranged from 50 (clone V130) to 90 (clone V49) with the average value of 75.2 %. 11clones out of 25 clones had the survival value higher than the mean value while 14 clones had poor survival percentage rate (Table 30.and Figure 25).

At the age of 17 years old, teak clones showed slightly decreasing on survival percentage of some clones. This indicated that the evaluation at the age of 15 was accurate enough to justify the good surviving clones. However, some clones had slightly decreased in survival percentage. Clone V49 still showed the high potential in its adaptation in this environment with the survival value of 90% was observed. While the lowest survival percentage was 50 (clone V130), the mean was slightly down to 74.0%.

The previous study at Mae Gar, clonal seed orchard showed that the survival percentage varying from 64.5-87.5% with the overall average value of 74.71% (Jaijing,1994). The present study showed similar pattern with the previous

Table 30 Survival percentage of 25 selected teak clones in Teak Clonal Seed Orchard, Uthai Thani, established in 1986

Clones	Average survival percentage at the age of	
	15 years old	17 years old
V3	80	75
V26	70	70
V32	70	70
V34	70	70
V35	70	70
V36	80	80
V37	85	80
V43	85	80
V45	80	80
V49	90	90
V72	55	55
V73	75	75
V83	65	60
V84	90	90
V99	70	70
V100	70	70
V110	80	80
V111	90	85
V112	75	75
V119	75	75
V120	85	85
V121	75	70
V127	65	65
V128	80	80
V130	50	50
Total	75.2	74.0

Table 31 Analysis of variance on survival percentage of 25 selected teak clones in clonal seed orchard, established in 1986, Uthai Thani

Survival percentage : 15 years old

Source of Variation	df	SS	MS	F
Block	19	19.808	1.043	6.941**
Clone	24	4.984	0.206	0.114^{ns}
Error	456	68.492	0.150	

Survival percentage : 17 years old

Source of Variation	df	SS	MS	F
Block	19	20.342	1.071	6.984**
Clone	24	4.492	0.187	1.221^{ns}
Error	456	69.908	0.153	

^{ns} = Non-significant limit **= Highly significant differences at 99% of confidence

study in Mae Gar where it is located in the center of biodiversity of teak and Uthai Thani is located in the southern marginal area.

Analysis of variance in survival percentage in the age of 15 and 17 years old displayed the result similarly as shown in Table 31. It was found that the difference among clones was insignificant ($F=0.114^{ns}$ and $F=1.221^{ns}$). However, on highly significant variation among blocks was found (F=6.941**and $F=6.984^{ns}$). This was caused by the undulating site and different drainage ability in this area. It is essential to note that site quality must be screened profoundly before establishing seed orchard and intensive management should be applied steadily.

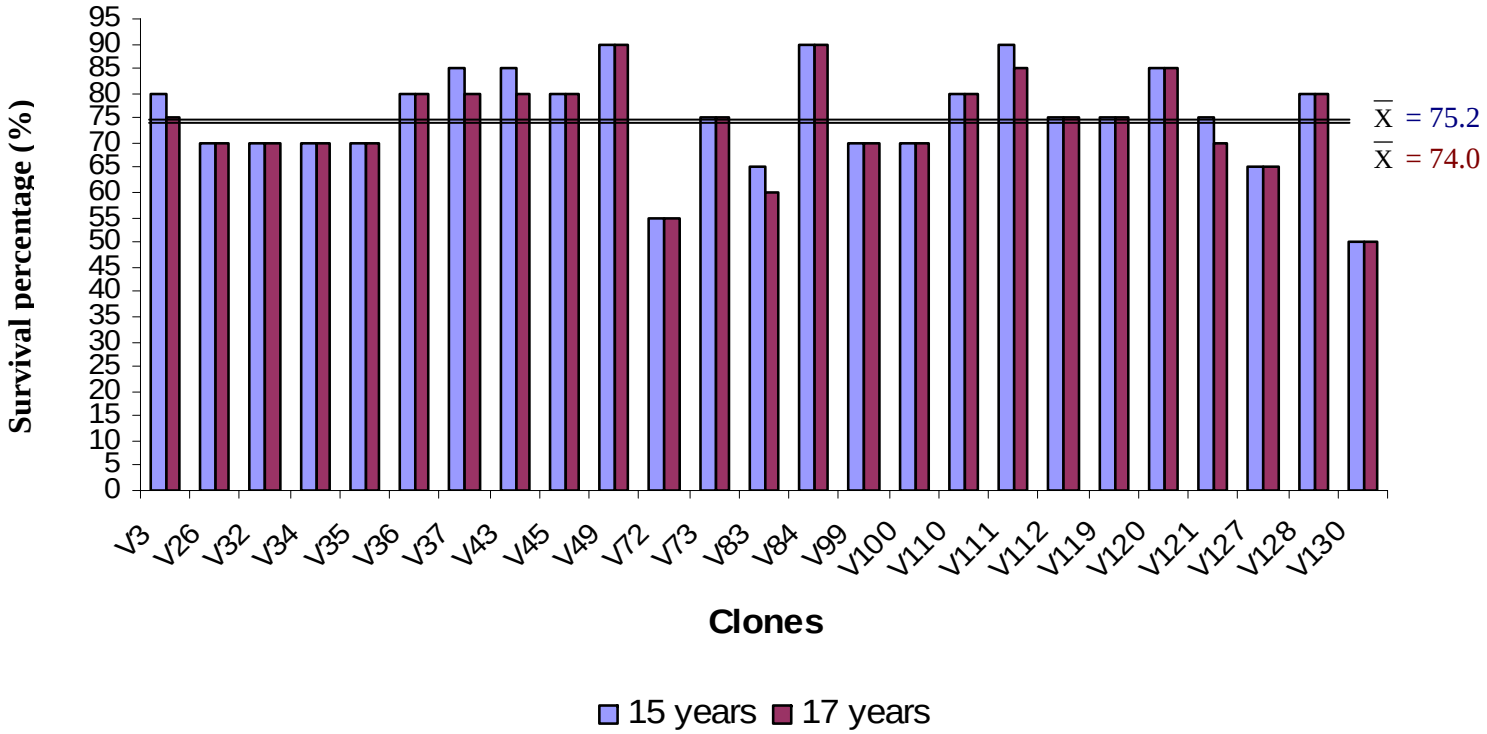

Figure 25 Survival percentage of 25 selected clones in Teak Clonal Seed Orchard, Uthai Thani, at the age of 15 and 17 year.

1.2 Height growth

In the present study, height growth of teak in teak clonal seed orchard at Uthai Thani was measured. It was found that 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) above the average value as shown in Table 32 and Figure 26. By using DMRT, it was possible to classify these clones into 5 height classes.

At 17 years old, height growth performances of teak clones were reassessed. It showed remarkably difference in height among clones (Table 32), ranging from 17.556 m (clone V3) to 23.313 m (clone V34) with the mean of 20.191 m. Mean annual increment in height growth of these clones was 1.19 m.

Table 33 showed the analysis of variance in height growth of teak when planted under seed orchard conditions. Highly significant differences in height growth between blocks and clones were analyzed at both ages. More block variations of both 15 and 17 years old (F=6.660**, F=3.901**) were found than clone variations (F=1.924**, F=2.135**). Results showed that height growth performance was directly related to soil quality and drainage of seed orchard site.

1.3 Diameter at 10 cm above ground level (D_{10})

Each morphological characteristic of tree has different ways of measurement. Diameter at 10 cm above ground level is normally used when trees are small and prior to the buttress formation. For most fast growing multipurpose tree species, trees will be harvested in this position at the age of 4-6 years. This allows the coppicing to grow vigorously afterward.

At the age of 15 year-old, result showed that the Diameter at 10 cm above ground level (D_{10}) of teak clones varied between 41.67 cm (clone V32) to 55.30 cm (clone V36) with the average value of 47.87 cm. And about 5 groups of teak clones could be classified by based on D_{10}.

At the age of 17 years, D_{10} ranged between 43.50 cm (clone V32) to 57.92 cm (clone V36). When compare with the mean of D_{10} (50.10 cm) in this present study, The number of group remained 5 and more than half of theses clones was superior as shown in Table 34 and Figure 27.

According to the Table 35, Analysis of variance in D_{10} at the ages of 15 and 17 years old teak showed statistically significant difference both among blocks and clones, F= 1.811* and F= 2.173** respectively. Results showed that to produce good teak log in the future, one has to consider both the teak clones and site condition. Good genetic materials can not be developed well if the site condition did not meet its requirement.

Table 32 Average height of 25 selected clones of teak at the age of 15 and 17 year-old in Teak Clonal Seed Orchard at Uthai Thani

Clones	Average Height (m) at the age of			
	15 years old	SD	15 years old	SD
V3	17.112^{e}	3.024	17.566^{d}	3.954
V26	19.907^{abcd}	2.465	20.150^{bcd}	2.530
V32	17.621^{de}	3.582	19.514^{bcd}	3.145
V34	21.586^{a}	3.963	23.313^{a}	3.879
V35	19.664^{abcde}	1.705	20.514^{bc}	1.777
V36	19.462^{abcde}	1.548	20.981^{ab}	2.707
V37	19.664^{abcde}	4.123	19.881^{bcd}	3.062
V43	19.629^{abcde}	3.282	20.762^{ab}	2.651
V45	20.756^{ab}	1.959	21.106^{ab}	2.958
V49	19.511^{abcde}	2.204	21.250^{ab}	2.104
V72	20.181^{abcd}	2.912	21.300^{ab}	2.651
V73	18.080^{bcde}	5.213	19.137^{bcd}	5.346
V83	19.315^{abcde}	2.364	20.133^{bcd}	3.193
V84	17.947^{cde}	4.232	18.794^{bcd}	3.909
V99	17.642^{de}	4.101	18.006^{cd}	3.947
V100	19.892^{abcd}	3.349	21.114^{ab}	3.558
V110	17.687^{de}	4.108	19.143^{bcd}	2.857
V111	18.755^{bcde}	5.161	20.700^{abc}	2.586
V112	19.166^{abcde}	4.126	19.766^{bcd}	2.812
V119	18.860^{bcde}	2.780	20.800^{ab}	3.149
V120	18.952^{abcde}	2.452	19.500^{bcd}	2.619
V121	18.153^{bcde}	4.787	20.985^{ab}	3.565
V127	19.776^{abcde}	2.431	20.314^{bc}	3.529
V128	18.625^{bcde}	3.986	20.143^{bcd}	2.962
V130	20.670^{abc}	2.406	20.350^{bc}	4.807
Total Average	19.104	3.547	20.191	3.377
CV(%)	18.56		16.72	

^{abcde} means that, by DNMRT, significant at 99% level

Table 33 Analysis of variance on height, DBH and D_{10} performance of 25 selected teak in Clonal Seed Orchard, established in 1986, Uthai Thani

Height: 15 years old

Source of Variation	df	SS	MS	F
Block	19	1183.208	62.274	6.660**
Clone	24	431.663	17.986	1.924**
Error	332	3104.209	9.350	

Height: 17 years old

Source of Variation	df	SS	MS	F
Block	19	687.592	36.189	3.901**
Clone	24	475.381	19.808	2.135**
Error	329	3052.120	9.277	

**= Highly significant differences at 99% of confidence limit

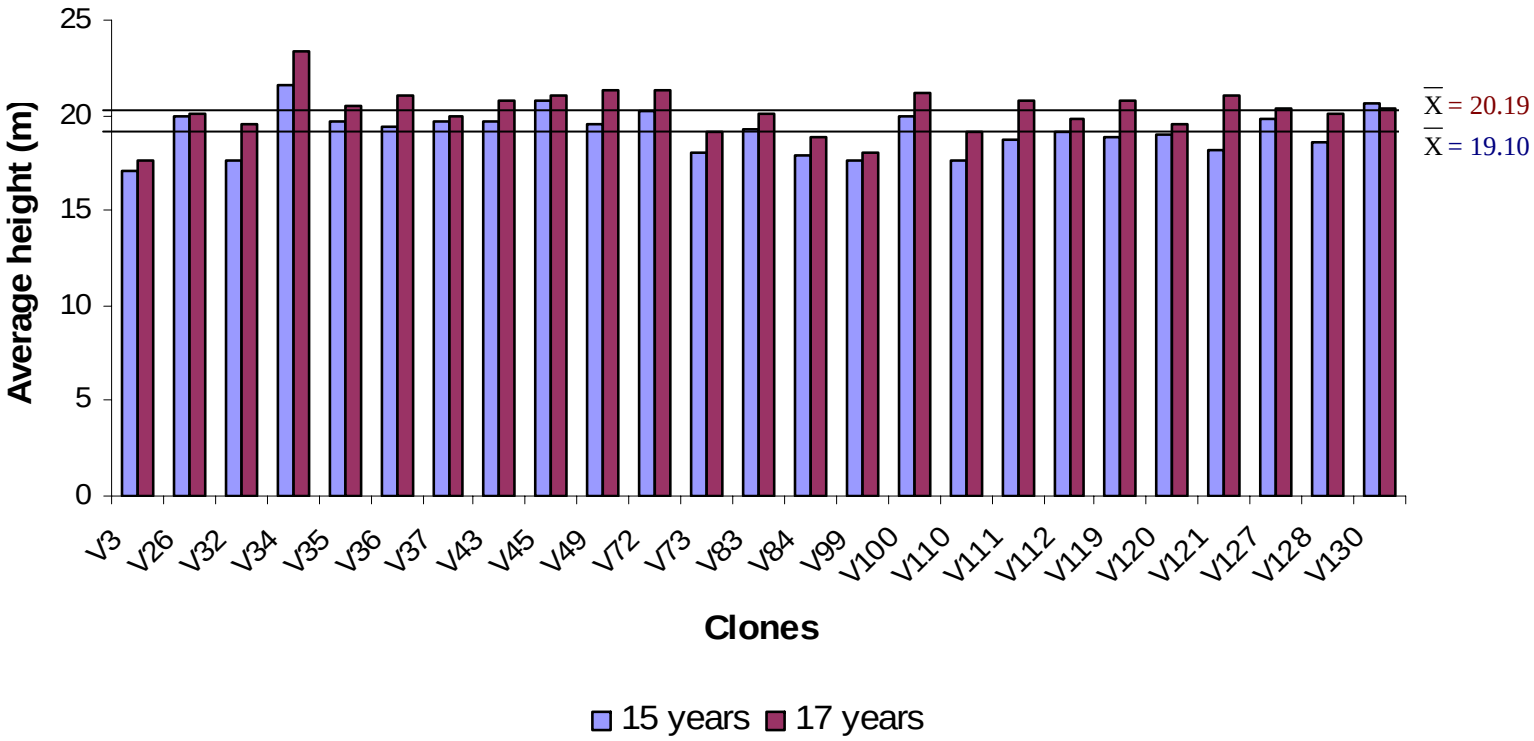

Figure 26 Average height of 25 selected clones in Teak Clonal Seed Orchard, Uthai Thani, at the age of 15 and 17 years.

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Table 34 Average diameter at 10 cm above ground level (D_{10}) of 25 selected clones of teak at 15 and 17 year- old in Teak Clonal Seed Orchard at Uthai Thani

Clones	Average D_{10} (cm) at the age of			
	15 Years old	SD	17 Years old	SD
V3	45.501^{bcde}	5.991	47.643^{bcdef}	7.718
V26	50.727^{abcd}	4.492	53.020^{abcde}	6.643
V32	41.676^{e}	9.917	43.503^{f}	9.661
V34	52.929^{ab}	10.978	54.475^{abcd}	10.605
V35	50.491^{abcd}	8.048	52.065^{abcdef}	8.095
V36	55.302^{a}	6.010	57.922^{a}	6.970
V37	47.624^{abcde}	12.697	46.580^{cdef}	17.879
V43	48.729^{abcde}	9.856	53.125^{abcde}	6.009
V45	51.389^{abc}	8.612	52.032^{abcdef}	15.104
V49	51.466^{abc}	5.459	54.642^{abc}	5.327
V72	50.175^{abcd}	5.861	51.700^{abcdef}	4.185
V73	47.764^{abcde}	12.758	48.570^{bcdef}	14.750
V83	47.246^{abcde}	5.594	50.371^{abcdef}	5.007
V84	45.429^{bcde}	13.769	50.359^{abcdef}	14.103
V99	44.765^{bcde}	6.725	45.583^{def}	9.729
V100	47.634^{abcde}	10.528	50.609^{abcdef}	9.835
V110	43.984^{cde}	9.523	45.696^{cdef}	9.006
V111	47.641^{abcde}	10.108	52.180^{abcdef}	5.012
V112	47.609^{abcde}	11.010	49.303^{abcdef}	10.652
V119	47.755^{abcde}	9.963	50.564^{abcdef}	9.290
V120	42.339^{de}	4.714	44.342^{ef}	5.372
V121	48.407^{abcde}	16.006	55.955^{ab}	17.369
V127	45.058^{bcde}	6.737	44.499^{ef}	10.822
V128	47.084^{abcde}	11.159	49.267^{abcdef}	10.846
V130	48.203^{abcde}	7.092	47.719^{bcdef}	12.136
Total Average	47.871	9.759	50.105	10.767
CV(%)	20.38		21.49	

^{abcdef} means that, by DNMRT, significant at 99% level

Table 35 Analysis of variance on D_{10} performance of 25 selected teak clones in Clonal Seed Orchard, established in 1986, Uthai Thani

D_{10}: 15 years old

SOV	df	SS	MS	F
Block	19	3350.640	176.349	2.046**
Clone	24	3746.923	156.122	1.811*
Error	332(330)	28448.048	86.206	

D_{10}: 17 years old

SOV	df	SS	MS	F
Block	19	5146.534	270.870	2.723**
Clone	24	5189.045	216.210	2.173**
Error	332(328)	32627.585	99.474	

* = Significant differences at 95% of confidence limit

**= Highly significant differences at 99% of confidence limit

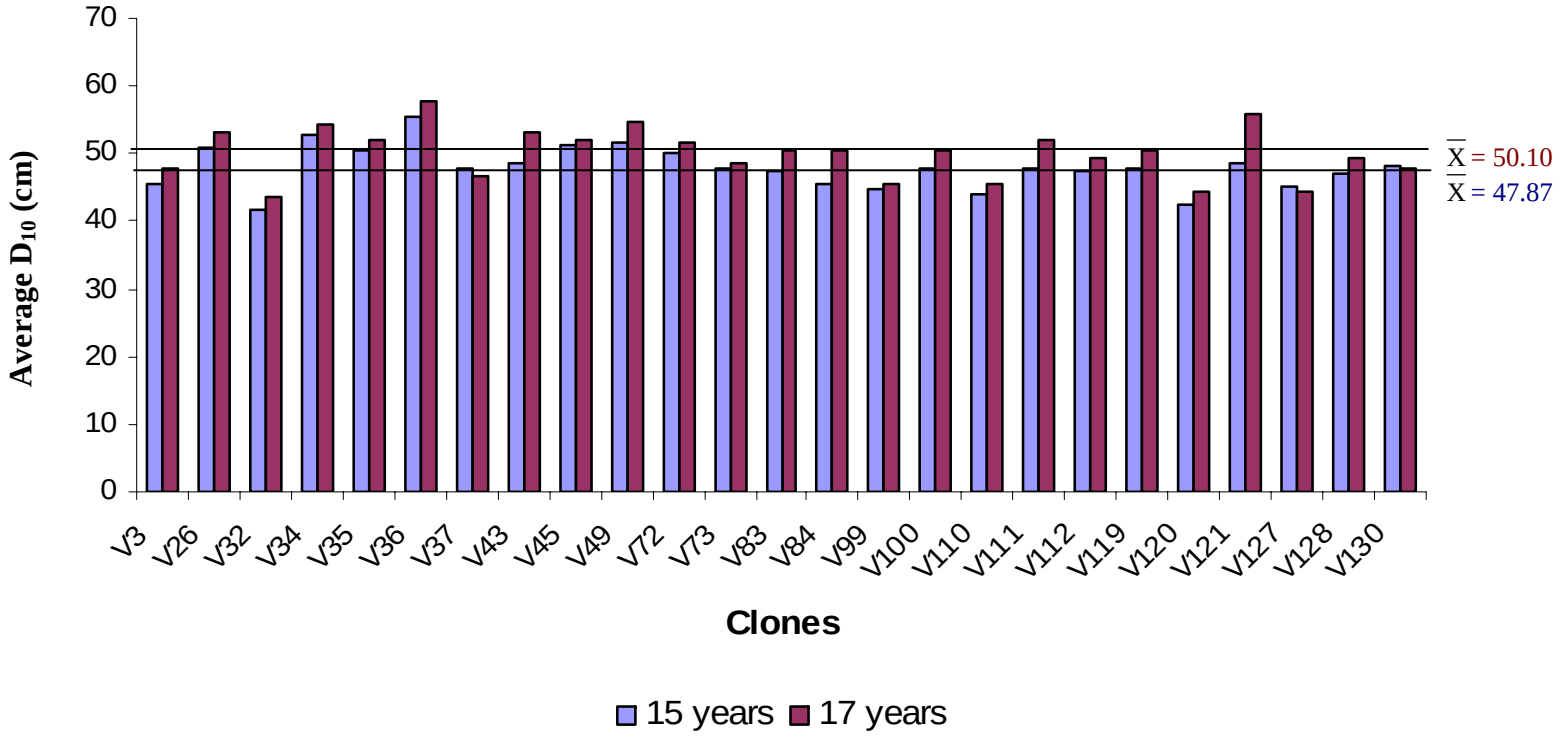

Figure 27 Average Diameter at 10 cm above ground level (D_{10}) of 25 selected clones in Teak Clonal Seed Orchard, Uthai Thani, at the age of 15 and 17 years.

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1.4 Diameter at Breast Height (DBH)

The diameter, measured at the 1.3 m above ground level, is an important character and generally used in determining growth of a tree. In the present study, the diameter at breast height of 15 and 17 year-old teak was recoded, as shown in Table 36 and Figure 28.

Results showed that the trend of DBH growth measured in 2 periods were similar. At the age of 15 year-old, DBH growth of teak varied from 33.40 cm (clone V32) to 43.45 cm (clone V34) and range between 35.15 cm and 46.18 cm at the age of 17 year-old, The former average was 38.75 cm and the latter was 41.05 cm. The annual DBH growth at this stage was 1.15 cm. Besides, Clone V34 manifested the outstanding performance in DBH growth whereas clone V32 was the poorest one for both period assessments. It was found that almost half of all teak clones performed above average DBH value.

Based on the Analysis of variance, highly significant difference on DBH was found only among blocks in both ages studied (F= 2.335** and F= 2.000**). Different among clones showed greatly significant in only the latest evaluation (17 year-old, F= 2.169**) whereas at the age of 15 year was not significant (F= 1.426^{ns}) demonstrated in Table 37.

As the results on growth characteristic of teak clonal seed orchard at the age of 15 years old, it 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 are needed if good tree characters and good seed crops are expected.

1.5 Fruiting Potential

The outcome of teak clonal seed orchard is teak fruits. The poly crossing teak in clonal seed orchard will guarantee the fruit quality and is needed in the establishment of good teak plantation. Though teak can produce fruits in various age as reported by Bhumibhamon (1984), some teak seedlings can produced flower even at the nursery bed. Such early flowering is however become undesirable for genetic selection since it produce poor teak growth. At the age of five years onward, teak clonal seed orchard in Uthai Thani has produced flower. However, variation on flowers and fruits production varied from clone to clone, as was observed at Mae Li Seed Orchard (Bhumibhamon, 1983).

Additionally, it was found that the climatic conditions may also decrease fruit production. For instance, heavy rain and storm may cause considerable loss of flowers or developing fruits. However the long flowering period of approximately two months may be safeguard for teak under such adverse climatic conditions. Hot dry weather during flowering has also been observed to adversely affect fruit set by

Table 36 Average diameter at breast height (DBH) of 25 selected clones of teak at 15 and 17 year- old in Teak Clonal Seed Orchard at Uthai Thani

Clones	Average DBH (cm) at the age of			
	15 years old	SD	17 years old	SD
V3	36.526	4.871	38.913^{bcdef}	5.618
V26	40.682	4.354	42.789^{abcde}	4.753
V32	33.409	8.818	35.150^{f}	7.395
V34	43.450	9.681	46.183^{a}	9.504
V35	40.066	6.281	42.625^{abcde}	6.773
V36	42.790	3.548	44.936^{ab}	3.563
V37	38.784	10.433	40.311 ^{abcdef}	10.217
V43	39.859	7.432	44.415^{abcd}	5.280
V45	41.070	6.803	44.765^{abc}	7.340
V49	40.541	3.933	42.916^{abcde}	4.217
V72	41.847	3.704	43.839^{abcde}	3.612
V73	37.685	9.801	38.033^{def}	11.448
V83	37.893	3.808	41.460^{abcdef}	3.574
V84	37.281	10.796	40.127^{abcdef}	10.621
V99	37.914	4.909	38.314^{cdef}	7.955
V100	38.905	10.253	42.276^{abcde}	8.301
V110	35.603	7.797	37.902^{def}	7.233
V111	38.016	7.397	41.656^{abcdef}	3.167
V112	38.431	9.012	40.645^{abcdef}	8.878
V119	38.953	5.895	40.798^{abcdef}	6.024
V120	35.788	4.772	37.336^{ef}	4.577
V121	38.785	13.866	42.894^{abcde}	11.275
V127	37.462	5.220	37.261^{ef}	8.312
V128	38.113	8.855	41.011^{abcdef}	7.802
V130	39.888	3.908	39.834^{abcdef}	10.219
Total average	38.752	7.733	41.052	7.777
CV(%)	19.95		18.94	

^{abcdef} means that, by DNMRT, significant at 99% level

Table 37 Analysis of variance DBH performance of 25 selected teak clones in Clonal Seed Orchard, established in 1986, Uthai Thani

DBH: 15 years old

SOV	df	SS	MS	F
Block	19	2425.500	127.658	2.335**
Clone	24	1871.198	77.967	1.426^{ns}
Error	332	18149.529	54.667	

DBH: 17 years old

SOV	df	SS	MS	F
Block	19	2040.751	107.408	2.000**
Clone	24	2795.570	116.482	2.169**
Error	332(329)	17670.832	53.711	

^{ns} = Non-significant **= Highly significant differences at 99% of confidence limit

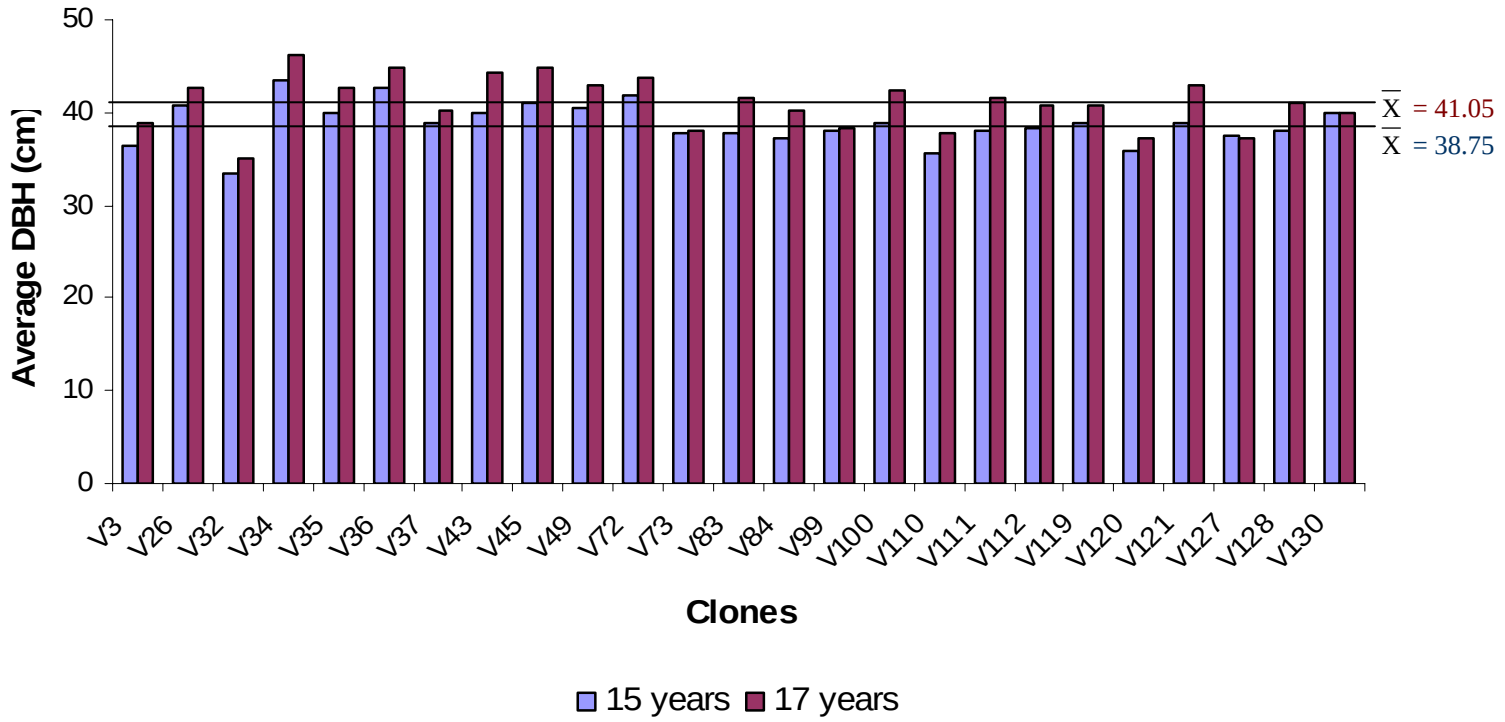

Figure 28 Average DBH of 25 selected clones in Teak Clonal Seed Orchard, Uthai Thani, at the age of 15 and 17 years.

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causing poor flowering and fruit formation, whereas, regular rainfall and cool weather promote flowering and fruit formation in many cases. Other factors, such as soil, disease, heredity, age and vigor of trees, and their interactions have been reported to be crucial to teak fruit production (Kittinanda, 1975).

Much of the advantage of a tree improvement is lost if the seed orchards do not produce seed to their maximum potential. It certainly is beneficial to use genetically superior genotypes that are inherently heavy seed producers to obtain maximum seed production. Generally, important constraint of seed orchard is extremely low in reproduction although fertilization occurred within 24 hours after flowering opening.

The fruiting potential of each distinguished clones in clonal seed orchard was studied through observation by giving scores divided into 4 groups (0= no fruit, 1 = fruits present in small amount, 2 = fruits present in some branches, 3 = fruits present in many branches, and 4 = fruits present in every branches). The evaluation of fruit production was shown in Table 38 and Figure 29. The present study showed good fruit production with the mean of 2.51$\pm$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.

In regard to the variance on fruiting ability, largely significant differences on teak fruit production was found among blocks and clones but clonal variation showed highly statistically significant (F= 4.794**) (Table 39).

1.6 Stem form and tree damaged tree

As the teak value depends on the quality of teak log, it is important to conduct the research on stem quality. In practices, one good log quality of 3 m is balances well with the expenditure to grow teak but two logs of 3 m is the ultimate aim of TPC Teak Improvement Program.

In the present study, the stem form of teak clones was studied. 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 the present study number 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% (Table 40).

Variation in straight and damage was calculated by using Analysis of Variance. It showed that no significant differences was found among clones in all case but variation in damaged remets among blocks was significantly differences (F=11.505**) as shown in Table 41.

To produce high seed yield, generally, wide spacing was used in seed orchard management that is why more forked stem usually occurred.

Table 38 Fruiting percentage of 25 selected clones planted in Clonal Seed Orchard, Uthai Thani, in 1986

Clones	Excellent (4)	Good (3)	Medium (2)	Poor (1)	No Fruiting	Mean±SD
V3	6.67	6.67	20.00	13.33	53.33	1.06±1.289
V26	42.86	21.43	21.43	7.14	7.14	2.86±1.292
V32	0.00	21.42	14.29	14.29	50.00	1.07±1.269
V34	33.33	46.67	0.00	13.33	6.67	2.93±1.163
V35	28.57	42.86	21.43	7.14	0.00	2.93±0.917
V36	75.00	18.75	6.25	0.00	0.00	3.69±0.602
V37	43.75	37.50	6.25	0.00	12.50	2.94±1.298
V43	43.75	43.75	0.00	0.00	12.50	3.06±1.249
V45	31.25	37.50	18.75	12.50	0.00	2.88±1.025
V49	27.78	44.44	22.22	0.00	5.56	2.94±0.873
V72	0.00	9.09	36.36	27.27	27.27	1.27±1.009
V73	6.67	40.00	6.67	20.00	26.67	1.87±1.356
V83	30.77	23.08	23.08	23.08	0.00	2.62±1.193
V84	0.00	43.75	25.00	6.25	25.00	2.00±1.323
V99	21.43	28.57	42.86	0.00	7.14	2.57±1.089
V100	14.29	35.71	35.71	0.00	14.29	2.36±1.216
V110	31.25	12.50	18.75	12.50	25.00	2.13±1.628
V111	35.29	29.41	17.65	5.88	11.76	2.67±1.328
V112	26.67	33.33	33.33	0.00	6.67	2.73±1.100
V119	53.33	13.33	13.33	13.33	6.67	2.93±1.387
V120	35.29	47.06	11.76	5.88	0.00	3.12±0.857
V121	14.29	35.71	14.29	7.14	28.57	2.07±1.486
V127	7.69	15.38	38.46	15.38	23.08	1.69±1.251
V128	31.25	37.50	12.50	6.25	12.50	2.69±1.352
V130	40.00	40.00	10.00	0.00	10.00	3.00±1.247
Average	27.25	30.62	18.81	8.43	14.89	2.51±1.343
CV(%)						53.50

0 = no fruit
1 = fruit presents in small amount
2 = fruit presents in some branches
3 = fruit presents in many branches
4 = fruit presents in every branches

Table 39 Analysis of variance on fruiting ability of 25 selected teak in Teak Clonal Seed Orchard, established in 1986, Uthai Thani

Fruiting ability

SOV	df	SS	MS	F
Block	19	48.90	2.574	1.831*
Provenance	24	161.753	6.740	4.794**
Error	331	466.712	1.406	

* = Significant differences at 95% of confidence limit
**= Highly significant differences at 99% of confidence limit

Table 40 Percentage of stem form and tree damaging of 25 selected teak clones planted in Clonal Seed Orchard, Uthai Thani, established in 1986

Clones	Stem form	
	Stem form: straightness (%)	Damaging (%)
V3	27	37
V26	86	15
V32	64	29
V34	73	13
V35	64	0
V36	81	19
V37	71	24
V43	82	29
V45	81	13
V49	67	17
V72	64	18
V73	60	7
V83	46	15
V84	59	24
V99	57	21
V100	36	7
V110	69	13
V111	61	17
V112	53	13
V119	73	13
V120	76	18
V121	67	20
V127	46	15
V128	63	13
V130	70	20
Average	64	17

Table 41 Analysis of variance on stem form and damaged remets of 25 selected teak in Teak Clonal Seed Orchard, established in 1986, Uthai Thani

Stem form: straightness

SOV	df	SS	MS	F
Block	19	5.678	0.299	1.351^{ns}
clone	24	7.172	0.299	1.351^{ns}
Error	331	73.198	0.211	

Damaged trees

SOV	df	SS	MS	F
Block	19	20.502	1.079	11.505**
clone	24	2.015	0.083	0.895^{ns}
Error	331	31.043	0.093	

^{ns} = non-significant **= highly significant differences at 99% of confidence limit

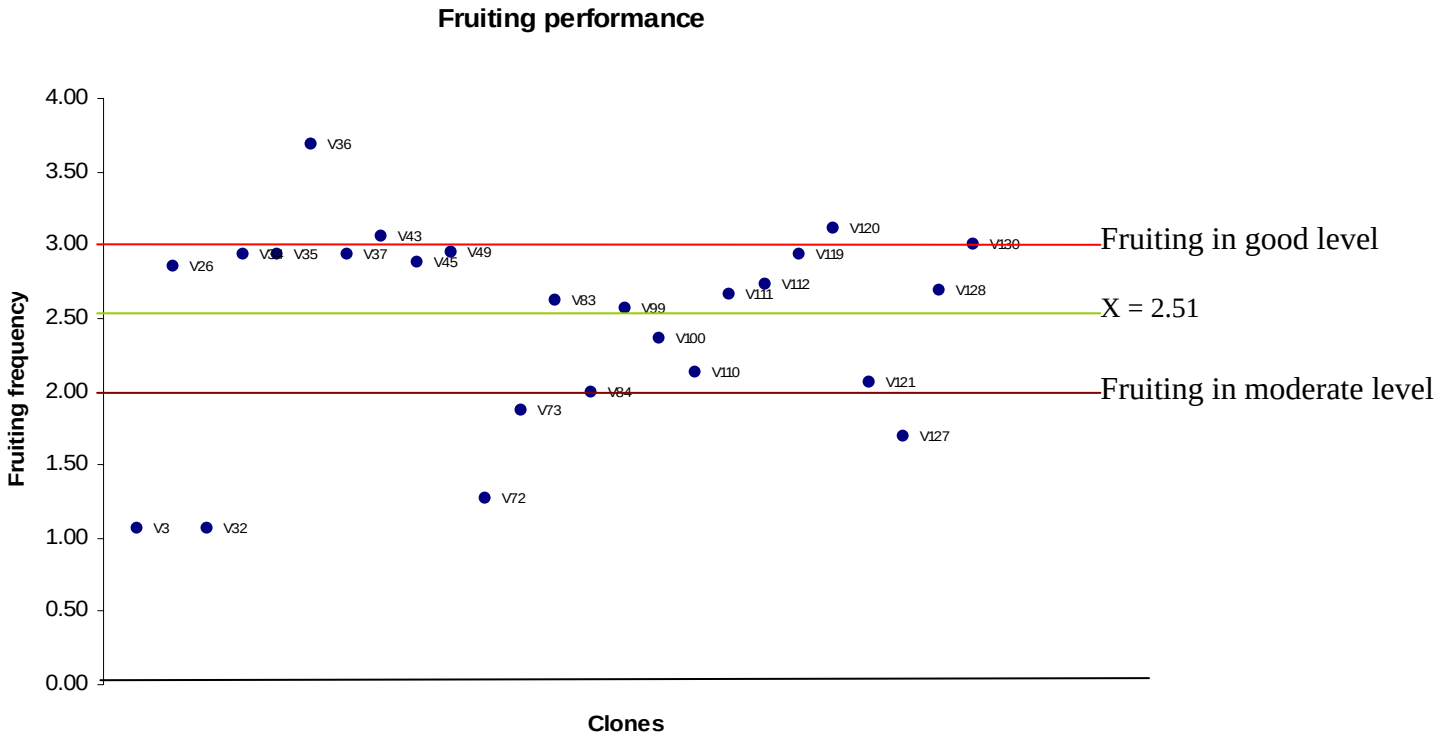

Figure 29 Average fruiting performance of 25 selected clones grown in Clonal Seed Orchard, Uthai Thani, established in 1986.

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