ORIGINAL ARTICLE

Family Variation in Early Growth Characteristics of Thai Neem (*Azadirachta indica* var. *siamensis* Valeton) Planted in Lad Krating Plantation, Chachoengsao

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ABSTRACT

12-month-old Thai Neem grown in the progeny trial in Lad Krating Plantation, Chachoengsao had average survival percentage, height, and diameter at ground level values as 91.65%, 31.77 cm, and 5.04 mm, respectively. Monthly height growth pattern of Thai Neem was slightly increased in the dry season and accelerated in the rainy season. On the other hand, the diameter growth increased continuously by months. While, in the dry season, the genetic factors showed less effect on growth performances than environmental factors, in the rainy season, the genetic factors stimulated the growth increments but environmental factors (site or replication) still had more effect. Not only monthly rainfall and mean air temperature were influenced to height increment but also factors as genetics, other environments, and silvicultural practices were collaborated in monthly height growth. Besides, monthly rainfall and mean air temperature showed the intimate correlation with diameter increment, thus, the monthly diameter growth of Thai Neem progenies were expected to be controlled by climatic factors and associated with other environmental and genetic factors. In an early growth evaluation, progenies of Plus Tree No. 1, 9, 23, 25, 32, and 33 showed superior growth characteristics when planted in Lad Krating Plantation, Chachoengsao. However, the growth investigation should be done until the time of a half rotation.

Key words: family variation, early growth, Thai neem, *Azadirachta indica* var. siamensis

INTRODUCTION

Thai Neem or Sadao Thai (*Azadirachta indica* var. *siamensis* Valeton) is one of the most popular multi-purpose tree species that planted widely in Thailand because it grows well in various sites even in poor soil and low annual rainfall (Bhumibhamon and Kamkong, 1997). Apart from its value as a timber tree, neem has antiseptic medicinal, insecticidal

properties, and sociocultural values (National Research Council, 1992; Tewari, 1992). The species is highly efficient to plant in small to commercial scales.

Because of the valuable utilizations and high potential productivities, Thai Plywood Company (TPC) established the provenance trial in Uthaitani and these results on survival percentage and growth were promissing. Thereafter, TPC considered promoting Thai Neem planting in the forest farm project in Chachoengsao so the establishment of seed orchard and study on family variation should be done.

The objectives of this research were to study the early monthly growth characteristics among Thai Neem progenies and effects of some climatic factors on Thai Neem progenies grown in the seedling seed orchard established in Lad Krating Plantation, Chachoengsao. Moreover, the results of the study were considered to provide the basic information for future tree improvement studies and mass planting program.

MATERIALS AND METHODS

Experimental Design

The seeds of progeny trial in Lad Krating Plantation, Chachoengsao were collected from 32 plus trees scatter distributed in Uthaitani in April 2003. The progeny trial of Thai Neem was established in October 2003, using Randomized Complete Block Design with 16 replications. There were 32 plots in each replication. Each plot was planted with 9 open pollinated progenies with 1 x 2 m spacing.

Seedling Measurement

The early growth of all trees was investigated every month. The tree heights were measured by a measuring tape. The diameters at ground level (Do) were measured by a veneer caliper. Moreover, the survival percentages of each family were also recorded. The analysis of variance on growth characteristics and the regression on growth increments and monthly rainfall as well as mean air temperature were analyzed by using SPSS statistical software.

RESULTS AND DISCUSSION

Effect of Climatic Factors on Early Growth Increment

From 1-12 months (Table 1 and Figure 1), the average survival percentages of seedlings were decreased every month. At the age of 1 month, the average survival percentage was seriously declined because of the critical adaptation of progenies from nursery to field environment. During the age of 2-7 months, the average mortality percentages were high due to the drought condition in dry season. From the age of 8-12 months in rainy season, the deaths of seedlings were few probably caused by climatic factors.

Table 1. Monthly variation on some climatic data and growth characteristics (survival percentage, height (HI), and diameter increment (DI)) of Thai Neem progenies of 32 plus trees planted in Lad Krating Plantation, Chachoengsao

Month	Age (months)	Rainfall (mm)	Mean air temperature(°C)	Survival percentage(%)	HI (cm.month^{-1})	DI (mm.month^{-1})
11/03	1	0	27.13	98.57	0.27	0.13
12/03	2	0	22.76	97.27	0.07	0.08
1/04	3	11.8	24.53	95.27	0.08	0.20
2/04	4	10.6	25.71	94.05	0.18	0.20
3/04	5	38.9	29.58	93.71	0.32	0.26
4/04	6	45.4	29.50	92.58	1.06	0.32
5/04	7	122.6	29.82	91.95	4.12	0.36
6/04	8	136.9	29.07	91.93	4.19	0.45
7/04	9	86.0	28.61	91.88	1.85	0.34
8/04	10	190.7	27.60	91.84	1.73	0.28
9/04	11	125.9	27.25	91.56	1.16	0.23
10/04	12	95.3	27.17	91.65	1.02	0.22

The average height growths of seedlings were increased every month. During dry season (October-March), at the age of 1-6 months, the average height growths were slightly increased due to the low rainfall. When the amount of rainfall was enough to activate the enlargement of the terminal buds, the heights of seedlings at the age of 7 and 8 months were remarkably increased. During the rainy season (May-October), the height growths were continuously increased but less than those during the early rainy season even though the monthly rainfalls were higher (Table 1 and Figure 1).

Whilst, the average diameter growths of seedlings were increased every month, the diameter increments in dry season compared with rainy season were slightly different (Table 1 and Figure 1). Similar to the study of Karumanchi and Rajput (2001) which recorded that Indian Neem (*A. indica*) cambium growth occurred throughout the year in Scrubland Forest whereas in moist deciduous forest and dry deciduous forest it occurred for the major part of the year.

The regression analysis of rainfall and average temperature on early growth of Thai Neem progeny (Figure 2) showed that the correlations between climatic factors and survival percentage were negative but the correlations between climatic factors and growth

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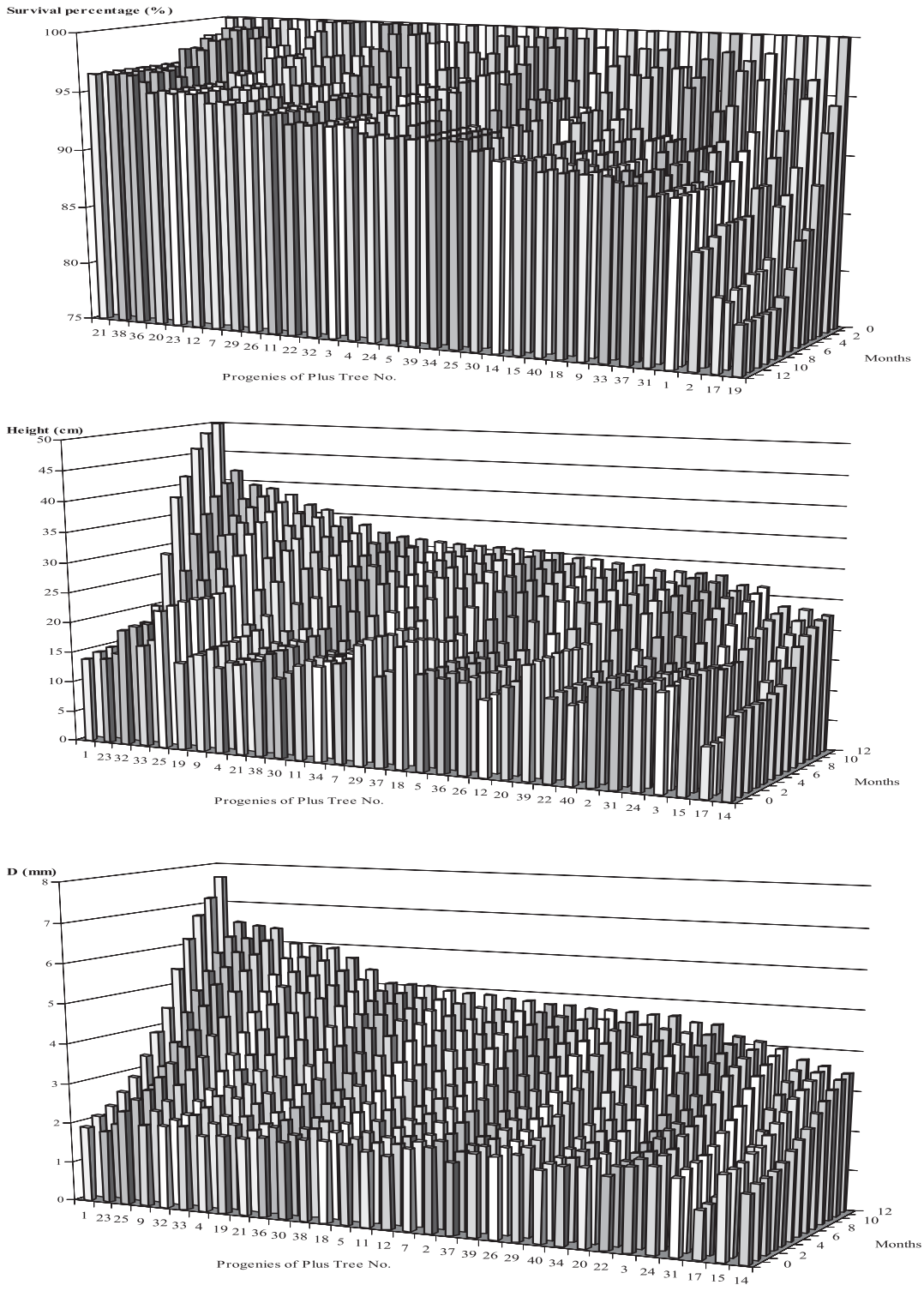

Figure 1. Family variation in survival percentage, height, and diameter at ground level (Do) among Thai Neem progenies of 32 plus trees planted in Lad Krating Plantation, Chachoengsao during the study period.

increments were positive. The R^2 of linear regression of rainfall on survival percentage (R^2 = 0.91) and diameter increment (R^2 = 0.78) was more than those on height increment (R^2 = 0.47) but the linear regression of average temperature on survival percentage and growth increments had the similar R^2 values (R^2 = 0.64, 0.64, and 0.69, respectively).

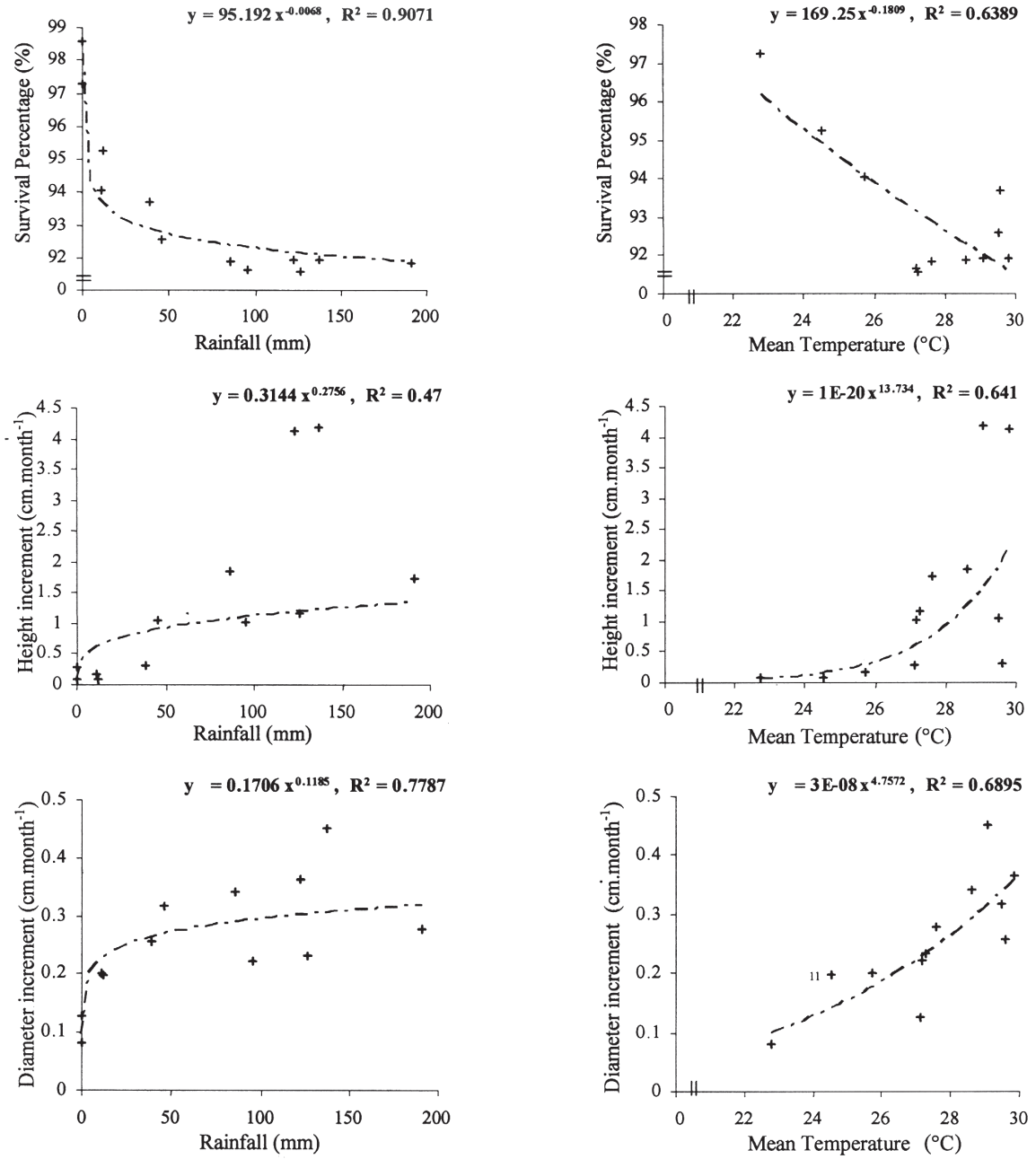

Figure 2. Effect of rainfall and mean temperature (11/03-10/04) on mean survival percentage and growth increments of Thai Neem progenies of 32 plus trees planted in Lad Krating Plantation, Chachoengsao.

Nevertheless, shoot elongation, like any other growth process, would be expected to respond to temperature changes, and three studies were reported in which the two apple orchard factors mentioned above eliminated (Barlow, 1975). According to Kozlowski (1958), diameter increment was affected more than the height growth by variations in moisture conditions since cambial activity usually initiates later in the season and lasts longer. Likewise, variation of cell diameter and wall thickness index for earlywood are both positively correlated with air and soil temperatures, while rainfall is also positively correlated with cell diameter index but not in all species (Rossi *et al*., 2002). Antonova and Stasova (1993, 1997) found a large amount of the variation in tracheid dimension for cell parameter is attributed to temperature because it is an important factor affecting radial cell en-largement and wall thickening and also found a positive influence of precipitation on cell enlargement with species of larch and pine. However, the yearly patterns, like the increase in wall thickness or the decrease in cell diameter, are the results of both external and internal factors (Creber and Chaloner, 1984).

It was clearly found that not only rainfall and temperature were influenced to height increment but also factors as genetic, other environments and silvicultural practices were collaborated in monthly height growth. Besides, the R^2 of rainfall and temperature on diameter increment were high, thus, the monthly diameter growth of Thai Neem progenies were extended by climatic factors and associated with other environmental and genetic factors.

Survival Percentage

In the present study, the survival percentage of 1-year-old Thai Neem grown in the progeny trial, Lad Krating Plantation, Chachoengsao (91.64%) was better than those grown in the international provenance trial, Kanchanaburi (87.71%, Sawatdee, 2003) and tea tree seedling (49.80%) grown in the nearby area and planted in the rainy season of the same year (Uthairatsamee, 2004) but lower than Thai Neem planted in Ratchaburi with 4 x 4 m spacing (98.44%, Tiyanon, 1987). The reason of these results may be caused by the difference of experimental sites, season of planting, and genetics of different species.

The variations on survival percentage among Thai Neem progenies in various months were presented in Figure 1. From 1-6 months after planting, survival percentage of Thai Neem progenies of almost all plus trees were decreasing due to the adaptation of seedling to hazard environment of field experiment but in the rainy season, mortality rates of all progenies were few. However, some progenies showed high ability in coppicing even in the dry season, especially progenies of Plus Tree No. 24 as survival percentage of 2-month-old was higher than 1-month-old. At the age of 12 months (Table 2), progenies of Plus Tree No. 21, 36, and 38 showed the best survival

percentage (96.53 %), followed by progenies of Plus Tree Nos. 12, 20, and 23 (95.14%) and progenies of Plus Tree Nos. 7 and 29 (94.44%). On the other side, progenies of Plus Tree Nos. 2, 17, and 19 showed poor survival percentage as 84.72, 81.25, and 79.17%, respectively.

The result of statistical test on survival percentage among replications and progeny of plus trees was shown in Table 3. The significant difference of replications at the age of 1 month was the highest due to the adaptation of seedling from nursery to field environment. The significant difference of replications at 2-month of age was decreased and then the significant differences of replication were increased by the heterogeneity of site conditions. Meanwhile, the significant differences of progeny of plus trees were increased by time after planting but lower than the significant differences of replications were. Thus, the replications or planting site factors had more effect on survival percentage than progeny of plus trees or genetic factors in almost all ages.

Height Growth

In the present study, the average height growth of Thai Neem at the age of 12 months grown in the progeny trial (31.77 cm) was less than those grown in Ratchaburi with spacing 4 x 4 m (Tiyanon, 1987), those grown in the international provenance trial, Kanchanaburi (Sawatdee, 2003) and tea tree seedling grown in the nearby area and planted in the rainy season of the same year (Uthairatsamee, 2004) where they were 1.28 m, 2.95 m, and 140.81 cm, respectively. These results probably caused by the different experimental site conditions, time of planting, quality of seedlings, and internal factors.

From Figure 1, in dry season, all Thai Neem progenies demonstrated few height increments but in the early rainy season, all Thai Neem progenies showed extreme height elongation, except progenies of Plus Tree No. 15. Comparing between progenies of Plus Tree Nos. 15 and 17, the average height of progenies of Plus Tree No. 15 after planting was longer than those of Plus Tree No. 17 but, after 12 months of planting, the average height growth of these progenies was not different. At the beginning of planting, progenies of Plus Tree No. 25 had the best height but at the age of 12 months, progenies of Plus Tree No. 1 showed the best height. These results showed that not only quality of seedlings but also the genetic factors affected on height increment of Thai Neem.

At the age of 12 months (Table 2), the best average height growth was detected in progenies of Plus Tree No. 1 (50.42 cm) followed by progenies of Plus Tree Nos. 23, 32, 33, and 25 (41.80, 39.50, 38.98, and 38.07 cm, respectively) but the poor height growths were found in progenies of Plus Tree Nos. 14, 15, and 17 (22.62, 23.55, and 23.30 cm, respectively).

The highly significant differences on

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Table 2. Mean and ranking of survival percentage, height, and diameter at ground level (Do) among 12-month-old Thai Neem progenies of 32 plus trees planted in Lad Krating Plantation, Chachoengsao. Values in the column followed by the same letter were not significantly different at the 0.05 level by Duncan's New Multiple Range Test

Progenies of Plus Tree No.	Survival		Height (m)		Do (mm)		Total
	Mean	Ranking	Mean	Ranking	Mean	Ranking	Ranking
23	95.14 a	2	41.86 b	2	6.49 b	3	7
1	88.89 abc	8	50.42 a	1	7.68 a	1	10
25	92.36 ab	6	38.07 bcde	5	6.42 b	2	13
32	93.06 ab	5	39.50 bc	3	6.00 bc	6	14
33	90.28 abc	7	38.98 bcd	4	5.96 bc	5	16
9	90.28 abc	7	35.70 cdefg	7	6.37 b	4	18
21	96.53 a	1	33.40 efghi	9	5.41 cdef	9	19
4	93.06 ab	5	34.53 defgh	8	5.92 bcd	7	20
38	96.53 a	1	32.20 fghij	10	5.06 defg	12	23
19	79.17 d	11	36.45 cdef	6	5.70 bcde	8	25
30	91.67 ab	7	31.69 fghijk	11	5.07 defg	11	29
36	96.53 a	1	30.37 hijk	19	5.08 defg	10	30
11	93.75 ab	4	31.37 ghijk	12	4.92 efgh	15	31
7	94.44 ab	3	30.92 ghijk	14	4.82 efgh	17	34
18	90.28 abc	7	30.66 hijk	17	4.96 efg	13	37
5	92.36 ab	6	30.55 hijk	18	4.92 efgh	14	38
12	95.14 a	2	29.58 hijk	21	4.84 efgh	16	39
29	94.44 ab	3	30.86 ghijk	15	4.68 fgh	22	40
34	92.36 ab	6	31.12 ghijk	13	4.65 fghi	24	43
37	89.58 abc	8	30.76 ghijk	16	4.76 efgh	19	43
26	93.75 ab	4	29.66 hijk	20	4.70 fgh	21	45
20	95.14 a	2	29.14 ijk	22	4.51 fghij	25	49
39	92.36 ab	6	29.07 ijk	23	4.70 fgh	20	49
2	84.72 bcd	9	28.26 ijkl	26	4.76 efgh	18	53
22	93.06 ab	5	28.36 ijkl	24	4.48 fghij	26	55
40	90.28 abc	7	28.35 ijkl	25	4.65 fghi	23	55
3	93.06 ab	5	26.60 klm	29	4.22 ghijk	27	61
24	92.36 ab	6	26.71 klm	28	4.13 ghijk	28	62
31	88.89 abc	8	28.12 jkl	27	3.98 hijk	29	64
15	90.97 ab	7	23.55 lm	30	3.62 jk	31	68
14	90.97 ab	7	22.62 m	32	3.47 k	32	71
17	81.25 cd	10	23.30 m	31	3.75 ijk	30	71

Table 3. Analysis of variance of survival percentage, height, and diameter at ground level (Do) of Thai Neem progenies of 32 plus trees planted in Lad Krating Plantation, Chachoengsao during the study period

Age	Source	Df	Survival percentage	Height	Do
0 month	Replications	15		20.92**	12.81**
	Progenies of Plus Tree	31		97.86**	32.26**
1 month	Replications	15	3.89**	24.94**	22.24**
	Progenies of Plus Tree	31	1.35^{ns}	97.49**	38.45**
2 months	Replications	15	1.72*	25.17**	18.92**
	Progenies of Plus Tree	31	1.61*	87.36**	34.04**
3 months	Replications	15	1.84*	21.20**	24.87**
	Progenies of Plus Tree	31	1.99*	66.39**	29.45**
4 months	Replications	15	2.82**	22.40**	29.93**
	Progenies of Plus Tree	31	2.24**	48.89**	21.39**
5 months	Replications	15	2.64*	24.84**	29.31**
	Progenies of Plus Tree	31	2.07*	38.07**	17.29**
6 months	Replications	15	2.95**	30.12**	30.26**
	Progenies of Plus Tree	31	2.16**	24.12**	14.50**
7 months	Replications	15	3.14**	43.84**	29.38**
	Progenies of Plus Tree	31	1.99*	15.01**	13.24**
8 months	Replications	15	3.15**	53.53**	31.05**
	Progenies of Plus Tree	31	2.08*	13.22**	11.50**
9 months	Replications	15	3.08**	51.58**	33.66**
	Progenies of Plus Tree	31	2.14**	12.83**	10.78**
10 months	Replications	15	3.40**	50.02**	33.67**
	Progenies of Plus Tree	31	2.11*	13.16**	10.53**
11 months	Replications	15	3.51**	48.42**	33.72**
	Progenies of Plus Tree	31	2.14**	13.00**	10.12**
12 months	Replications	15	3.50**	48.83**	33.21**
	Progenies of Plus Tree	31	2.09*	12.89**	9.78**

Remarks: ** = Highly significant differences at 99% confident limit

* = Significant differences at 95% confident limit

^{ns} = Insignificant differences

height growth among replications and progeny of plus trees were shown in Table 3. While, the significant differences of progeny of plus trees declined every month. The significant differences of replications increased from the age of 0-8 months because many site factors might cause the heterogeneity of replication such as slope, soil properties, erosion and ditches by water runoff, invasive weeds, etc. Then when the planting site conditions had been stabilized, the significant differences of replications were slightly decreased. During 0-5 months after planting, the progeny of plus trees or genetic factors had more effect on height growth than replications or planting site factors did, thereafter genetic factors had less effect due to the uneven site and planting site conditions of each replication.

Diameter at Ground Level Growth

In the present study, 12-month-old Thai Neem grown in the progeny trial were found to have less diameter at ground level growth (Do, 5.04 mm) than those grown in Ratchaburi with 4 x 4 m spacing (2.71 cm, Tiyanon, 1987), those planted in the international provenance trial, Kanchanaburi (2.48 cm, Sawatdee, 2003) and tea tree seedling grown in the nearby area and planted in the rainy season of the same year (20.39 mm, Uthairatsamee, 2004). The causes of these different results were perhaps by the difference of site and seedling qualities, time of planting, and genetic factors.

At the beginning (Figure 1), Do of progenies of Plus Tree No. 15 was bigger than those of Plus Tree No. 17, but at the age of 12 months, Do of these were not different. Furthermore, after planting, progenies of Plus Tree No. 25 were found to be bigger in Do but after 12 months of planting, progenies of Plus Tree No. 1 had the best diameter growth shown by the largest Do. Likewise the height growth, the quality of seedling and genetic factors might have some influences on diameter growth of Thai Neem.

At the age of 12 months (Table 2), progenies of Plus Tree No. 1 were found to have the greatest Do followed by progenies of Plus Tree Nos. 23, 25, 9, and 32 (6.49, 9.42, 6.37, and 6.00 mm, respectively). Similar to height growth, the poor Do growth were detected in progenies of Plus Tree Nos. 14, 15, and 17 (3.47, 3.62, and 3.75 mm, respectively).

The highly significant differences on Do among replications and progeny of plus trees were shown in Table 3. The trends of statistically differences of replications and progeny of plus trees on diameter growth were similar to those on height, that the significant differences of replications were increased from the age of 0-11 months because of the heterogeneity of replication and then when the planting site was settled, the significant differences of replications were slightly decreased. On the other hand, the significant differences of progeny of plus trees declined every month. From 1-3 months after planting, the progeny of plus trees or genetic factors

had more effect on height growth than replications or micro-environment factors, did thereafter genetic factors had less effect due to the greater effect of planting site conditions of each replication.

CONCLUSIONS

The study on effects of climatic factors on Thai Neem seedling found that both mean air temperature and amount of monthly rainfall had the negative influences on survival percentage but positive influences on height and diameter growth increments. Meanwhile, the significant differences of progeny of plus trees were increased by time after planting but lower than the significant differences of replications were. Thus, the replications or planting site factors had more effect on survival percentage than progeny of plus trees or genetic factors in almost all ages. On the other hand, during the dry season, the progeny of plus trees or genetic factors had more effect on growths than replications or micro-environment factors did, thereafter genetic factors had less effect than planting site factors due to the heterogeneity of planting site conditions of each replication. Progenies of Plus Tree Nos. 1, 9, 19, 23, 25, 32, and 33 showed good growths but progenies of Plus Tree Nos. 2, 17, and 19 had poor survival percentage. Thus, at the early growth periods, progenies of Plus Tree Nos. 1, 9, 23, 25, 32, and 33 were superior progenies when planted in Lad Krating Plantation, Chachoengsao.

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