Original article

Provenance Trial of *Melaleuca cajuputi* Powell at Khuan Khreng Peat Forest, Nakhon Si Thammarat Province, Thailand

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ABSTRACT

The objectives of this study were to compare height, diameter at ground level, survival rate, and physiological development of *Melaleuca cajuputi* Powell grown from seeds collected from 10 different provenances in southern Thailand that planted at Chaipattana foundation area, Khuan Khreng Peat forest. A Randomized Complete Block Design (RCBD) was applied with 3 replication (blocks), each containing the 10 provenances. Twenty-five seedling, with 1 m x 1 m spacing were planted per provenance within each block. The seedling growth rate, survival rate and physiological development were observed in each plot after 1 month, 6 months, and 12 months. This study suggested that there were a significant differences in the height growth among the provenances at ages 1 month, 6 months, and 12 months ($p < 0.01$), with the heights of 62.69 cm, 121.93 cm, and 181.15 cm, respectively. There was also a significant difference in the diameter at ground level among the provenances at ages 1 month, 6 months, and 12 months ($p < 0.01$), with the average diameter values of 0.33 cm, 1.52 cm, and 3.11 cm, respectively. However, the survival rates were not significantly different. Regarding the physiological development, it was found that leaf areas and chlorophyll concentrations were significantly different among provenances ($p < 0.01$). The provenances were scored and ranked for the most appropriate seed sources, based on the findings on growth rate, survival rate and physiological development. The top three suitable *M. cajuputi* seed sources were Nakhon Si Thammarat, Chumphon, and Satun.

Keywords: *Melaleuca cajuputi* Powell, provenance trial, growth, physiology, Khuan Khreng Peat Forest

INTRODUCTION

Melaleuca cajuputi Powell, a tree species within the family "Myrtaceae", is an important economic tree, with approximately 250 species (Brophy and Doran, 1996) recorded in this genus. In Thailand, *M. cajuputi* is the only species recorded. *M. cajuputi* grows well in a wide range of environmental conditions including high acid soil, saline, waterlogged soil and arid soil (Sasaki, *et al.*, 1995). *M. cajuputi* has the adaptability, this species displays different morphological characteristics in response to its habitat conditions. *M. cajuputi* is characterized as a pioneer species and requires high light Demand It has small and light seeds with high growth potential. Seeds can disperse and dominate degraded peat swamp forests which are commonly found in degraded peat lands of southern Thailand. There was 343,441.33 rais in south region and 3,578.13 rais in east region of Thailand which had found peat swamp forest with *M. cajuputi*. (Chukwamdee *et al*., 1999)

Parts of the *M. Cajuputi* tree are widely utilized. The leaves, for example, are used to make essential oil, called Cajuput oil, which has a similar odor to camphor; and wood is used as building materials and over-cutting of this species may result' in However, long-term forest degradation. Considering to tree planting, same species with different provenance shows different growth performance. This is very important for forest plantation. Therefore, provenance trial of *M. cajuputi*. It is also necessary to select the proper provenance, considering shape, weight, and quality of oil component in leaf, to ensure planting in Khuan Khreng peat swamp forest is eligible, and also to maximize forest resource utilization and adequate for need of use. This led to the Chaipattana Foundation in Thailand to initiate the "Integral and sustainable usages of *M. cajuputi* Powell" Project, to maximize the benefits from forest resources while ensuring sustainable supplies. The Project involves research on sustainable utilization of *M. cajuputi* under the principle of economic, social and environmental sustainability. In addition, the project generates additional income for the communities, and this also

encourages forest conservation for direct and indirect uses.

This study collected *M. cajuputi* seed from several habitats in the south of Thailand and planted them as provenance trials at Khuan Khreng Peat Forest of the Chaipattana Foundation's area. The objectives of this study were to investigate the growth, survival rate and physiological characteristics of *M. cajuputi*; compare these characteristics of the plants from different provenances; and recommend the most suitable provenances for planting at Khuan Khreng Peat Forest to support sustainable usages in term of economy, conservation and restoration, and development of good quality strains (shape and quantity) for commercial scale plantations in the future

MATERIALS AND METHODS

The study methodology aspects are outlined below.

1. Project area: The study was conducted in the Chaipattan Foundation's area where permission was granted by the Royal Forest Department to use 1,997 rai under the "Integral and sustainable usages of *M. cajuputi* Powell" Project in Karaket Sub-district, Chain Yai District, Nakhon Si Thammarat Province.

2. Provenance: *M. cajuputi* seeds were collected from 10 provenances in southern Thailand to experiment at the Chaipattana Foundation's area under the "Integral and sustainable usages of *M. cajuputi* Powell" Project:

Provenance 1 Thai Mueang District, Phang Nga Province (Khao Lampi-Hat Thai Mueang National Park)

Provenance 2 Thalang District, Phuket Province (Sirinat National Park)

Provenance 3 Khuan Niang District, Songkhla Province (Thungbangnok-ok National Reserved Forest)

Provenance 4 Mueang District, Krabi Province (Hat Noppharat Thara-Mu Koh Phi Phi National Park)

Provenance 5 Mueang District, Satun Province (old airport area)

Provenance 6 Mueang District, Trang Province (Thung Khai)

Provenance 7 Lamae District, Chumphon Province (Maejo University)

Provenance 8 Phynphin District, Surat Thani Province (Tha Sathon Sub-district)

Provenance 9 Mueang District, Nakhon Si Thammarat Province (Tha Ruea Sub-district)

Provenance 10 Mueang District, Narathiwat Procince (Kaluwo Nuea Sub-district)

The seeds were planted in July 2016 and the seedlings were transplanted in March 2017.

3. Experimental Design: All the *M. cajuputi* trees and seedlings growing naturally in the experimental area were cleared prior to the study. Three blocks (replications) of 25 m x 10 m experimental areas (a total area of 25m x 30 m) for *M. cajuputi* from the 10 provenances were set up using a Randomized Complete Block Design (RCBD) (Figure 1). Each experimental area consisted of 5 m x 5 m plots, one for each of the provenances. Twenty-five plants from the same provenance were planted in each plot at 1 m × 1 m. spacing

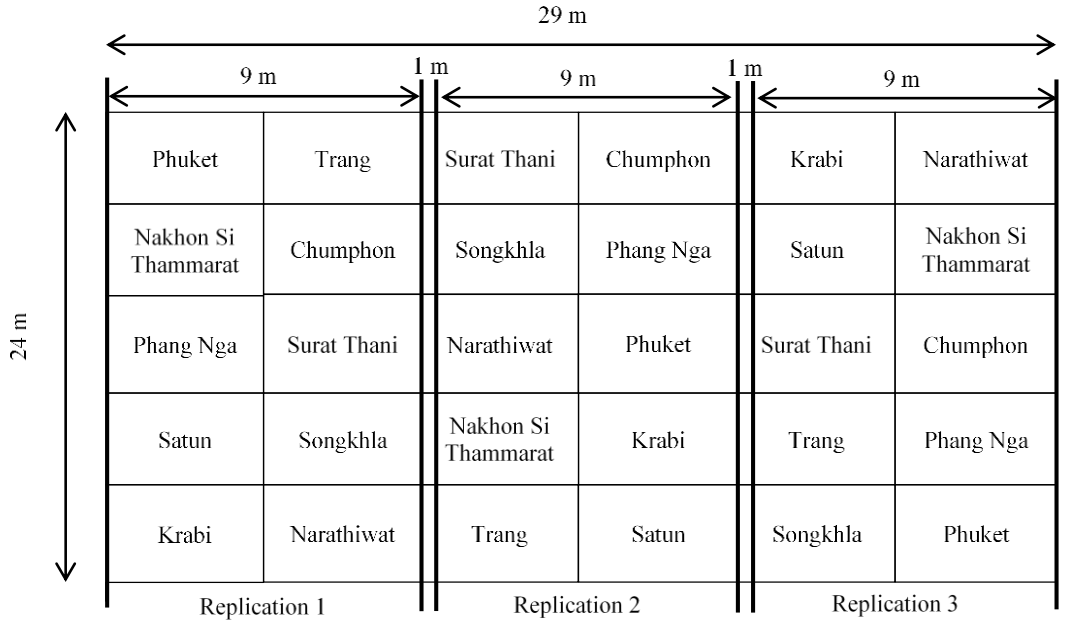

Figure 1 Layout of the experiment plots and blocks for the provenance trial of *M. cajuputi* Powell at Khuan Khreng Peat Forest, Nakhon Si Thammarat Province

4. Data Collection: The following data were collected.

4.1 Growth: height (Ht) and the diameter at ground level (D_0) of the *M. cajuputi* seedling or saplings were collected every 6 months for 1 year (from April 2017-April 2018).

4.2 Physiological characteristics:

4.2.1 Chlorophyll concentrations in leaves were estimated using allometric equations. Approximately 20 leaf samples of different color shades (from light to dark) were collected. For each leaf, 0.758 cm^2 of leaf were sampled and chopped into small pieces for chlorophyll extraction in the laboratory according to Moran (1982). The samples were placed in sealed glass vials with 8 milliliters of DMF (N, N-Dimethyformamide) on and kept in the dark at 4°C for 48 hours in the laboratory. The pigment solutions were measured for absorbance (A) at 2 wavelengths (6 4 7 and 6 6 4 nm) with a spectrophotometer. The following equations were used for chlorophyll estimation:

$$\text{Chl a} = (-2.99*A_{647}+12.64*A_{664}) * \text{Vol}/(\text{Dilution}*\text{Area}*100) \quad (1)$$

$$\text{Chl b} = (23.26*A_{647}-5.6*A_{664}) * \text{Vol}/(\text{Dilution}*\text{Area}*100) \quad (2)$$

$$\text{Chl total} = \text{Chl a} + \text{Chl b} \quad (3)$$

where Chl a = Chlorophyll a concentration (mg dm^{-2})
Chl b = Chlorophyll b concentration (mg dm^{-2})
Chl total = Total chlorophyll concentration (mg dm^{-2})
A_{647} = Absorbance at wavelength 647 nm
A_{664} = Absorbance at wavelength 664 nm
Vol = Volume of DMF used for extraction (Ml)
Dilution = Dilution ratio
Area = Area of the extracted leaves (cm^2)

Leaf greenness was measured using chlorophyll meter (SPAD – 502 model). Leaf samples of the plants in the middle of each plot were chosen. Three plants were selected and 3 leaves from each plant were measured. Mature leaves from the middle of the canopy which were exposed to light were selected. Leaves with signs of disease and damage by insects were avoided. Five measurements were made on each leaf. The averages of the 5 measurements were calculated and used as the greenness level of the leaf for the assessment of the relationship between the greenness (unit: SPAD) and chlorophyll concentration. The greenness' unit is "unit SPAD".

4.2.2 Leaf area: leaf samples were collected from 3 plants in the middle of the plot. Three leaves were collected from each tree (3 replications). Leaves with signs of disease and damage by insects were avoided. Leaf areas were calculated using the dot grid method, where leaf area is equal to the number of dots counted and calibrated with numbers of grids in the table.

5. Provenance scoring: data on growth, survival rate, leaf area and chlorophyll concentration were used for provenance scoring. The highest scores for each trait were given using paired comparison and were not equal as follows:

Height - Highest score is 25
Diameter at ground level - Highest score is 25
Survival rate - Highest score is 40
Leaf area - Highest score is 5
Mean chlorophyll concentration - Highest score is 5

The highest scores of each trait were given sub-scores according to % superiority of each tree over the average of total tree (% superiority) using to the following equation:

$$\% \text{ superiority} = [(y_i-y')/y'] \times 100 \quad (4)$$

Where y_i = average value of M. *cajuputi* from the *i*th provenance.
y' = average value of M. *cajuputi* from all the provenances.

When each trait of *M. cajuputi* was scored, the provenance with the total highest score deemed to be the most suitable provenance for *M. cajuputi* planted at Khuan Khreng Peat Forest.

6. Data Analysis: The number of plants that survived in each plot were used for the calculation of mean survival rate, average height, and mean diameter at ground level for each provenance. The Relative Growth Rate (RGR) of average diameter at ground level and mean height were estimated using Kasemsap's formula (1995):

$$RGR = (\ln W2-\ln W1)/(t_2 - t_1) \quad (5)$$

where RGR is Relative Growth Rate of diameter at ground level or height.
W1 is Diameter at ground level or height from the first measurement.
W2 is Diameter at ground level or height from the second measurement.
$t_2 - t_1$ is the time interval between the measurements.
ln is natural logarithm.

Chlorophyll concentrations, leaf areas and average chlorophylls of each provenance were assessed. Relationships between greenness and chlorophyll concentration were analyzed. Analysis of variance (ANOVA) was used to compare the statistical differences among all the traits. If there was a significant difference, the average values were grouped using Duncan's Multiple Range Test at 95% confident level.

RESULTS AND DISCUSSION

Survival Rate

Survival rate of the seedlings at age 1 month of all the provenances were 100%, except for seedlings from Sonkhla and Krabi which had an average survival rate of 98.67 ±2.31. At age 6 months, the saplings from Nakhorn Si Thammarat and Narathiwat had a survival rate of 100%. At age 12 months the saplings from Nakhorn Si Thammarat had a survival rate of 98.67±2.31%. Statistical analysis suggested that there was no significant difference among survival rates of all the provenances at age 1 month, 6 months and 12 months (Table 1). The top three provenances with the highest survival rate were Nakhon Si Thammarat, Satun and Narathiwat. The lowest survival rate, or poorest ability to adjust to the conditions of the plantation, was the Phuket provenance. The results of this study were consistent with those of the experiment in degraded peat forest by Nuyim (1998), which showed that *M. cajuputi* from Narathiwat, Nakhon Si Thammarat and Phatthalung had the highest growth compared to seedling from other provenances. Hence, seedling from Nakhon Si Thammarat provenance which had similar environmental conditions to the planting area were best adopted, and modified its genetic to fit in the new environment through natural selection and artificial selection (Tangmitcharoen, 2014). The traits of the plant might be favorable or non-favorable depending on their adaptability when initially planted and the provenance of the seeds (Eldridge *et al*., 1997)

Table 1 Survival rate of *M. cajuputi* Powell of seedling/saplings at age 1 , 6 and 12 months from 10 provenances planted at Khuan Khreng Peat Forest, Nakhon Si Thammarat Province with mean ±SD (standard deviation).

	Provenances	Survival rate (%) ± SD		
		1 month	6 months	12 months
1	Phang Nga	100.00±0	89.33±6.11	82.67±12.22
2	Phuket	100.00±0	96.00±6.93	76.00±12.00
3	Songkhla	98.67±2.31	89.33±6.11	88.00±8.00
4	Krabi	98.67±2.31	89.33±4.62	84.00±4.00
5	Satun	100.00±0	97.33±4.62	97.33±4.62
6	Trang	100.00±0	97.33±4.62	92.00±4.00
7	Chumphon	100.00±0	96.00±4.00	93.33±6.11
8	Surat Thani	100.00±0	90.67±6.11	90.67±6.11
9	Nakhon Si Thammarat	100.00±0	100.00±0	98.67±2.31
10	Narathiwat	100.00±0	100.00±0	97.33±4.62
	F-value	**1.00^{ns}**	**2.26^{ns}**	**3.23^{ns}**

Remark: ns = non-significant difference ($p>0.05$) between provenances

Height and diameter at ground level

Mean heights and diameters at ground level of seedlings at ages 1 month, 6 months and 12 months from the 10 provenances were significantly different ($p<0.01$). At age 1 month, the seedlings from Trang displayed the highest cumulative growth with the height of 81.77 cm and the diameter at ground level of 0.44 cm. At age 6 months, saplings from Narathiwat had the highest cumulative growth with the height of 135.52 cm and the diameter at ground level of 1.89 cm.

Chumphon, Nakhon Si Thammarat and Satun Provenances displayed the highest growth at age 12 months with the average heights of 198.65cm, 195.10cm, and 191.61cm, respectively. Saplings at age 12 months from Phuket had the lowest height of 155.74cm. The top 3 provenances with the biggest diameter at ground level were Chumpon (3.57cm), Nakhon Si Thammarat (3.56cm) and Narathiwat (3.47cm). Phuket provenance also had the smallest diameter at ground level of 2.35cm (Table 2). Nuyim (2001) conducted experiments with 13 peat swamp plant species in degraded peat swamp forests and concluded that *M. cajuputi* had the best growth in terms of diameter and height, particularly the *M. cajuputi* at age 12 months planted at 2 m × 2 m spacing which had the mean height of 140 cm and diameter at ground level of 2.1 cm. The average growth of *M. cajuputi* in the Nuyim

(2001) study was lower than that of the provenance trial in this study.

Regarding relative Growth Rate (RGR) of height and diameter at ground level, the study revealed that average RGR during the first 6 months period were significantly different ($p<0.01$). Nakhon Si Thammarat and Chumphon had the highest RGRs with heights of 0.25 and 0.20 respectively; and diameters at ground level of 0.31 and 0.30, respectively. For the second 6 months period, there was also a significant different among the RGRs ($p<0.01$). In most of the provenances, the RGRs of the first 6 months were higher than RGRs of the second 6 months (Table 3). It was found that there was 850 mm precipitation in April- October 2018, which was less than October 2017- April 2018, measured 2,103 mm. However, the study reported that the RGR was higher in April-October 2017 than in October 2017-April 2017. It reflected that the lower precipitation would result in higher RGR. The growth rate of *M. cajuputi* in this study would be high at seedling stage and would be gradually reducing as it grows. Therefore, it is necessary to continue studying and monitoring in long term, since this study only covered 1 year of period, so that the more precise growth pattern would be realized.

Relationship between greenness and chlorophyll concentration

Greenness (unit: SPAD) and chlorophyll concentration (chlorophyll a, chlorophyll b and total chlorophyll) displayed a linear relationship (Figure 2). Replacing "X" in the linear equation of the greenness-chlorophyll relationship with the SPAD reading and assessing the linear relationship between SPAD Unit and chlorophyll of *M. cajuputi* Powell from each provenance, showed that chlorophyll concentrations increased with increase in SPAD (Table 4)

The provenances with the highest SPAD reading and chlorophyll concentration were Surat Thani, Chumphon and Songkhla (Table 4). The relationship between greenness and chlorophyll concentration in this study was consistent with the results of the study by Marquard and Tipton (1987) who reported a linear relationship between greenness and chlorophyll in 12 plant species, the study of 8 species of tropical and sub-tropical fruits by Schaper and Chacko (1991) and the study of southern langsat and rambutan in Thailand by Chanaweerawan and Sdoodee (2002). However, the results from this study were different from those of the study by Diloksumpun and Duriya (2005) who reported a non-linear relationship described by quadratic equation between greenness and chlorophyll concentration of 13 species of dry evergreen and mixed deciduous plants. That study revealed that there was no significant difference between greenness and chlorophyll concentration. Greenness and chlorophyll concentration are only two physiological characteristics that have been demonstrated to be highly correlated with tree growth and survival. However, other environmental factors which can greatly contribute to growth should also be considered.

Leaf Area

This study suggested that there was a significant difference in leaf areas and mean chlorophyll concentrations among the provenances ($p<0.01$). Seedlings from Songkhla provenance had the highest chlorophyll concentration of 1.96 mg/ dm^2 followed by Nakhon Si Thammarat and Satun provenances with values of 1.81 mg/dm^2 and 1.76 mg/dm^2, respectively, while Phang Nga provenance displayed the lowest chlorophyll concentration with value of 1.32 mg/dm^2 (Table 5). Chlorophyll concentration indicates the amount of chlorophyll in leaves, an indicator of photosynthetic ability which can refer to food production and growth of *M. Cajuputi* in different provenances. The analysis of relationship between chlorophyll concentration and growth revealed a positive linear relationship ($R = 0.394$) with higher R value than the relationship between leaf area and growth ($R = 0.371$). The trend from this study was similar to that of the study by Yansarn *et al.* (2015). Yansarn *et al.* (2015) reported that average chlorophyll and production had positive linear relationship ($R=0.671$) with higher R score than linear relationship between leaf area and production ($R=0.578$). However, chlorophyll concentrations and production of 4 strains of cassava (Kaset 50, Rayong-11, Rayong 5 and Huaybong 80) were not significantly different.

The most suitable provenances were assessed using scoring of diameter at ground level, height, survival rate, leaf area and chlorophyll concentration. The 3 provenances that received the highest scores, and hence the most suitable seed sources for planting at Khuan Khreng Peat Forest, were Nakhon Si Thammarat, Chumphon and Stun, respectively (Table 6).

Table 2 Growth (height and diameter) of *M. cajuputi* Powell at age 1, 6 and 12 months with mean ±SD (standard deviation).

	Provenance	1 Month		6 Months		12 Months	
		Height (cm)	Diameter at Ground level (cm)	Height (cm)	Diameter at Ground level(cm)	Height (cm)	Diameter at Ground level (cm)
1	Phang Nga	58.64^{d} ±8.12	0.32^{d} ±0.20	118.41^{abc}±29.35	1.39^{b}±0.43	189.25^{cd}±48.89	2.85^{abc}±1.04
2	Phuket	71.59^{e}±10.87	0.33^{d}±0.07	112.41^{a}±36.75	1.19^{a}±0.59	155.74^{a}±50.07	2.35^{a}±1.26
3	Songkhla	68.95^{e} ±10.60	0.32^{cd} ±0.08	117.36^{ab}± 27.80	1.39^{b}±0.48	174.89^{bc}±49.84	2.83^{ab}±1.19
4	Krabi	78.25^{f}±13.13	0.37^{e} ±0.07	116.22^{ab}±27.38	1.37^{b}±0.53	174.92^{bc}±47.81	3.41^{cd}±3.88
5	Satun	78.05^{f}±10.55	0.37^{e} ±0.07	126.03^{bc}±24.63	1.70^{d}±0.40	191.61^{cd}±32.26	3.20^{bcd}±0.74
6	Trang	81.77^{g} ±11.59	0.44^{f} ±0.05	123.44^{bc}± 27.30	1.47^{b}±0.45	161.30^{ab}±49.17	2.66^{a}±1.07
7	Chumphon	37.60^{b} ±10.10	0.26^{b}±0.06	128.93^{cd}± 26.48	1.70^{d}±0.46	198.65^{d}±41.77	3.57^{d}±1.08
8	Surat Thani	55.31^{c} ±9.16	0.29^{c}±0.05	122.38^{abc}±29.76	1.46^{bc}±0.57	187.29^{cd}± 42.15	3.20^{bcd}±1.18
9	Nakhon Si Thammarat	26.49^{a} ±5.84	0.23^{a} ±0.04	118.55^{abc}±31.38	1.59^{cd}±0.53	195.10^{d}±42.15	3.56^{d}±0.96
10	Narathiwat	70.23^{e}±9.48	0.37^{e} ±0.08	135.52^{d}±22.65	1.89^{f}±0.45	182.70^{cd}± 38.25	3.47^{d}±1.19
	F-value	**249.75^{**}**	**16.00^{**}**	**4.04^{**}**	**12.50^{**}**	**6.19^{**}**	**5.00^{**}**

Remark: ** = highly significant difference ($p<0.01$).The different superscript letters indicate significant differences among the provenances according to ANOVA F- test followed by Duncan's Multiple Range Test ($p<0.05$).

Table 3 Relative growth rate of *M. cajuputi* Powell during the first 6 months of the experiment (April-October 2017), and the second 6 months (October 2017 to April 2018) with mean ±SD (standard deviation).

	Provenances	1st six month old		2nd six month old	
		Height (cm)	Diameter at Ground level (cm)	Height	Diameter at Ground level
1	Phang Nga	0.11^{c} ±0.06	0.24^{b} ±0.08	0.08^{cd}±0.04	0.11^{bcd}±0.06
2	Phuket	0.06^{a} ±0.07	0.18^{a} ±0.12	0.05^{ab}±0.06	0.11^{bcd}±0.13
3	Songkhla	0.09^{b} ±0.05	0.24^{b} ±0.07	0.06^{bc}±0.04	0.11^{bcd}±0.07
4	Krabi	0.06^{a} ±0.04	0.20^{a} ±0.07	0.06^{bc}±0.06	0.13^{cd} ±0.09
5	Satun	0.08^{ab}±0.04	0.25^{bc}±0.05	0.07^{cd}±0.03	0.10^{a} ±0.05
6	Trang	0.06^{a} ±0.05	0.19^{a} ±0.06	0.04^{a} ±0.06	0.08^{a} ±0.08
7	Chumphon	0.20^{e} ±0.04	0.30^{d} ±0.05	0.07^{cd}±0.05	0.12^{bcd}±0.06
8	Surat Thani	0.13^{d} ±0.06	0.25^{bc}±0.08	0.07^{cd}±0.05	0.14^{d} ±0.08
9	Nakhon Si Thammarat	0.25^{f} ±0.05	0.31^{d} ±0.06	0.09^{d} ±0.07	0.14^{d} ±0.08
10	Narathiwat	0.11^{c} ±0.04	0.27^{c} ±0.06	0.05^{ab}±0.04	0.10^{ab} ±0.08
	F-value	**107.10^{**}**	**26.82^{**}**	**5.77^{**}**	**4.09^{**}**

Remark: ** = highly significant difference ($p<0.01$). The different superscript letters indicate significant differences among the provenances according to ANOVA F-test followed by Duncan's Multiple Range Test ($p<0.05$).

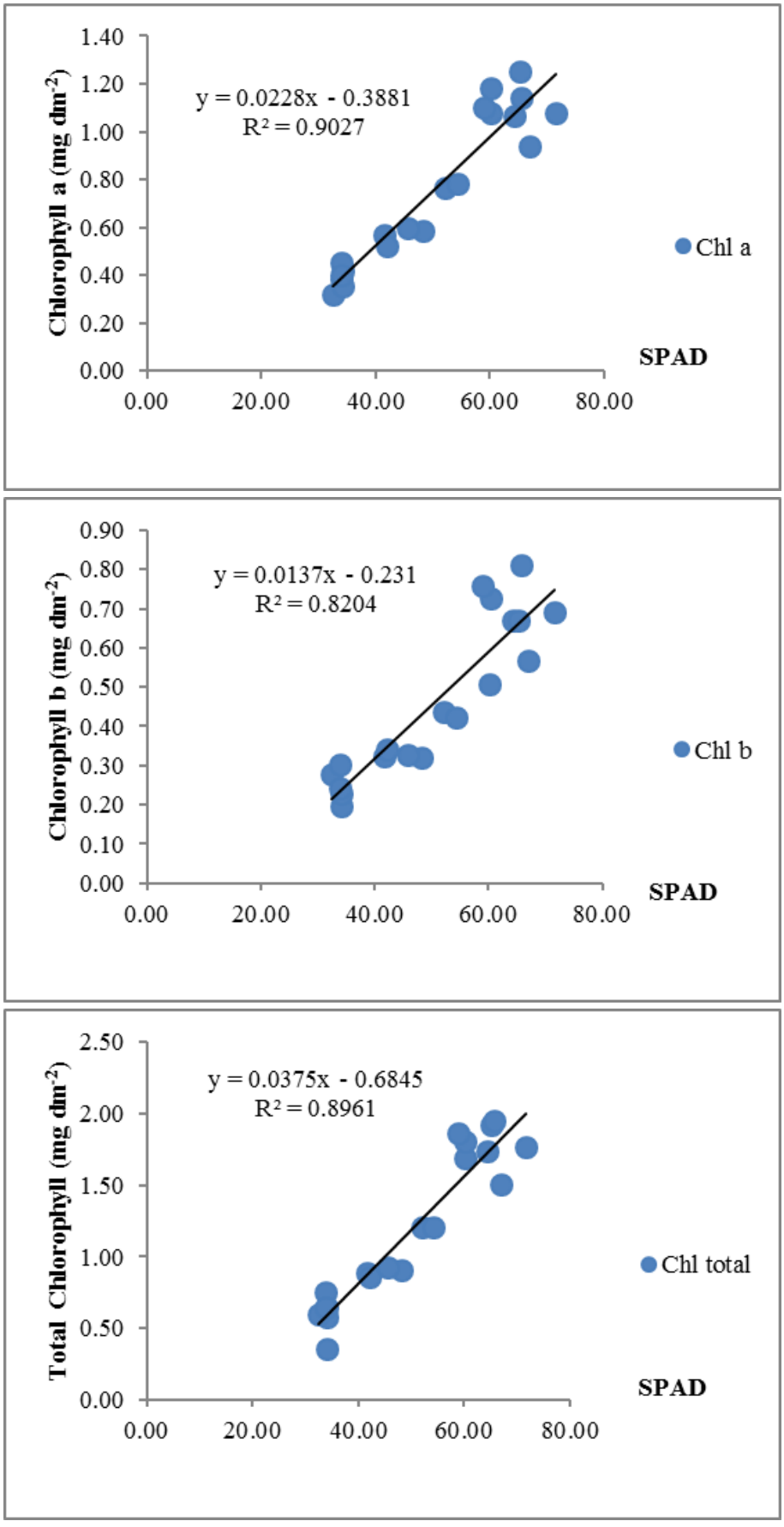

Figure 2 Relationship between greenness (SPAD reading) and Chlorophyll a, Chlorophyll b and Total

Table 4 Chlorophyll content and greenness (SPAD Reading) among the provenances of *M. cajuputi* Powell SD is standard deviation.

	Provenance	SPAD Reading ±SD	Chlorophyll a ±SD (mg dm^{-2})	Chlorophyll b ±SD (mg dm^{-2})	Total Chlorophyll ±SD (mg dm^{-2})
1	Phang Nga	56.32±6.31	0.90±0.14	0.55±0.07	1.45±0.22
2	Phuket	57.95±4.92	0.93±0.11	0.57±0.05	1.50±0.17
3	Songkhla	59.57±7.06	0.97±0.16	0.59±0.08	1.56±0.24
4	Krabi	54.86±6.09	0.86±0.14	0.53±0.07	1.40±0.21
5	Satun	58.09±6.58	0.94±0.15	0.57±0.07	1.51±0.22
6	Trang	58.12±8.84	0.94±0.94	0.57±0.10	1.51±0.30
7	Chumphon	59.84±4.95	0.98±0.11	0.59±0.06	1.57±0.17
8	Surat Thani	60.90±5.79	1.00±0.13	0.60±0.07	1.60±0.20
9	Nakhon Si Thammarat	58.89±5.66	0.95±0.13	0.58±0.06	1.53±0.19
10	Narathiwat	56.61±6.72	0.90±0.15	0.55±0.08	1.46±0.23
	F-value	**2.22^{ns}**	**2.20^{ns}**	**2.17^{ns}**	**2.22^{ns}**

Remark: ns = non-significant difference (p>0.05)

Table 5 Average (±SD) leaf areas and chlorophyll concentrations of *M. cajuputi* Powell leaves from the 10 provenances. SD is standard deviation.

	Provenance	Chlorophyll concentration (mg dm^{-2})	Average leaf areas (dm^2)	Chlorophyll per Leaf areas (mg dm^{-2})
1	Phang Nga	1.45±0.22	0.92^{ab}±0.24	1.32^{a}±0.31
2	Phuket	1.50±0.17	0.89^{a}±0.38	1.36^{a}±0.49
3	Songkhla	1.56±0.24	1.25^{e}±0.30	1.96^{c}±0.42
4	Krabi	1.40±0.21	1.10^{cde}±0.20	1.54^{ab}±0.31
5	Satun	1.51±0.22	1.17^{de}±0.23	1.76^{cd}±0.34
6	Trang	1.51±0.30	0.99^{abc}±0.25	1.51^{ab}±0.45
7	Chumphon	1.57±0.17	1.04^{abcd}±0.30	1.61^{ab}±0.29
8	Surat Thani	1.60±0.20	1.06^{bcd}±0.23	1.70^{bc}±0.32
9	Nakhon Si Thammarat	1.53±0.19	1.17^{de}±0.26	1.81^{bc}±0.37
10	Narathiwat	1.46±0.23	1.03^{abcd}±0.28	1.52^{ab}±0.42
	F-value	**2.22^{ns}**	**4.77****	**4.26****

Remarks: ** = highly significant difference (p<0.01); ns = non-significant difference (p>0.05)
Different superscript letters indicate significant difference among the provenances according to ANOVA – F- test followed by Duncan's Multiple Range Test, (p<0.05).

Table 6 Scoring and ranking of *M. cajuputi* Powell provenances using data on growth (height and diameter at ground level), survival rate average leaf areas and chlorophyll concentration per leaf area.

	Provenance	Score					
		Height	Diameter at ground level	Survival rate	Average leaf areas	Chlorophyll per leaf areas	Total
1	Nakhon Si Thammarat	23	25	40	4	4	96
2	Chumphon	25	25	31	3	3	87
3	Satun	21	18	38	4	4	85
4	Narathiwat	16	23	38	2	2	81
5	Surat Thani	19	18	27	3	3	70
6	Songkhla	12	10	22	5	5	54
7	Krabi	12	22	15	3	2	54
8	Phang Nnga	20	11	13	1	1	46
9	Trang	4	7	29	2	2	44
10	Phuket	1	1	1	1	1	5

CONCLUSION

12 months saplings from Chumphon provenance had the highest height and diameter at ground level, while those from Nakhon Si Thammarat had the highest survival rate. In contrast, saplings from Phuket provenance had the lowest height, diameter at ground level and survival rate. The physiological analysis suggested that Surat Thani provenance had the highest mean total chlorophyll concentration. Songkhla provenance had the highest average leaf area and chlorophyll concentration. In conclusion, the top 3 most appropriate sources of *M. cajuputi* seedlingfor planting at the Chaipattana Foundation's area were Nakhon Si Thammarat, Chumphon and Satun, due to good growth and relatively high survival rates.

RECOMMENDATION

This provenance trial of *M. cajuputi* Powell only covered growth parameters and some physiological characteristics up to age 12 months, and the results had high variation. Therefore, further long-term monitoring assess for the most suitable provenances of *M. cajuputi*, are recommended. Moreover, further studies should be conducted on the benefits and other characteristics of *M. cajuputi* from the most suitable provenances suggested in this study, to further develop diverse and high quality products from *M. cajuputi*.

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