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Suitability of Seven Oil Yielding Australian Tree Species in Bukidnon, Philippines

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ABSTRACT

The suitability of seven Australian essential oil producing trees in the Philippines was tested in order to identify the candidate species for plantation establishment. Percent survival, average stem diameter, total height, total biomass and essential oil percentage were used as indicators. Survival ranged from 40% to 91.25% while stem diameter and total height were from 25 to 40 cm and 25 to 35 m, respectively. Total biomass ranged from 100 to 1200 gcm^{-3} whereas percent oil yield from the leaves was from 0.2 to 3.4%. If the main purpose of plantation establishment is for wood and timber production, Corymbia citriodora (Hook.) K.D. Hill & L.A.S. Johnson is the candidate species because of its stem volume. But if the main consideration is for essential oil production, Eucalyptus staigeriana F. Muell. ex Bailey is the species of choice because it produced as much as 3.4% of essential oil at 30 months of age.

Keywords: *Corymbia citriodora, Eucalyptus staigeriana, essential oil, percent survival, stem diameter, total biomass*

INTRODUCTION

Essential oils are used extensively in the perfumery, cosmetic, pharmaceutical and food industries (Bakkali *et al*. 2008) because of the presence of phenols, aldehydes and alcohols. Some have cytotoxic activities (Bruni *et al*. 2003, Sacchetti *et al*. 2005) that could be harnessed in the manufacture of biopesticides. Overall, this industry has an accumulated value of close to USD 24 billion worldwide (Govindasamy *et al*. 2013).

The Philippines is not a major player in the essential oil production. Only lemon grass (*Cymbopogon flexuosus* [Steud.] Wats.), vetiver grass (*Vetiveria zizaniodes* [L.] Nash), patchouli (*Pogostemon cablin* Benth), and *ylang–ylang* (*Cananga odorata* [Lam.] Hooker F. & Thomas) are commonly utilized. In order to meet the domestic demand for essential oil, the country imports processed essential oil from China, Australia and India (BETP–DTI 2000). In 2011 alone, the country imported about USD 15,163,775 worth of processed essential oil products (Comtrade 2010). In order to augment the essential oil shortage of the country, several field trials using seven essential oil yielding tree species from Australia were established in Mindanao in 2006. Being new to the site, their suitability to the site was still questionable. Besides determining their survival and growth performance, essential oil production was also evaluated. From this, candidate species for plantation establishment were identified.

METHODOLOGY

Site Characteristics and Location

The study was conducted in Bukidnon Province, Mindanao between April to August, 2009. One site was in Imbayao, Malaybalay City and the other was in Dahilayan, Manolo Fortich, Bukidnon (Figure 1). The Imbayao site was at the northern part while the Dahilayan site was at the southern part of the Mount Kitanglad Range Nature Park (MKRNP) buffer zone. Table 1 shows the physical characteristics of the two sites. The two sites were practically similar in elevation, annual temperature, amount of rainfall, and soil type. Each plot had 16 trees with planting distance of 2 m between trees along the rows, and 2.5 m between rows.

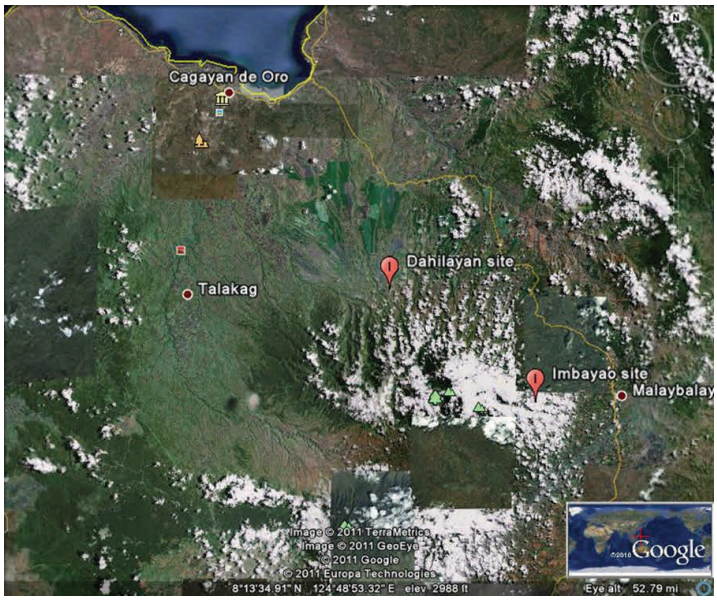

Figure 1. Location map of the two sites.

Sample species

Seven essential oil producing species from Australia were used in the study. These species were: 1) *Corymbia citriodora* (Hook.) K.D. Hill & L.A.S. Johnson; 2) *Melaleuca cajuputi*

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Table 1. Site characteristics and description.

Site Characteristic	Imbayao Study site	Dahilayan Study site
Location	125^0 51' 50" E ; 8^0 6' 12" N	124^0 51' 03" E ; 8^0 14' 24" N
Aspect	Southern Part	Northern part
Elevation (masl)	1293	1100
Temperature (°C)	18.0 to 30	18.0 to 30
Rainfall (mm)	800 to 3000	800 to 3000
Soil type	clay loam	clay loam
Soil pH	4.5	5.2
Soil organic matter (%)	3.80	6.75
Nitrogen (%)	1.90	3.37
Phosphorus (ppm)	3.50	1.90
Potassium (c–mol/kg)	0.34	0.14

Source: DENR 2003

subsp *cajuput* Powell; 3) *Melaleuca cajuputi* subsp *platyphylla* Powell; 4) *Eucalyptus staigeriana* F. Muell.ex Bailey; 5) *Leptospermum petersonii* F.M. Bail.; 6) *Melaleuca quinquenervia* Smith; and 7) *Melaleuca ericifolia* (Cav.) S.T. Blake. The wildlings were 30 months old during measurement. Table 2 shows the characteristics of the seven essential oil producing species grown in Bukidnon.

Survival and Growth Performance

Percent survival and growth performance including base diameter (measured 30 cm from the ground), total height (measured 30 cm from ground level to the top of the crown) and biomass production were measured. Biomass measurements were conducted following Chojnacky (1984) discussion using four randomly selected trees in every 32 m^2 plot. The trees were cut down at 30 cm from the base, the leaves, twigs (<5 mm diameter), and woody materials (*e.g.*, stem and branches >5 mm diameter) were segregated and weighed. Five percent of the fresh leaves, twigs, and woody materials from each tree were collected, labeled, and were brought to the laboratory for oven drying (DX–58 American Standard). Oven dried densities were determined and total biomass was computed. Measurements were replicated five times.

Table 2. Characteristics of the seven essential oil producing species grown in Bukidnon.

Species	Native Range	Growth Habit
Corymbia citriodora	Queensland, Australia	Fast growing medium to large size tree reaching a height of 25 to 35 m*
Eucalyptus staigeriana	Northern Queensland and Eastern Australia	Fast growing small to medium size tree or shrub reaching a height up to 9 m in good soil condition ****
Leptospermum petersonii	Northern New South Wales and Southern Australia	Fast growing multi–stemmed shrub reaching a height of up to 7 m in good soil condition ****
Melaleuca caupiti subsp *cajuput*	Northwestern Australia	Fast growing small to medium size tree reaching a height of up to 25 m in good soil condition*
Melaleuca cajuputi subsp *platyphylla*	Northern Queensland and Southern Papua New Guinea	Fast growing small to medium size tree reaching a height up to 25 m in good soil condition*
Melaleuca quinquenervia	Southern New Guinea and New Caledonia	Fast growing small to medium size tree reaching a height of up to 25 m**
Melaleuca ericifolia	New South Wales and Tasmania	Small shrub or multi–stemmed, grows 3 to 5 m high***

Sources: Doran 1999, Geary & Woodall 1999**, Brophy & Doran 2004***, Doran & Pinyopusarerk 2006*****

The seven essential oil producing tree species in Bukidon.

Essential oil yield

Five hundred grams of fresh leaves were harvested from two randomly selected trees in each sample plot. Steam distillation process was performed to extract the essential oil. Percent oil yield was determined using the formula:

$$\text{Oil yield (\%)} = \frac{\text{Volume of extracted oil}}{\text{Oven dried weight of samples}} \times 100$$

Measurements were replicated five times.

Statistical Analysis

A 2 x 7 factorial experiment was performed where site and species were considered as factors. Evaluation was conducted at $\alpha = 0.05\%$. Likewise, regression analysis was performed in order to determine the relationship between the different parameters.

Biomass measurement of the selected oil producing tree species at Imbayao.

Biomass measurement of the selected oil producing tree species at Dahilayan.

RESULTS AND DISCUSSION

Survival and Growth Performance

Percent survival of the plants ranged from 40% to as high as 91.25% (Table 3). Generally, the Imbayao site had better survival rate as compared to the Dahilayan site. This difference could be attributed to the disparity in maintenance activities conducted on the two sites. Managed by the Mount Kitanglad Range Nature Park, the Imbayao site is better maintained through regular weeding and with proper protection against stray animals both of which were lacking in the Dahilayan site. Nonetheless, the results were very promising for it showed that these exotic trees could thrive in the area.

Table 3. Percent survival of the individual species per plot.

Species	Dahilayan	Imbayao
Corymbia citriodora	73.65	85.62
Melaleuca cajuputi	52.50	78.75
Melaleuca cajuputi subsp. Platyphylla	60.00	76.25
Melaleuca quinquinerva	50.00	58.75
Eucalyptus staigeriana	83.75	81.25
Leptospermum petersonii	71.25	91.25
Melaleuca ericifolia	40.00	63.75

In their natural habitats, *Corymbia citriodora* (Hook.) K.D. Hill & L.A.S. Johnson is a medium to large tree with a diameter ranging from 25 to 40 cm with a height of 25 to 35 m. *Melaleuca cajuputi* subsp *platyphyllla* Powell, *Melaleuca cajuputi* Powell and *Melaleuca quinquinervia* (Cav.) S.T. Blake are medium sized trees reaching a height of up to 25 m (Doran 1999, Geary & Woodall 1990). Lastly, *Eucalyptus staigeriana* F. Muell.ex Bailey, *Leptospermum petersonii* F.M. Bail, and *Melaleuca ericifolia* Smith are shrubby to small trees reaching a height of 7 m, 5 m, and 9 m, respectively (Wrigley & Fagg 1996).

Figure 2a and 2b depict the base diameter and total height of the individual species, respectively. Regardless of site, *C. citriodora* gave the largest diameter with 28 cm while *M. ericifolia* had the smallest with 7cm. Samples from the Dahilayan site were slightly bigger in diameter than those samples planted in the Imbayao site. Similarly, *C. citriodora* was the tallest at 7.3 m regardless of site at 30 months. This value was not too far from the total height of a 4–year old *C. citriodora* planted in Capiz, Visayas, Philippines at 8.5 m (Lustica 1997). On the other hand, *M. cajuputi* particularly at the Imbayao site was the shortest sample at 1.8 m.

Table 4 gives the individual growth rate of the samples per site. This clearly showed how vigorous *C. citriodora* is both in terms of diameter and total height with a monthly increment of approximately 0.9618 cm and 0.2465 m, respectively. The slowest growing sample in terms of diameter was *M. ericifolia* with 0.2304 cm mo^{-1} while in terms of total height, it was *M. cajuputi* with 0.0620 m mo^{-1}. Both samples were grown in the Imbayao site.

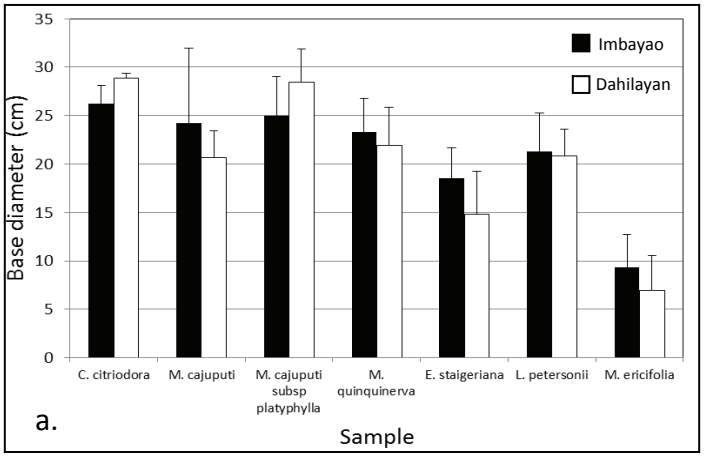

Figure 2a. Base diameter of the individual samples. (Bar = Standard Deviation)

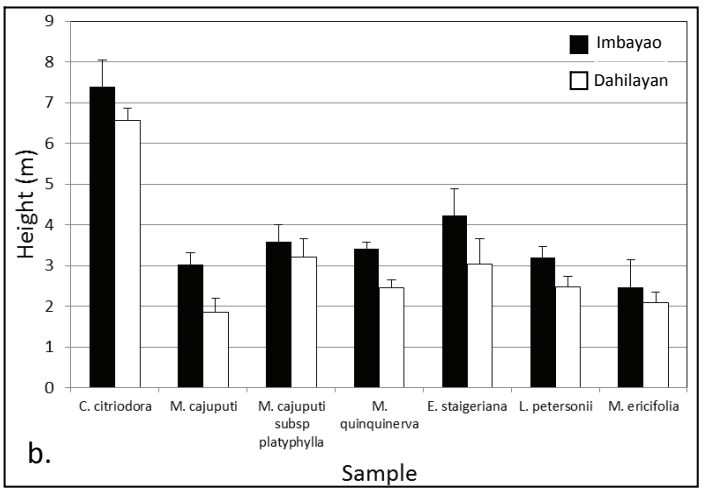

Figure 2b. Total height of the individual samples. (Bar = Standard Deviation)

Total Biomass

Seven–year old *Melaleuca* species growing in Cambodia had a recorded biomass of 740 to 785 kg m^{-3} while *Eucalyptus* species of the same age had a biomass of 25 kg $tree^{-1}$ (PROSEA 1999). There was a large discrepancy in terms of total biomass production between species (Figure 3). This can be attributed to the different growth characteristics of the individual species. *C. citriodora* gave the highest biomass with 1200 g cm^{-3} while *M. ericifolia* gave the smallest with only 100 g cm^{-3}. Considering the age of the plantation, it was very promising that in a period of 30 months, *C. citriodora* had accumulated a considerable amount of biomass. This was expected knowing *C. citriodora* is a large tree upon maturity. *L. petersonii*, a multi–stemmed tree and *E. staigeriana*, a small tree, were able to produce comparatively high total biomass at 350 g cm^{-3} and 400 g cm^{-3}, respectively.

Essential Oil Production

Essential oil production of the plant is an ecophysiological process (Sangwan *et al*. 2001). It is affected by several factors including physiological variations, environmental conditions,

Table 4. Growth rate of the individual samples per plot.

Species	Diameter (cm mo^{-1})		Height (m mo^{-1})	
	Dahilayan	Imbayao	Dahilayan	Imbayao
Corymbia citriodora	0.8733	0.9618	0.2465	0.2187
Melaleuca cajuputi	0.8089	0.6887	0.1075	0.0620
Melaleuca cajuputi subsp. *platyphylla*	0.8327	0.9472	0.1194	0.1069
Melaleuca quinquinerva	0.7775	0.7314	0.1141	0.0815
Eucalyptus staigeriana	0.6179	0.4941	0.1411	0.1009
Leptospermum petersonii	0.7101	0.6956	0.1067	0.0822
Melaleuca ericifolia	0.3103	0.2304	0.0821	0.0694

geographic, genetic (Figueiredo *et al*. 2008) and plantation tree density (Khorshidi *et al.* 2009). *E. staigeriana* yielded the highest percent oil yield among the samples with 3.4% while *M. cajuputi* subsp *platyphylla* gave the least amount with only 0.2% (Figure 4). These values are comparable to the measurements conducted by other authors (Da Silva *et al*. 2005; Midgley *et al*. 1996; Brophy & Doran 2004). *C. citriodora* produced only 0.7 – 1.1% of essential oil which was a little lower than the observed values for the same species planted in Brazil with about 2% (Da Silva *et al*. 2009). This is very promising because even at an early age of the plants (30 months), they could already produce the same amount of essential oil similar to that of mature trees. Table 5 shows the percentage oil yield of the species in the two sites and compared with the values from other countries.

Statistical Analysis

There was a great deal of variation between the observed values among samples. Figures 3 to 6 show that both diameter and biomass were unaffected by site differences. Although percent survival was lower in the Dahilayan site, it produced bigger trees than in the Imbayao site. Interesting to note that site and species interaction affected only height and essential oil production and not the diameter and biomass generation. As expected, species differences resulted to greater variation than site differences.

Influence of leaf biomass on essential oil production

Figure 5 depicts the amount of leaf biomass per species. *C. citriodora* again gave the highest leaf biomass at 250–300 g cm^{-3} while *M. ericifolia* gave the lowest with 40 g cm^{-3}. Correlating these values with the essential oil values show that the two are inversely proportional with each other (Figure 6). *C. citriodora*

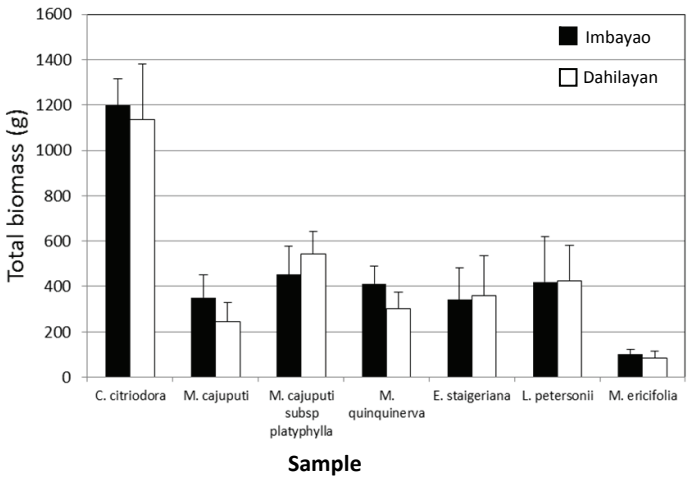

Figure 3. Total biomass of the individual samples. (Bar = Standard Deviation).

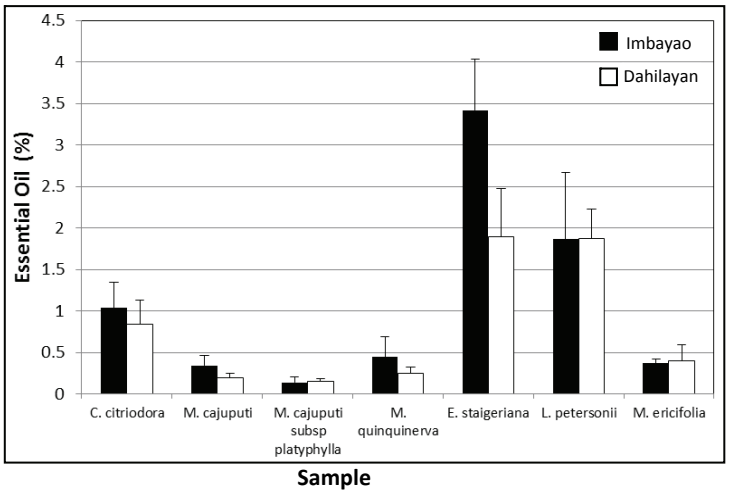

Figure 4. Essential oil production of the individual samples (Bar = Standard Deviation).

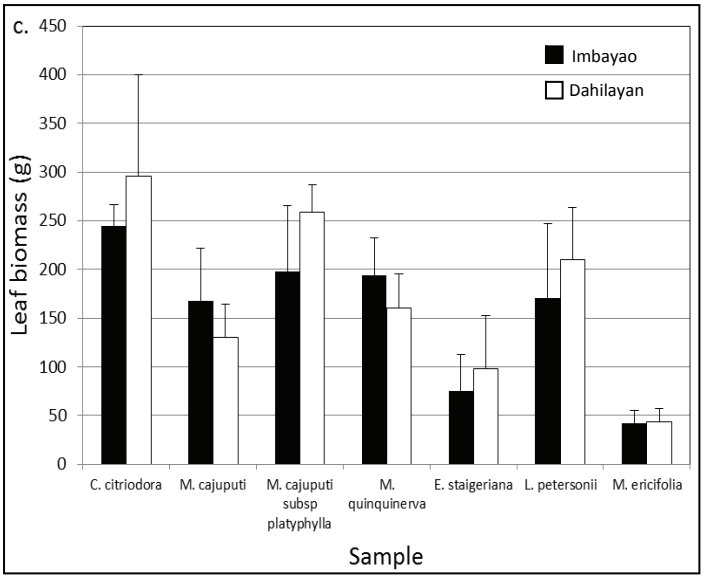

Figure 5. Leaf biomass of the individual samples. (Bar = Standard Deviation).

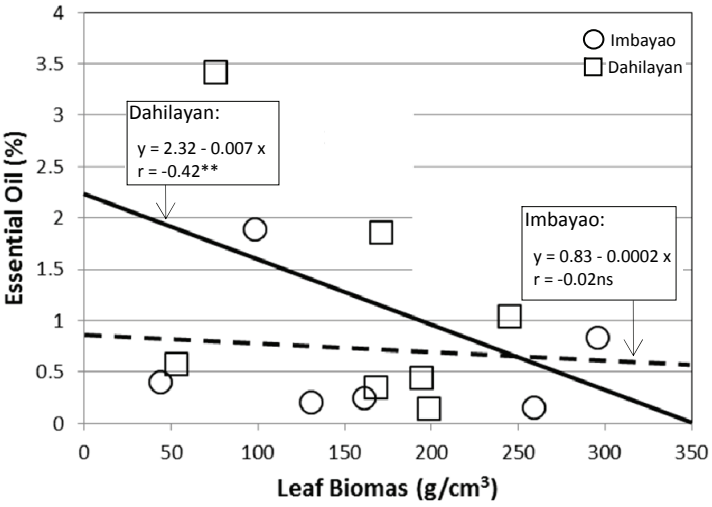

Figure 6. Relationship between the percent oil yield of the plant and its leaf biomass (α = 5%).

which gave the highest leaf biomass only produced 0.8 – 1% of essential oil, while *E. staigeriana* with a leaf biomass of only 70 – 100 g cm^{-3} gave 3.4% oil. Interestingly, high leaf biomass did not mean high essential oil content.

The amount of oil present within a species has been found to be highly affected by the genetic makeup of the species (Doran 2002). Essential oils protect the aerial parts of the plants against herbivores and pathogens (Werker 1993) as well as keep the leaf surface and stomata moist helping to maintain leaf gas exchange (Baldocchi *et al*. 1983; Brewer & Smith 1995). Close inspection of the leaves showed that the leaves of *E. staigeriana* were thick, wide, and without hairs while that of *C. citriodora* and *M. cajuputi* were thin and hairy. Leaf hairs increase the surface area of the leaves consequently reducing the accessibility of steam to the essential oil trapped within its structure (Copetta *et al*. 2006). This is in line with the findings of Serrato–Valenti *et al*. in 1997 which showed that the trichomes or leaf hairs prevent the loss of essential oil of the leaves. It is no wonder that the more hairs would result to lesser amount of extracted oil after distillation and vice versa.

CONCLUSIONS

Variations in growth characteristics, biomass and essential oil production between species were observed. These differences were not influenced so much by the site but by the species. If the main objective of the plantation is for wood and timber production that relies on stem growth and volume, *Corymbia citriodora* is the candidate species for plantation development. But if the consideration is for essential oil production, *Eucalyptus staigeriana* is the species of choice.

Table 5. Percentage oil yield of the species in the two sites and compared with other countries.

SPECIES	Other Countries	Imbayao	Dahilayan
Corymbia citriodora	0.5 – 5.0	0.93	1.06
Eucalyptus staigeriana	2.9 3.4	2.10	3.42
Leptospermum petersonii	0.5 – 3.0	1.99	1.87
Melaleuca cajuputi	0.4 – 1.2	0.18	0.34
Melaleuca cajuputi subsp. *platyphylla*	0.4 – 1.2	0.15	0.15
Melaleuca ericifolia	0.3 – 0.6	0.40	0.36
Melaleuca quinquinerva	0.3 – 1.3	0.285	0.33

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