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LAND SUITABILITY ASSESSMENT FOR PATCHOULI (*Pogostemon cablin*) DEVELOPMENT AND ESSENTIAL OIL PRODUCTION

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ABSTRACT

Patchouli (*Pogostemon cablin*) is one of the important crop species in Indonesia, since over 80% of patchouli oil global market is produced in Indonesia. Pacthouli oil is the key ingredients for fragrance and aromatherapy products. Patchouli oil is extracted from the stems and leaves of pathouli plants. Therefore, it is important to improve Patchouli plant productivity and increase resources for sustainable patchouli cultivation. The suitability of abiotic factors in the growing environment of crops remarkably determines the success of crop production. This study aimed to assess and evaluate land suitability for plant growth and development of Patchouli (*Pogostemon cablin*) in Dilem Wilis, Bendungan District, Trenggalek Regency, Indonesia. Initially, a survey was conducted and then an analysis was done to classify the land suitability for crops cultivation. The research was conducted on 3 locations from May to July 2017 for land suitability and from July to November 2017 for Patchouli crops cultivation experiment. The results indicated that Location 1 had a land suitability of N class, implying that this location was not suitable due to its limiting factor of low K_2O content (0.08 me/100 g). Meanwhile, both Location 2 and Location 3 showed similar land suitability class of S3s, tc, f, n signifying as less appropriate. The results of this study also indicated the influence of land suitability classes on plant growth however, the different classification (in this case S3 compared to N) did not demonstrate a correlation between land classes and oil yield and Patchouli alcohol, where the element Potassium was the limiting factor.

Keywords: abiotic factor, land suitability, Patchouli alcohol, potassium

INTRODUCTION

Patchouli (*Pogostemon cablin*) is one of the important crop species in Indonesia, since Indonesia is one of top producers of patchouli oil. Patchouli oil is used as key ingredients for fragrance as well as for cosmetics and aromatherapy products (Ramya *et al.* 2013; Nugraha et al. 2019). Indonesia is the world's largest producer of patchouli oil, accounting for 80% of the global market (Kusumaningrum *et al.* 2017). Patchouli oil is difficult to synthesize or substitute. Therefore, patchouli oil produced by natural patchouli plant remains the only source of the oil (van Beek & Joulian 2018). As patchouli oil is extracted from the stems and leaves of patchouli plants, it is important to improve patchouli plant productivity and resource use efficiency through suitable cultivation.

Land suitability is known to significantly affect the growth and the quantity and quality of crop yields, especially in essential oils. Differences in land suitability classes is expected to be directly proportional to plant growth and yield. However, the essential oil produced from secondary metabolites, is strongly influenced by stress conditions (Baher *et al.* 2002; Sangwan *et al.* 2001; Simon *et al.* 1992; Taarit *et al.* 2009). Land suitability determines the success of crop production, especially if the target output involves primary metabolites such as carbohydrates, proteins and fats. However, little is known on production targets that include metabolic secretions such as flavonoids, alkaloids and terpenoids. Therefore, the

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assessment of land suitability for essential oil-producing plants is necessary particularly for the Patchouli (*Pogostemon cablin*) plant.

Patchouli plants are considerably easy to grow like other herbaceous plants. However, an optimum ecological condition is deemed necessary to obtain the maximum production. Patchouli can grow and develop in the lowlands up to a plateau at 1,200 m above sea level (m asl), although its best growth is at altitudes between 50 - 400 m asl. The oil content of Patchouli on the lowlands is higher but the alcohol content is lower (low plateau Patchouli plant would generate low oil content and high alcohol levels). Environmental factors greatly affect Patchouli alcohol (PA) levels (Singh *et al.* 2002).

For the optimal growth, Patchouli plants require hot and humid temperatures; with annual rainfall ranging from 2,000±2,500 mm/year, evenly distributed throughout the year; optimum temperature of 24 - 28 °C; moisture of more than 75%, and radiation intensity ranging between 75 - 100%. In certain protected areas, Patchouli can still grow well with lower oil content. Patchouli planted under shady location will grow better, with wider, thinner and greener leaves, but with low oil content. Patchouli plants grown in the open area are considerably less dense with smaller plant habitus, small and thick leaves that are yellowish and slightly red, yet having higher oil content. Therefore, the addition of little shade at the beginning of growth was suggested because Patchouli is vulnerable to stress drought (Ritung *et al.* 2007).

Patchouli plants grow best on fertile and loose soil, which is rich in humus and properly drained. The most suitable soil types are those that have a crumb texture, such as Andosol or Latosol. For clays, a more intensive processing is required to obtain optimal conditions. In soil with less humus, the application of manure is highly recommended to improve soil fertility and humidity (Ritung *et al.* 2007). A problem arises when the plant is cultivated in suitable condition, yet producing low essential oil content. Thus, to increase its essential oil production level, the plants require relatively stress-free environmental conditions. Several factors could affect the growth and yield of Patchouli plants (both quality and quantity) however, this study focused only on the assessment of land suitability for the growth of Patchouli and its oil production.

MATERIALS AND METHOD

Study Site

This study involved two steps, namely: 1. land suitability assessment conducted in May 2017 to July 2017 and 2. Patchouli crop production conducted in July to November 2017 at Dilem Wilis Plantation, Dompyong Village, Bendungan District, Trenggalek Regency, Indonesia (Figs. 1 & 2). Laboratory test was conducted at the Chemistry Laboratory of Soils Department, Faculty of Agriculture, Universitas Brawijaya. Data were then analyzed at the Environmental Resources Laboratory, Department of Agronomy, Universitas Brawijaya. Steam distillation process was performed to extract the oil and to analyze the Patchouli alcohol content (PA) at the Institute of Atsiri, Universitas Brawijaya, Indonesia.

Land Suitability Assessments

The experiment involved the use of several tools, such as ruler to measure the depth of the soil, hoe to obtain soil samples from the different locations, clinometer to measure the percent slope of the land, GPS (Global Positioning System) to find the Location of coordinates and altitude of the place. Laboratory procedures and facilities were also used to analyze C-organic, CEC, K_2O, and pH, as well as computer for map workmanship and data analysis. The soil texture and drainage were also analyzed.

The first step in the evaluation of land suitability involved the ground check for the location of Patchouli plantation. Soil samples were then collected at some locations for observation of land physiography. The composite soil samples were obtained from each Location at a depth of 10 - 20 cm. These samples were analyzed for soil texture. Meanwhile, laboratory procedures were done to examine the organic matter content, K_2O, pH, and CEC level. Observations of land physiography included recording of coordinate Locations, altitude, and slope of the land. The land suitability assessment method in this study was based on Dengiz (2013).

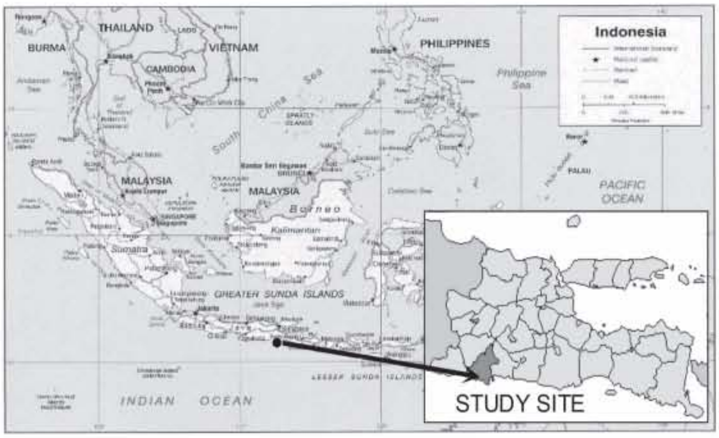

Figure 1 Study site

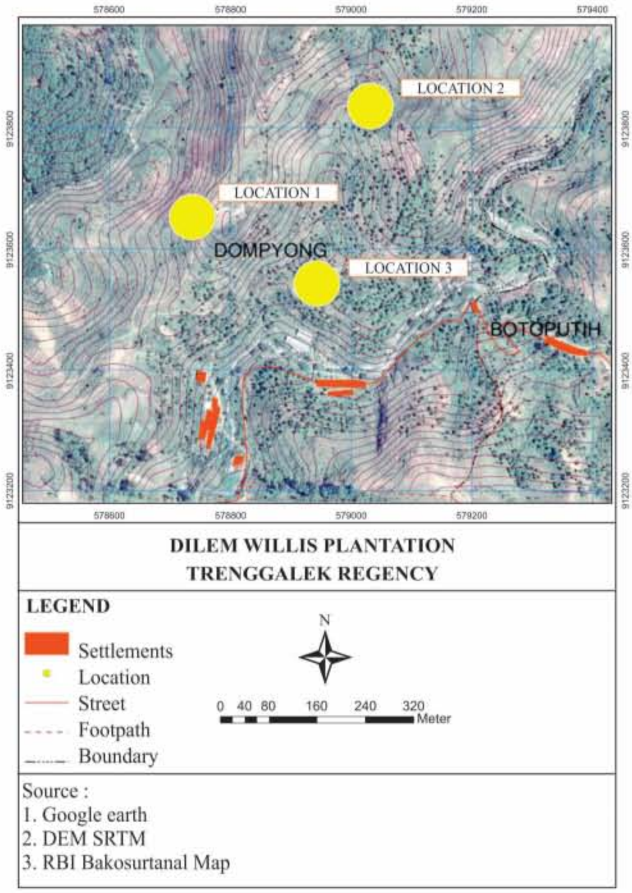

Figure 2 Location of assessment plot

The data analysis was initiated by establishing the data base to cluster the land suitability by using the matching method adjusted to each parameter as growth requirement of Patchouli plant (FAO 1976; Djaenudin *et al.* 2003; Ritung *et al.* 2007; Safuan *et al.* 2013). The land suitability classification was determined by the most constraining limiting factor (Rossiter & van Wambeke 1997; Djaenudin 2008; Wirosoedarmo *et al.* 2011; Jayanti *et al.* 2013). This study applied such basis to investigate the effect of land suitability on the agronomic aspects of plants.

The assessment was performed by matching the requirement of Patchouli plant growth and the characteristics of the land which were categorized into 3 groups based on: topography, soil and climate (Ritung *et al.* 2007). The land suitability assessment was used to reveal the limiting factor of Patchouli cultivation, as reference to improve the Patchouli cultivation area. The land suitability classification based on FAO (1976) was consisted of four categories, namely: a. Order: indicating the general state of the land suitability; b. Class: indicating the order level of conformity; c. Subclass: indicating the status of the class level based on the type of constraint or improvement as required in the class; and d. Unit: indicating the level in the subclass based on minor differences that affect the management.

Three locations were identified to obtain the composite soil samples and the land characteristics, including the required pH, C-Organic, N, P, K, Na, Ca, Mg, and CEC. The slope, altitude, temperature, drainage and texture.

Patchouli Growth and Result Evaluation

After conducting land suitability analysis, the locations were classified based on suitability. To evaluate the effect of land suitability on growth and yields, the patchouli was planted without adding improvements to the soil conditions or to the existing topography. It is suspected that there is a positive correlation between patchouli yield and land suitability evaluation.

The one-month old *sidikalang* variety of Patchouli seedlings were planted at a spacing distance of 50 x 100 cm. The soil was cultivated applying minimum tillage with weed control every 2 weeks. Soil was irrigated every 2 days to adjust the soil conditions with the same dosage equally given for each location without addition of soil nutrients/fertilizer. This study utilized a randomized block design with 3 replications at each location, each replication consisting of 27 plants with 3 plants for each replication.

Table 1 Land suitability classification of Patchouli plants

Category	Land suitability classes			
	S1	S2	S3	N
Land position (s)				
Slope (%)	0 - 2	2 - 8	8 - 15	> 15
Altitude (m asl)	100 - 400	0 - 100 or 400 - 700	> 700	> 700
Temperature (tc)				
Average temperature (°C)	24 - 26	22 - 24 or 26 - 28	20 - 22 or 28 - 33	18 - 20 or > 33
Water availability (wa)				
Rainfalls (mm)	2300 - 3000	1750 - 2300 or 3000-3500	1200 - 1750 or > 3500	<1200 or >5000
Root media (rc)				
Texture	Sandy clay, sandy clay, Clay quartz	Clay and other sandy clay	Other	Other
Drainage	Very Good	Good	Bad	Very Bad
Soil depth (cm)	> 100 cm	75 - 100 cm	50 - 75 cm	< 50 cm
Nutrient retention (f)				
Acidity (pH)	Acidic (5.5 - 7)	Acidic to Neutral (5.5 - 5)	Acidic to Very Acidic (4,5-5)	Very Acidic to Alkaline (< 4.5 or > 7.5)
C-Organic (%)	2 - 3	3 - 5	< 2	-
CEC (me/100 g)	> 17	5.6	< 5	-
Nutrition (n)				
K_2O (me/100 g)	> 10	0.6 - 10	0.2 - 0.6	-
P_2O_5 (ppm)	16 - 25	10 - 15	> 25	-

Source: Djaenudin *et al.* (2003).

The plant growth was assessed based on the branch height and canopy diameter of the plant at 2, 4 and 6 months after planting. Results were obtained by destructive sampling based on wet/fresh weight and curing dry weight (± 20% water content). The oil yield component was obtained by the 8-hour steam distillation method to obtain Patchouli alcohol (PA) level as an indicator of the quality of essential oils (Idris *et al.* 2014; Buré & Sellier 2004). The obtained growth and yield data were tested by using analysis of variance (F-test) at significance level $P < 0.05$). Furthermore, to test the significant differences between treatments, the Tukey test performance by R statistics was applied.

RESULTS AND DISCUSSION

Land Suitability

The differences among Location 1, Location 2 and Location 3, were based on the land suitability class (Location 1 is N as not appropriate, Locations 2 and 3 are less appropriate (Table 2). The slopes of Mount Wilis is considered hilly to mountainous reliefs. Location 1 has a slope of 8%, Location 2 has 10%, and Location 3 has 12%. At the observation point the altitude was about 600 - 850 m above sea level (m asl). Location 1 lies at an altitude of 792 m asl, Location 2 at an altitude of 809 m asl, and Location 3 at an altitude of 768 m asl. The average altitude for optimum Patchouli cultivation was at 780 m asl. Average air temperatures at each location based on the formula of Braak (1928) were: Location 1 at 21 °C, Location 2 at 21 °C, and Location 3 at 22 °C. The air temperature got cooler as the altitude went higher. Based on the formula of Braak (1928), the temperature registered a steady decline by 0.61 °C with an increasing altitude of 1 m.

The soil texture at the study site was dominated by clay and dust. At Location 1, the soil texture was sandy clay, while at Location 2 and Location 3 it was clay. Drainage at Location 1 is considerably good as water moves quickly or seeps into the soil through the infiltration process, supported by sandy clay texture having a larger pore than the sand fraction. Meanwhile, both Location 2 and Location 3 have a good or medium drainage class. Soil acidity (pH) at Location 1 is 4.6, at Location 2 is 4.9 and at Location 3 is 4.5 (where the soil pH at the observation point is acidic). Based on laboratory test, C-Organic at the observation site was 1.63% at Location 1, 1.50% at Location 2 and 0.71% at Location 3. The Cation Exchange Capacity (CEC) at Location 1 is 18.75 me/100 g, at Location 2 is 5.38 me/100g, and at Location 3 is 18.45 me/100 g. The availability of K_2O macro elements at Location 1 is 0.08 me/100 g, at Location 2 is 0.46 me/100 g, and at Location 3 is 0.25 me/100 g.

Table 2 Land suitability classification of location 1, 2 and 3 at Dilem Wilis Plantation, Trenggalek Regency, Indonesia

Category	Land characteristics data		
	Location 1	Location 2	Location 3
Land Position (s)			
Slope (%)	8%	10%	12%
Altitude (m asl)	792	809	768
Temperature (tc)			
Average temperature (°C)	21	21	22
Water availability (wa)			
Rainfalls (mm)	1,428	1,428	1,428
Root Media (rc)			
Texture	Clay Dust	Clay	Clay
Drainage	Good	Good	Very bad
Soil Depth (cm)	> 50	> 50	> 15
Nutrient retention (f)			
Acidity (pH)	4.6	4.9	4.5
C-Organic (%)	1.63	1.50	0.71
CEC (me/100 g)	18.75	5.38	18.45
Nutrition (n)			
K_2O (me/100 g)	0.08	0.46	0.25
P_2O_5 (ppm)	-	-	-
Land Suitability Class	N n	S3s, tc, f, n	S3s, tc, f, n

Source: Primary Data (2017)

Crops Production Evaluation

Correlation between Crop Production Yield and Suitability

The results showed that the different land classes significantly affected the plant height at 6 months after planting (Figs. 3, 4, 5). However, the number of branches and canopy diameter did not differ significantly.

The different land classes produced higher biomass in plant fresh/wet weight and curing dry weight, indicating the effect of land suitability on plant growth (Fig. 6).

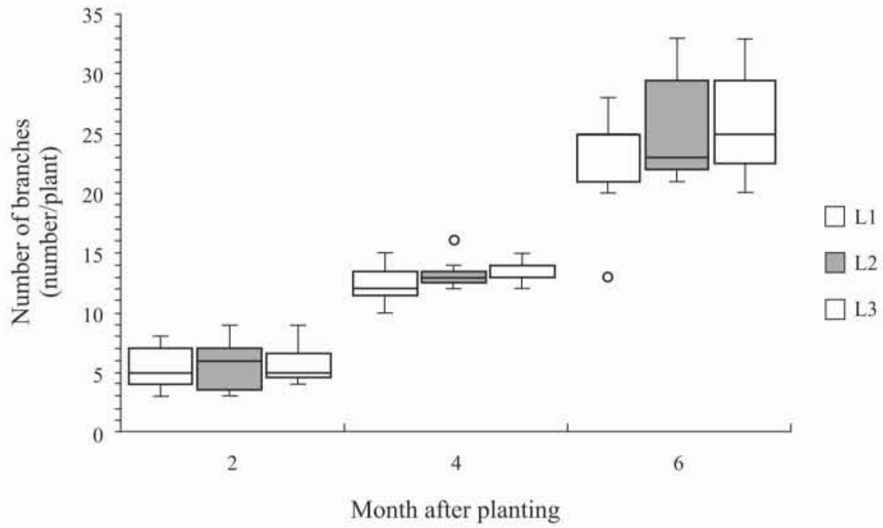

Figure 3 Number of branches
Notes: a = 2 months; b = 4 months; c = 6 months after planting.

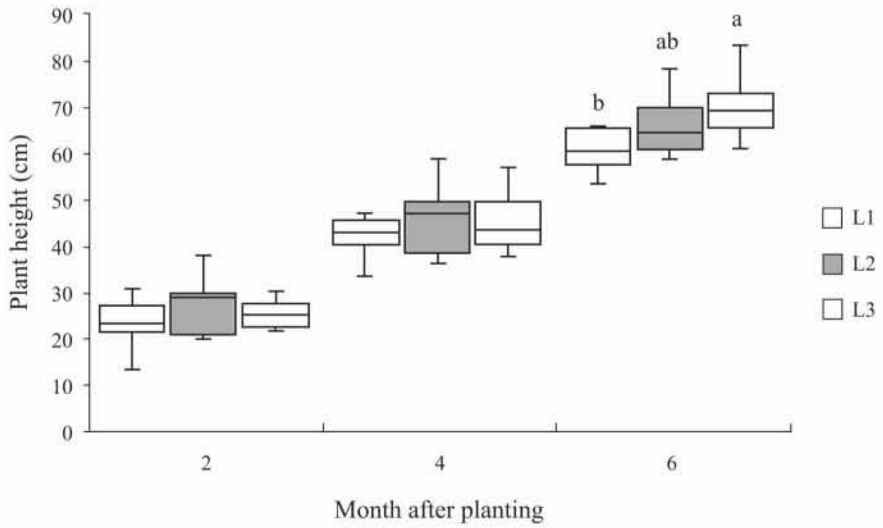

Figure 4 Plant height
Notes: a = 2 months; b = 4 months; c = 6 months after planting;
different letters in the figures indicate significant difference at 0.05 level.

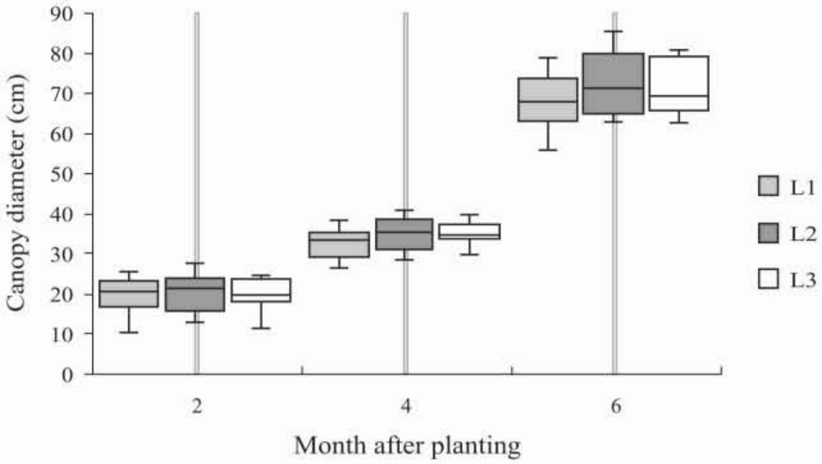

Figure 5 Canopy diameter among location (L) 1, 2, and 3 on the 2, 4 and 6 months after planting

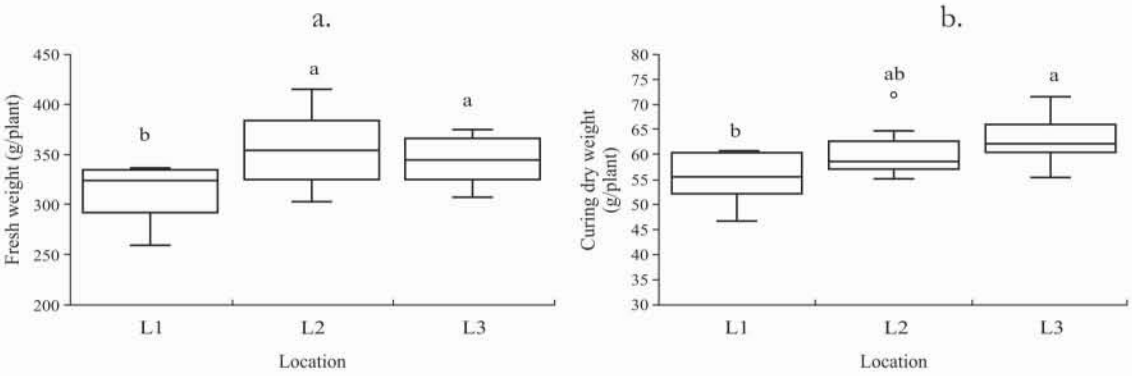

Figure 6 Fresh weight (g per plant)
Notes: a = curing dry weight (g per plant); b = harvested 6 months after planting; different letters in the figures indicate significant differences at 0.05 level.

Although Location 1 has the lowest yield value, the average oil yield and Patchouli alcohol (PA) quality in each location were not significantly affected by the limiting factors (Table 3).

Table 3 Average oil yield and quality PA (Patchouli Alcohol) of Patchouli

Location	Yield (%)	PA (%)
Location 1	2.36 ns	23.40 ns
Location 2	2.42 ns	22.82 ns
Location 3	2.49 ns	24.14 ns

Note: ns = no significant difference.

Patchouli Cultivation and Land Suitability

Matching the land characteristics with the growth requirement of Patchouli resulted in Location 1 having a land suitability class "N", indicating that the cultivated land was not suitable because of the limiting effect of the very low K_2O content. Location 2 and Location 3 have S3 class, tc, f, n indicating that the cultivation area was less suitable because of the limiting effect of the slope, altitude, temperature, pH, C-organic, and K_2O. Potassium (K) plays a key role in plant metabolism affecting the synthesis and accumulation of nutrients and secondary metabolites (Bihter *et al.* 2016).

Limiting factors that have significant effects included the altitude and the slopes. The cultivation area was located on the southern slopes of Mount Wilis which is hilly to mountainous with an altitude of 600 - 850 m asl. The slope of the land varies. The land on slopes were prone to erosion due to the lack of soil reinforcement plants and the absence of soil protection from splashing rainwater. The land on the slopes will be eroded if there is no improvement on it. In the highlands with low temperatures, soil fertility will be preserved, but steep slopes and unstable lands will lead to landslides making it more suitable for trees

(Djaenudin 2008). The elevation of the observed location is in the range of > 700 m asl. Patchouli plants can grow and produce well at an altitude of 10 - 400 m above sea levels with air temperature ranging from 24 to 28 °C (Pujiharti *et al.* 2008).

The other limiting factor was the acidic soil pH which has a value ranging from 4.5 to 4.9. The optimum growth and production of Patchouli plants requires optimum soil pH value of 5.5 to 7 which is quite acid to neutral. Nutrients and microorganisms are affected by the soil pH as nutrients are only available at certain pH level. The soil pH is influenced by the manner of land utilization. The C-organic value, representing the organic matter percentage in the soil, at all the locations were also low (< 2%), as compared to the growth requirement of Patchouli plants which is about 2 - 3%. K_2O content at all three locations was also low (< 0.6 me/100 g), lower than the optimal growth requirement of Patchouli (> 10 me/100 g of K_2O). Low K_2O content is due to several factors such as lack of fertilization. Potassium is an alkaline cation, which balances charges of organic and inorganic anions activating more than 50 enzymes (Nurzynska-Wierdak *et al.* 2011).

Agronomic Factor

Land suitability increased the plant growth despite the insignificantly different oil quantities (Figs. 3, 4, 5, 6; Table 3). The current study showed that the effect of limiting factors (potassium) and land suitability does not affect Patchouli oil and alcohol yields, similar results with Singh (2014). However, distinguishable differences were observed in the potassium content among location 1, 2 and 3 (Table 2). Potassium is considered a plant essential mineral which has high concentration in the meristematic tissues and in the phloem. However, K uptake by the plant roots is accomplished by at least two distinct kinetic systems such as the high and low affinity K^+ transporters (Hafsi *et al.* 2014). Potassium serves as an important element in plant metabolism, promoting carbohydrates, fats and protein synthesis, increasing crop yield and improving fresh produce quality. Moreover, K enables plants efficacy to resist pests and diseases as well as acting as enzymes co-factor, including enzymes related to the essential oil synthesis (Hafsi *et al.* 2014). The application of K has also affected the growth and essential oil yield of lemongrass (*Cymbopogon flexuosus*), dittany (*Origanum dictamnus*), basil (*Ocimum basilicum*) and rosemary (*Rosmarinus officinalis*) (Economakis 1993; Puttanna *et al.* 2010).

Improvement of Land Characteristics and Cultivation

The improvement of land characteristic was aimed at optimizing the land condition for Patchouli cultivation by using the limiting factors as a reference. The slope of the land is unchangeable, yet such condition could still be addressed by constructing terraces to reduce surface runoff that leads to erosion (Whitman *et al.* 1985); and the position of the porch slope affects the reception of light (Auslander *et al.* 2003). Fertilization is another alternative to improve the soil pH value, K_2O content, and c-organic percentage, including appropriate fertilization system such as: fertilization time and method, and fertilizer type selection. The application of organic fertilizer is intended to supply the nutrients that could not be provided by the chemical fertilizer, and also to improve the physical and biological properties of the soil (Abdurachman *et al.* 2008). Liming is another method applied to increase soil acidity values (pH) to be more neutral during land cultivation. Potassium (K) affects the growth and essential oil synthesis in aromatic plants as it is required by plants to build abundant organic compounds such as amino acids, proteins, enzymes and nucleic acids. These minerals affect the function and levels of enzymes involved in the terpenoides biosynthesis (Hafsi *et al.* 2014).

The low potassium content at Location 1 is a limiting factor. However, certain strategies could be applied to ensure the quantity of essential oil yields, where the main target of the harvest is secondary metabolites. It is necessary to synchronize the suitability of the growth conditions for secondary metabolite-producing plants in as much as both the growth and yield targets also implied the achievement of good quality essential oils. The planting patterns are also considered as a solution to increase stress as the harvesting period approaches (Sacks *et al.* 2010).

CONCLUSION

The land suitability analysis of the three sampling locations (Location 1, 2, 3) revealed that Location 1 is not suitable for the growing of Patchouli because of its low K_2O content at 0.08 me/100 g. Both Location 2 and Location 3 showed similar land suitability class of S3s, tc, f, which is less appropriate, because of the limiting effects of land, altitude, rainfall, air temperature, C-organic, soil pH (acidity), and K_2O. However, the different locations did not significantly demonstrate any inhibiting effects on the growth and yield of the Patchouli plants. Although the land suitability test indicated differences in growth as well as quality and quantity of yields, this correlation between land suitability and growth becomes less relevant to Patchouli oil yield and alcohol level (indication of the quality of oil obtained). Differences in locations under certain conditions, in this case S3 compared to N, did not affect the Patchouli alcohol (PA) content of the essential oil. Lastly, potassium was a limiting element on the growth of the essential oil-producing plant Patchouli, *Pogostemon cablin*.

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