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ASSESSING AND EVALUATING LAND SUITABILITY IN THE DEVELOPMENT OF PATCHOULI (*Pogostemon cablin*) EFFECT ON PATCHOULI ESSENTIAL OIL**

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ABSTRACT

The conformity of abiotic factors in the growing environment of crops determines the successful result of crop production. This study aims to assess and evaluate land suitability for plant growth and result of patchouli development in Dilem wilis, Bendungan Distric, Trenggalek Regency. The study was initiated with the survey and continued by utilizing analysis method to adjust the data with the criteria according to the classification of land suitability clashing and crops cultivation as indicator for assessing land suitability. 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 result indicated from the three sampling Locations, specifically Location 1 presented the land suitability of N class, conforming that this Location was not suitable with the limiting factor of low K_2O content of 0.08 me / 100 g. Meanwhile, both Location 2 and Location 3 presented similar land suitability class of S3s, tc, f, n conforming as less appropriate. The results of this study also depicted the influence of land suitability classes on plant growth; however, the difference in land classes (in this case S3 compared to N) did not demonstrate a correlation for oil yield and patchouli alcohol, where the element Potassium becomes a limiting factor.

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

INTRODUCTION

The researchers assess and evaluate whether land suitability will significantly affect the growth or the quantity and quality of crop yields, especially in essential oils. It is suspected that differences in land suitability classes will be directly proportional to plant growth and yield. However, it is also indicated that the essential oil factor produced from secondary metabolites, was 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 involves primary metabolites such as carbohydrates, proteins and fats. However, it remains debatable if the production target includes the production of metabolic secretions (such as flavonoids, alkaloids and terpenoids), will the result is similar? Therefore, the assessment and evaluation of land suitability in essential oil-producing plants are encouraged to be conducted, especially in Patchouli plant.

As an illustration in this study, patchouli plants are considerably easy to grow alike other herbaceous plants. However, suitable ecological condition is deemed necessary to obtain the maximum production. Patchouli can grow and develop in the lowlands up to the plateau at 1200 m above sea level, despite its best grow at altitudes between 50 - 400 m above sea level. 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 PA levels (Singh *et al.* 2002).

For the optimal growth, patchouli plants require: hot and humid temperatures with annual rainfall ranges from 2000 ± 2500 mm / year (with an even distribution throughout the year), the optimum temperature of 24 – 28^{o}C with 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 more fertile, presenting wider, thinner and greener leaves, with low oil content. Patchouli plants grown in the open area are considerably less dense with smaller plant habitus, small and thick leaves with yellowish and slightly red color, despite 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).

The fertile and loose soil, which is rich in humus and not stagnant, provides a significantly proper condition for patchouli plants. 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 less humus soil, the application of manure is highly recommended to improve soil fertility and humidity (Ritung *et al.* 2007). Problem arises when the plant is cultivated on the suitable condition, yet resulting in low essential oil content. Thus, to increase the level of essential oil, plants require less stressing condition. Several factors will affect the growth and yield of patchouli plants (both quality and quantity); however, this study focuses, limits the assessment of land suitability and evaluates as indicator of suitability.

MATERIALS AND METHOD

Study Site

This study involves the two steps of: (1) land suitability as conducted in May 2017 to July 2017 and (2) Patchouli crop production as conducted in July to November 2017 at Dilem Wilis Plantation, Dompyong Village, Bendungan district, Trenggalek regency. Laboratory test was conducted in Chemistry Laboratory of Soil Department, Faculty of Agriculture. Then data analysis was performed in Environmental Resources Laboratory of Department of Agronomy. Steam distillation process was performed to obtain yield and Patchouli alcohol content was extracted in Institute of Atsiri, University of Brawijaya.

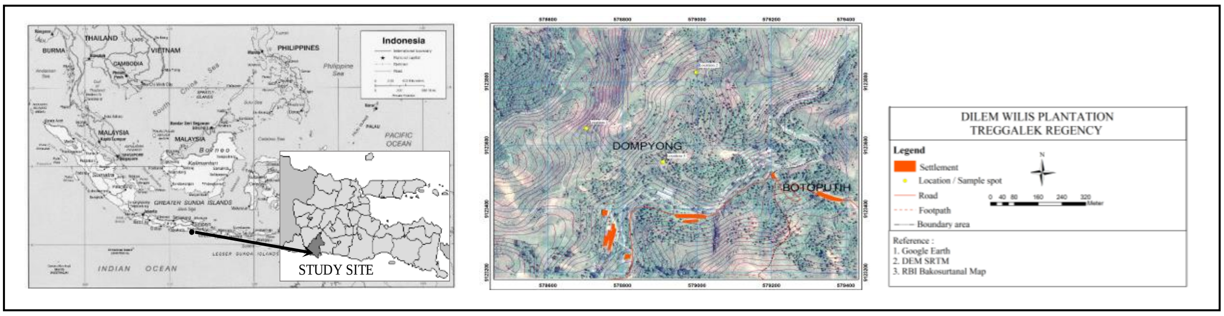


Figure 1. Plot location of analysis and study site

Land Suitability Assessments

The experiment of this study involves several tools, such as: hoe to obtain soil samples from the Location and clinometer to measure the percent slope of the land; GPS (Global Positioning System) to find the Location of coordinates and altitude of the place; and ruler to measure the depth of the soil. Laboratory apparatus was also engaged to analyze C-organic, CEC, K_2O, and pH, as well as computer for map workmanship and data analysis. Materials used included water to analyze soil texture, drainage, and laboratory test and soil as the main ingredient of parameter analysis.

The first step in the evaluation of land suitability involved the ground check for location of Patchouli plantation. Then soil was collected at some Location for sampling and observation of land physiography. The sampling was composite from each Location, obtained at a depth of 10-20 cm. Soil samples were utilized to observe the texture. Meanwhile, laboratory analysis examined organic, 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 base on Dengiz (2013).

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

The assessment was performed by matching the requirement of Patchouli plant growth and the characteristics of the land. Characteristics of land as an evaluation were categorized into 3 groups including: topography, soil and climate (Ritung *et al*. 2007). Assessment of land suitability class was utilized to reveal the limiting factor of Patchouli cultivation, providing as reference to improve Patchouli cultivation area. The classification of land suitability was based on FAO (1976) consisting of four categories which are: a) Order: indicating the general state of the land suitability, b) Class: indicating the order level of conformity, c) Subclass: indicating the state 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.

There are three locations of land sampling and observation of land characteristics, required to obtain the composite soil samples including pH, C-Organic, N, P, K, Na, Ca, Mg, and CEC. The experiment was continued with the observation of land slope, altitude, temperature, drainage and texture.

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 (^oC)	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).

Patchouli Growth and Result Evaluation

Patchouli planting was conducted at a distance of 50 cm x 100 cm with *sidikalang* varieties (seedling age of 1 month). Soil cultivation was minimally (minimum tillage) performed with weed control for every 2 weeks. Provision of irrigation was given in every 2 days to adjust soil conditions with similar dosage was equally given for each location and 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 a sample of 3 plants each replication.

Patchouli plant growth observations were conducted on several branches with height and diameter of the plant canopy at the age of 2, 4 and 6 months after planting. Observation for the results was carried out by destructive sampling of wet/fresh weight and curing dry weight (±20% water content). Further, the yield components such as oil is obtained by the 8-hour steam distillation method (Idris *et al.* 2014) to obtain patchouli alcohol (PA) level as an indicator of the quality of essential oils (Buré & Sellier, 2004). The obtained growth and result data were tested by using analysis of variance (F-test) with significance level (P. 0.05). Furthermore, in order to investigate the difference between treatments, a comparative test was applied by using Tukey test performance by R statistics.

RESULTS AND DISCUSSION

Land Suitability

Land characteristics and suitability of Dilem Wilis Plantation, Trenggalek Regency were presented in Table 2.

Table 2. Land Suitability Classification of Patchouli Plants at Location 1, 2 and 3

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 (^oC)	21	21	22
Water availability (wa)			
Rainfalls (mm)	1428	1428	1428
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

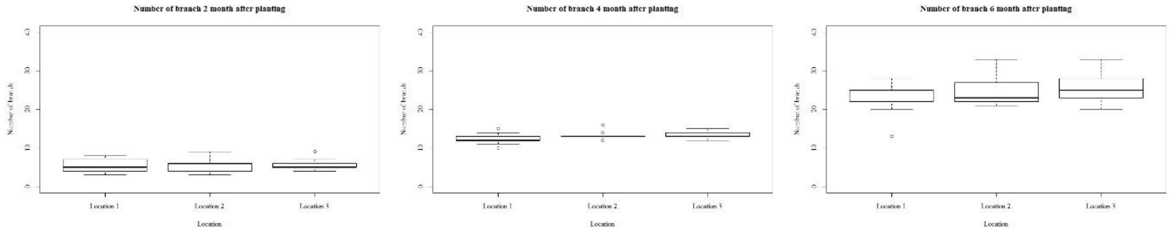
Note: Source by Primary Data 2017

Table 2 indicates that the difference among Location 1, Location 2 and 3, was based on the land suitability class (Location 1 containing N is not appropriate, Location 2 and 3 are less appropriate. As an explanation of the condition of land cultivation in the slopes of Mount Wilis which has hilly to mountainous reliefs). The slope of land at Location 1 is 8%, at Location 2 is 10%, and Location 3 is 12%. The altitude of the place at the observation location is about 600-850 m above sea level. Location 1 lies at an altitude of 792 m above sea level, Location 2 is at an altitude of 809 m above sea level, and Location 3 is at an altitude of 768 m above sea level. The average altitude of the patchouli cultivation is at 780 m above sea level. Air temperatures at each location based on calculation formula of Braak (1928) were: Location 1 equal to 21°C, Location 2 equal to 21°C, and Location 3 equal to 22° C. The air temperature was affected by the altitude where higher place generates lower air temperature. Based on the formula of Braak (1928), the temperature marks a steady decline by 0.61°C with increasing altitude towards 1 meter.

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

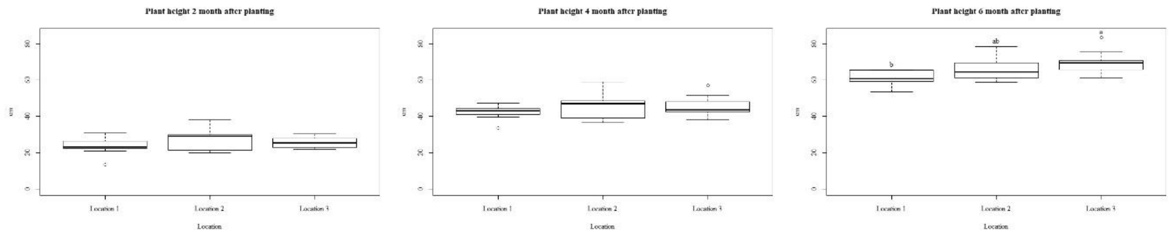
Crops Production Evaluation

Upon conducting land suitability analysis and obtaining land suitability classes, the researchers attempted to conduct further research to evaluate whether land suitability classes affected growth and patchouli yields. The study was initiated by planting 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 researchers also conducted a trial by measuring, several areas such as: number of branches, and plant height and canopy diameter as indicators of growth (Figure 2-4). The results indicated that the land class had a significant effect on plant height at the age of 6 months after planting. The rest on the number of branches and canopy diameter have not presented significant appearance.



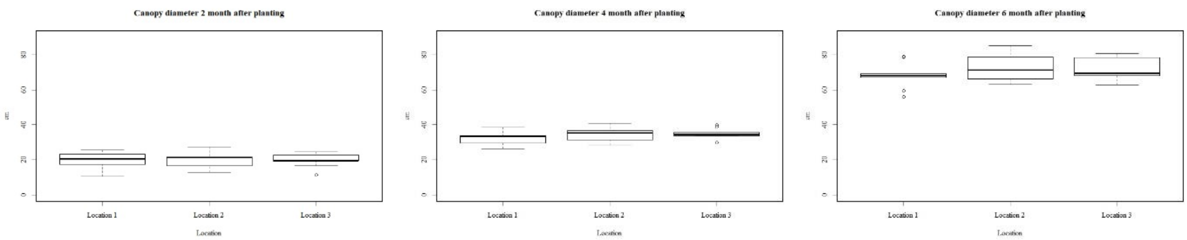
a. b. c.

Figure 2. Number of branch 2 (a), 4 (b) and 6 (c) month after planting



a. b. c.

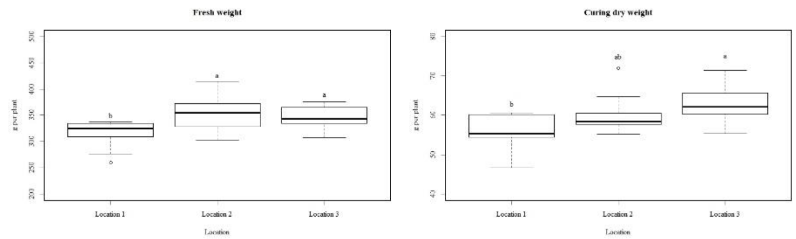
Figure 3. Plant hight 2 (a), 4 (b) and 6 (c) month after planting (different letters in the figures indicate significant difference at 0.05 level)



a. b. c.

Figure 4. Canopy diameter 2 (a), 4 (b) and 6 (c) month after planting

The researchers also inspected the crop fresh weight (Figure 5) as an indicator whether land suitability affects patchouli quality and quantity. The researchers present the evidence in the following figure depicting different land classes in producing higher biomass in plant fresh/wet weight and curing dry weight, clarifying the effect of land suitability on plant growth.



a. b.

Figure 5. Fresh weight (g per plant) (a) and Curing dry weight (g per plant) (b) harvesting 6 month after planting (different letters in the figures indicate significant difference at 0.05 level)

Table 3 presents the oil yield and PA content, emphasizing the effect of limiting factors on land suitability on yield results, where Location 1 has the lowest yield value but no significant different with another Location. Furthermore, PA value also does not reflect the correlation between the results of land suitability in the three locations.

Table 3. Average oil yield and quality (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

Limiting Factors of Land Suitability on Patchouli Cultivation

The matching characteristics of land with the growth requirement of patchouli plant resulted that Location 1 has a land suitability class of N n indicating that cultivated land is not appropriate because of the limiting factor of K_2O content which is very low. Location 2 and Location 3 have S3s class, tc, f, n indicating that cultivation area including is less suitable because of limiting factors such as land slope, altitude, temperature, pH, C-organic, and K_2O. In addition, potassium (K) plays key roles in plant metabolism affecting the synthesis and accumulation of nutrients and secondary metabolites (Bihter *et al.* 2016).

Limiting factors that became the main elements include: the altitude and the slopes due to location of the cultivation area on the southern slopes of Mount Wilis with its hilly to mountainous nature with an altitude of 600-850 m above sea levels. The slope of the land varies; thus, field observations revealed that the land on slopes were prone to erosion due to the lack of soil reinforcement plants and the absence of soil protection from rain water splashing. 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 above sea levels. 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).

Another limiting factor includes pH which has a value ranging from 4.5 to 4.9 classified as acid type. The growth of Patchouli plants requires appropriate pH value of 5.5 to 7 which is quite acid to neutral for optimum growth and production. In this range, pH value affects the nutrient content in the soil. Nutrients and microorganisms are only available at certain pH level. The pH value is influenced by the way of land processing. The C-organic content at all locations are also low (<2%), compared to the growth requirement of Patchouli plants requiring optimal organic c-content of about 2-3%. This c-organic value demonstrates the percentage of organic matter which was calculated from organic c-percentage. K_2O content at all three locations is considered in the low category (<0.6 me / 100g), lower than the optimal growth requirement of Patchouli (>10 me / 100g of K_2O). Low K_2O content value 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).

Agronomy Factor

Land suitability increases the plant growth despite insignificantly different oil quantities based on evidence Figure 2-5 and Table 3. The effect of limiting factors (potassium) and land suitability does not affect Patchouli oil and alcohol yields, the result is similar study with Singh (2014). However, the researchers suspected the differences in the potassium content that distinguishes among location 1, 2 and 3 (Table 2). Potassium is considered a plant essential mineral which has high concentration in tissues (in meristem and in phloem). However, according Hafsi *et al.* (2014) reviewed that K uptake by the plant roots is accomplished by at least two distinct kinetic systems such as: high and low affinity K^+ transporters. 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 acted as enzymes cofactor, including enzymes related to the essential oil synthesis (Hafsi *et al.* 2014). The application of K affects plant growth and essential oil yield of lemongrass (*Cymbopogon flexuosus*), dittany (*Origanum dictamnus*), basil (*Ocimum basilicum*) and rosemary (*Rosmarinus officinalis*) plants (Economakis, 1993; Puttanna *et al.* 2010).

Improvement of Land Characteristics and Cultivation

Improvement of land characteristic was aimed to optimize the land condition for Patchouli cultivation by using limiting factors as a reference. The slope of the land is unchangeable, yet such condition is possible to be addressed by constructing terrace to reduce runoff surface leading to erosion (Whitman *et al.* 1985); the position of the porch slope affects the reception of light (Auslander *et al.* 2003). Fertilization serves as another alternative to improve pH value, K_2O content, and c-organic percentage, including appropriate fertilization system such as: fertilization time, fertilization method, and fertilizer type selection. The application of organic fertilizer is intended to add the nutrients that could not be provided by chemical fertilizer, also to improve the physical and biological properties of the soil (Abdurahman *et al.* 2008). Further, liming is the utilized method to increase soil acidity (pH) to be more neutral during the processing of the land. Potassium (K) may affect the growth and essential oil synthesis in aromatic plants; and potassium is also 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 element of potassium at Location 1 is indicated as a limiting factor. However, certain attempt is required to ensure the quantity of essential oil crop yields, where the main target of the harvest is secondary metabolites. It is necessary to synchronize the suitability of the growth conditions in secondary metabolite-producing plants. Thus, both growth and yield targets are accompanied by the quality of essential oils. The researchers also believed that planting patterns become a solution to increase stress when approaching harvesting (Sacks *et al.* 2010).

CONCLUSION

The analysis of three sampling locations (Location 1, 2, 3) revealed that the land suitability class at Location 1 is N n or not in accordance with limiting factor of K_2O (indicating low content of 0.08 me / 100 g). However, both Location 2 and Location 3 present similar land suitability class of S3s, tc, f, n which is less appropriate with limiting factor of land, altitude, rainfall, air temperature, c-organic, pH (soil acidity), and K_2O. Based on the land suitability class in this study, each Location has not demonstrated inhibiting factor for growth and yield of patchouli plants. The results of land suitability testing indicated differences in growth as well as quality and quantity of yields. However, the correlation between land suitability and growth becomes less relevant to oil yield and patchouli alcohol level as an indication of the quality of oil obtained. Differences in locations under certain conditions do not affect PA of essential oils in this case S3 compared to N. The effect of potassium as a limiting element on land suitability influences the growth of essential oils.

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