Developing sustainable production of patchouli oil in Kolaka, South East Sulawesi, Indonesia: a problem-solving approach

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Abstract. Patchouli oil is an essential oil extracted from the patchouli plant (Pogostemon cablin Benth), widely cultivated by farmers in Kolaka District, South East Sulawesi Province, as intercrop or monoculture farming. This research aimed to search for probable solutions to the problems faced by farmers in developing sustainable patchouli oil production. The research was conducted in Kolaka, South East Sulawesi, in May-June 2021 using problem-solving approach. The snowball method was used to select the key informants consisting of farmers, distillers, and extension workers. The primary data was obtained through online interviews. The problems and probable solutions identified in the cultivation and distillation of patchouli consisted of the soil problems that could be overcome through the right and balanced fertilization; the scarcity of certified seed, the government should initiate the production; the synthetic chemical weed and disease control that can be replaced by application of mechanical weed and integrated disease control; and herbage immaturity by conducting gradual harvesting according to plant maturity and capacity of distillation equipment. It is suggested to utilize a stainless kettle in the distillation and farmers’ organizations can provide a soft loan when farmers need cash and the patchouli oil price is low to delay selling.

1. Introduction

Indonesia is the world’s largest producer of patchouli oil and supplies most of the world’s needs. Patchouli oil is one of the essential oils produced by patchouli plants (Pogostemon cablin Benth.) and used in the cosmetic, perfume, and pharmaceutical industries. Demand for patchouli oil is increasing in domestic and international markets, so there is an opportunity to increase production with increased areas and productivity. In the perfume industry, patchouli oil becomes a core constituent mainly for developing exotic perfumes and therapeutic scents because it can provide a rich and spicy aroma. In addition, patchouli oil can also be used as a perfume of its own and the best natural fixative substances, particularly for soap perfumes [1].

Patchouli oil production centers in Indonesia were initially only developed in Sumatra and Java. However, since the beginning of the 2000s, patchouli oil production developed into Sulawesi, especially South Sulawesi, Southeast Sulawesi, and Gorontalo. The development occurred due to the presence of some factors in Sumatera and Java, such as the infection of budok disease (caused by Synchytrium pogostemonis), bacteria wilt disease (caused by Ralstonia solanacearum), and decreased productivity caused by allelopathy or toxin produced and owned by patchouli plants in the soil [2]. In addition, in Sulawesi, many other plantation developments, particularly coconut, coffee, cocoa, and oil palm, are still newly planted so that patchouli can be planted as an intercrop. Moreover, in recent years, the price
of patchouli oil has been very attractive. Therefore, if the development of patchouli in Sulawesi does not heed the existence of the factors experienced in Sumatera and Java, then it may also have unsustainable consequences.

Based on this experience, the development of sustainable patchouli plantations should pay attention to environmental aspects, both biotic and abiotic, in the management of crop cultivation and economic and social aspects. In other words, sustainable cultivation should be a cornerstone in the production of patchouli oil. Because this concept is intended to achieve high productivity and quality by utilizing appropriate technology and resources wisely to preserve the environment, improve social welfare and achieve economic efficiency in the short and long term [3]. Since the production of patchouli oil consists of two processes, namely the cultivation of patchouli and distillation of patchouli oil, both processes must also apply the concept of sustainable production.

Sustainable patchouli cultivation in practice should apply the principles of Good Agricultural Practices (GAP). It consists of selecting the right location that has the suitability of soil and climate, superior seed following the environmental conditions of the land and climate, applying proper soil and water management, planting patterns, and pest and disease control. These principles have applied the perspective of maintaining the environmental balance, improving the income and welfare of farmers [4].

In general, the practice of sustainable cultivation is adopted by farmers gradually according to the ability of farmers both technically and economically [5]. Most farmers model other farmers who look successful, such as farmers who directly follow the planting of patchouli regardless of the suitability of the land and the climate; if the results are not satisfactory, they usually just look for suitable land. In addition, the main consideration in adopting sustainable agricultural technology is the risk of failure that may arise [6].

Sustainable patchouli oil distillation is a distillation that can extract patchouli oil to the maximum, with the best quality, cost-effective, and minimum environmental impacts. The factors that determine the sustainability of distillation are the quality of distilled plant materials, time, temperature and pressure, and the method and quality of distillation equipment [7]. The distillation method widely used to distill patchouli oil is the distillation of water and steam method. This distillation method can produce stable steam and heat due to the constant pressure of steam. In terms of environmental impact, research shows that patchouli oil distillation is efficient in using wood fuel. However, it can decrease the quality of human health and ecosystems, so it is necessary to mitigate [8].

Most farmers do distillation using the services of distillers adjacent to their plantations, with a rental system. Privates mostly own distillation services, but some belong to cooperatives whose members are patchouli farmers. Aside from providing distillation services, most distillers also act as patchouli oil collectors for sale to exporters [9].

This research was intended to search the probable solutions to the problems faced by farmers in developing sustainable patchouli oil production in Kolaka, South East Sulawesi, as a relatively new development area; in particular, to identify the cultivation problems of each stage of the cultivation and distillation and the possible solutions that the environmentally tolerable and economically feasible.

2. Methodology

2.1 Approach

A problem-solving approach used in this research was identifying the real problems faced in each patchouli cultivation activity and patchouli oil distillation. Then it was followed by the submission of probable solutions, both done by farmers and from the research results and advice from patchouli experts to realize sustainable patchouli production. The cultivation activity problem areas have consisted of land preparation, preparation of superior seeds, provision of fertilizers, weed control, pest and disease control, and harvesting. Patchouli oil distillation activities are the provision of patchouli herbage, the rental of distilled equipment, and the sale of patchouli oil.

Sustainable patchouli cultivation is patchouli cultivation aimed to produce patchouli herbage as a raw material for distillation of patchouli oil at the highest productivity and the best quality, achieved by applying cost-effective and environmentally friendly innovations. Developing sustainable patchouli
cultivation in smallholders’ patchouli farming requires overcoming some smallholder problems that lead it to be unsustainable. There are problems at every stage of the cultivation of patchouli activity, but certainly, not all such problems can be solved simultaneously; they should be prioritized. The prioritization of the problems to be solved can be done based on the influence on productivity and quality of herbage produced. The innovations utilized to solve problems are selected based on cost-effectiveness criteria and environmental impacts.

The problem should be identified in each area and described, followed by probable solution submission (figure 1). The problem description can present the situation by answering ‘what should happen, what is happening, and why is it happening.’ In contrast, in the probable solution submission, the questions are ‘what should be done, and what has been done [10].

![Figure 1](image.png)

**Figure 1.** The steps in problem-solving (adapted from [10]).

### 2.2 Data collecting

This research was conducted in Toari and Polinggona Subdistricts, The District of Kolaka, The Province of South East Sulawesi, in May-June 2021. The research locations were chosen based on the number of farmers who work on patchouli farming and patchouli oil distillers.

The methodology used in this research was qualitative research, and the primary data collected from the key informants consisted of 3 farmers, one private patchouli extension worker, and two distillers. Secondary data was also used, especially related to the general condition of Kolaka obtained from the online publications of the Agency of Statistical Center (BPS) of Kolaka District.

The farmers and distillers who were selected used snowball sampling (chain-referral-sampling) methods, or the selection of respondents based on the reference of other respondents who were first selected in a chain, was chosen by convenience sampling method [11]. Initial key informants were selected based on information from the extension worker. The in-depth interviews were conducted through online communication used open structured questionnaires.

### 3. Results and discussions

Patchouli farming in Kolaka is generally as an intercropping of palm oil, coconut, cocoa, and coffee. In coconut plantations, patchouli is intercropped among immature and old plants. Hence it will change the soil and water balance, particularly affected to the growth and productivity of coconut plants due to the high population of patchouli. In addition, it requires distillation to process patchouli oil, which deploys soil organic matter. Sustainable patchouli oil production can be developed by adjusting farmers’ production process on cultivation and distillation. However, the practices that are not appropriate can cause problematic situations because it impacts decreasing cost-effectiveness or environmental quality. Therefore, to solve the problematic situation can be submitted probable solutions for adjustment. By applying the solutions, the sustainable production of patchouli potentially can improve farmers’ income and welfare in the long term.

#### 3.1 Developing sustainable cultivation

The problematic situation in patchouli cultivation was identified based on problem areas or the sequence of activity in cultivation (Table 1). The problem identified in land preparation activities was that the land available for patchouli cultivation was from coconut, palm oil, or coffee. The land’s soil is generally marginal due to the minimal organic matter and tends to be sandy (except in newly opened forest land). At the same time, patchouli requires clay and organic matter [12][13]. Since the addition of organic
matter can determine the sustainability of patchouli cultivation in available land and can avoid the tendency of the cultivations to move to use newly opened forest land, then the development of organic fertilizer production with compost and manure is a must.

Table 1. Description of problematic cultivation situations and probable solutions.

| Problem area         | Problematic situations                                                                 | Probable solutions                                                                         |
|----------------------|----------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------|
| Land preparation     | • Patchouli well-grow at the soil that tends to contain clay and organic matter,        | • In soil with poor organic material, it is necessary to be added organic fertilizer;      |
|                      | • The available land is mostly sandy and low organic except for newly opened forest land,| hence it needs to develop compost production                                             |
|                      | • Patchouli planting is mostly done on land in the hallways of coconut, palm oil, and coffee crops. | • Due to the rare of organic matter, some farmers use distillation waste as a source of organic matter |
| Seed preparation     | • It should be used certified seeds (superior varieties)                                | • Government initiates sustainable-certified seed production                              |
|                      | • Uncertified local seeds are still widely used                                         | • Introduction of superior varieties                                                     |
| Fertilization        | • Fertilization is required at every stage of patchouli growth                          | • Organic and inorganic fertilization is indispensable to increase the production        |
|                      | • Fertilization is still very limited, especially on newly opened forest land            | and quality of herbage                                                                   |
|                      | • Fertilization is still considered too expensive because patchouli farming is a       | • Fertilization is still limited with inorganic fertilizers                              |
|                      |   relatively high risk.                                                                  |                                                                                           |
| Weed control         | • Weed control should be done manually or mechanically                                  | • Weed control should be conducted at least twice in two months after transplanting      |
|                      | • Some farmers still use herbicides for weed control                                     | • Introduction of simple mechanical equipment                                             |
|                      | • It is easier and cheaper to control with herbicides                                   |                                                                                           |
| Pest and diseases    | • Most pest and disease control is carried out after an infestation, often too late     | • Pest and disease control should be done preventively                                   |
| control              |   • Budok and bacteria wilted disease is a disease that is difficult to control even    | • The concept of integrated control of pests and diseases has been introduced, although   |
|                      |     though in Kolaka, it is lower infestation rates                                      |     it needs efforts to encourage farmers to adopt gradually, including the use of      |
|                      |   • Budok and bacteria wilted disease caused by *Synchytrium pogostemonis* (fungus) and |     tolerant varieties like Patchoulina 2.                                               |
| Harvesting           |   *Ralstonia solanacearum*                                                               |                                                                                           |
|                      | • Harvesting should be done when the leaves have yellowed evenly                         | • Harvest should be conducted gradually according to the maturity of leaves                |
|                      | • The leaves turn yellow unevenly among the site blocks due to variations in environmental conditions | • Some farmers harvest gradually based on the maturity among the site blocks.               |

Because the source of organic matter in the site is rare, some farmers utilize organic material from patchouli distillation waste. Compost from patchouli distillation waste is of high quality due to pH 9, C-organic 20.08%, C/N ratio 12%, phosphor (P$_2$O$_5$) 0.62%, and moisture content 52.73% [14]. Since that patchouli distillation waste is widely used as additional fuel for patchouli distillation, there must be added from other sources. The use of chicken manure obtained from chicken farms around the site can be suggested to be used as a source of organic materials. After the second harvest of patchouli, the use of organic fertilizer is necessary to avoid a decrease in production in the third harvest; even many farmers
can only harvest patchouli twice because the organic matter in the soil is no longer sufficient to support the growth of patchouli in the third period. In addition, organic fertilizer is also to minimize the influence of allelopathy issued by patchouli plants.

Farmers in Kolaka generally plant directly the seeds obtained from patchouli shoots which are then covered with plastic cups. In this way, farmers tend to use the seeds available in the vicinity because they are cheap and easy. It can be understood because the patchouli plant population is about 25,000, so the need for seeds can reach 30,000 per ha. Therefore, farmers purchase patchouli shoots at IDR 15,000-20,000 per kg containing about 100 so that the minimum seed purchase cost can reach IDR 4,500,000 per ha.

Varieties on-site are varieties that pioneer farmers once brought in Kolaka, likely a variety of Sumatera origin, especially from Aceh. The government has introduced superior varieties but has not institutionalized the cultivation of patchouli by farmers. The development of superior varieties should be through multiplication with polybags so that it is easy to be certified and can be sent between subdistricts in Kolaka. The initiation of this certified seed production should be financed by the government, as this initial production will increase the price of seeds at the time of purchase by farmers. However, it is expected that the price of this superior seed is not far from the price of patchouli shoots that are directly planted. Hence, adopting these superior seeds can be faster so that patchouli productivity can increase, unit production costs can be reduced, and the competitiveness of patchouli oil increases.

Fertilization often becomes a determining factor in crop productivity, particularly for plants on relatively marginal land. It has been explained that patchouli in Kolaka is widely grown among the plants of coconuts, palm oils or coffees, that had previously been used to cultivate various annual crops, so the soil tends to be sandy and poor organic matter. Thus, fertilizers with both organic and inorganic fertilizers are necessary to increase productivity and sustainability of production in the long term. In addition, patchouli fertilization can improve the production and quality of herbage when done with other treatments, such as water management and mulch use. For example, the research shows that the production of herbage and the quality of patchouli oil (patchouli alcohol content) increases with mulch. However, fertilization alone can only increase production, but the quality of patchouli oil has the potential to decrease [15].

Fertilization done by patchouli farmers is too little compared to the needs of crops, so normal productions are only achieved at the first or second harvest. In the next harvest, production is decreasing, even some plants have died after the second harvest. However, other factors such as pests and diseases infestations also contributed. For some farmers who conduct better fertilization, the patchouli plants can be harvested at least five times. For most farmers, patchouli fertilization is still considered too expensive because the risk of patchouli farming is relatively high, mainly due to disease infestation. However, farmers acknowledge that income from patchouli farming is an income that contributes significantly to the increase in farmers’ income.

The population density of patchouli plants is very high; however, weeds can grow within two months after transplanting. The recommended weed control is mechanical control with or without tools. This control is better than chemical control using herbicides because it is relatively safe and cheap [16]. Chemical control is not recommended because it adversely affects the biotic and abiotic environment, including patchouli plants themselves. Instead of chemicals in weed controls, it is suggested to implement manual or simple mechanical weed controls. The trash from the weeding can be used as mulch to prevent weeds from regrowing and decrease groundwater evaporation during the dry season. The manual or simple mechanical weed controls eventually can make higher costs than chemical weed control, particularly labor costs in the short term. However, chemical weed control can negatively affect soil fertility and productivity in the long term.

Some farmers still use chemical control before or after planting as long as the cup lid is still attached so that it does not hit patchouli plants. However, this method should be avoided as long as it can still use a safe way for the environment. Introduction of the use of mulch such as rice straw or other trash is highly recommended to hamper weeds type wide leaves (*Portulaca oleracea* L, *Galinsogaciata* L, *Amaranthus gracilis* L), teki (*Cyperus rotundus* L), grass (*Eleusine indica* L) [15]. It is further stated
that the application of minimum soil tillage is also effective for weed control. Patchouli is a plant susceptible to disease infestations, especially budok disease caused by Synchytrium pogostemonis (fungus) and bacteria wilted disease (by Ralstonia solanacearum). The infestation rate of both diseases is very high and very quickly spread, so it is very detrimental to farmers. Thus, the control must be done in an integrated manner. It starts from land selection (not replanting patchouli plants at the same land without rotation), the building drainage, the healthy seeds used and have relatively tolerant to diseases, the use of biological agents to increase resistance, and the proper dose of fertilization. If this effort is still not successful, the use of pesticides is the last choice.

Most farmers have not implemented the concept of integrated control, so they still rely on control with pesticides. The government has introduced the concept of integrated pest and disease control, but further efforts are needed to encourage gradual adoption. The bacteria wilted disease can spread quickly especially following the flow of water rain. Therefore, it is necessary to be aware that it is better to be eradicated with surrounding plants when there are already infected plants.

Patchouli harvest is done by cutting the stem and leaving the bottom two branches or about 15 cm from the ground surface to accelerate the growth of the next plants. Harvesting is done at 56 months for the first harvest and 3-4 months for the next harvest, with the characteristic yellowing leaves on most plants indicating optimal physiological maturity. It is recommended that the harvest be done in the morning to obtain the highest content of patchouli oil. However, in the sun during the day, it can result in volatile patchouli oil evaporation. In addition, variation of the environmental condition among the site blocks, particularly the shady and water supply, can make the maturity of the plants unevenly. Hence, some farmers with wider land harvest gradually according to the maturity among the site blocks.

### 3.2 Developing sustainable distillation

Patchouli herbage produced sun-dried (2-3 hours) to vaporize the outside water then dried indoors (2-3 days). The herbage is cut into smaller sizes before distillation to speed up oil extraction. The kettle used should be a stainless steels kettle to obtain clear patchouli oil.

| Problem area     | Problematic situations                                                                 | Probable solutions                                                                 |
|------------------|----------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------|
| Herbage preparation | • The patchouli herbage should be dried indoors before distillation, some farmers distilled herbage without indoor drying<br>• It could be a lack of information or forced due to the distillation queue schedule | • It should be planned that the number of plants harvested should be adjusted to the capacity of the distillation kettle.<br>• Some farmers who have large patchouli land have harvested gradually adjusted to the capacity of the equipment. |
| Distillation equipment | • Distillation uses stainless steel kettle with a capacity of 300-500 kg<br>• Some distillers do not use stainless kettles, and the capacities are less than 300 kg.<br>• There could be a lack of information and investment capital to install standard distillation equipment. | • Farmers are directed to use standard distillation equipment that produces a better quality of patchouli oil<br>• Most farmers have known about good distillation because the quality of patchouli oil yielded can influence the selling price. |
| Sale of patchouli oil | • Sales is arranged according to the selling price<br>• Sales are forced to be done even with a low selling price<br>• Due to the urgency of the need for cash | • Increasing the role of farmers’ organizations to address cash needs<br>• Capable farmers can delay selling patchouli oil when the price is low while waiting for a better price. |

The distillation method used is a steam method with a 300-500 kg capacity, with a distillation time of about 7-8 hours. Some distillers do not use stainless steel kettles, so the quality of patchouli produced
does not meet the standard requirement due to the low patchouli alcohol, and the color is too dark.

The main problem of patchouli farming is the selling price fluctuation; farmers’ incomes become erratic. To deal with this problem, some farmers can already delay sales waiting for prices to increase, or at least when urged to cash needs, farmers can gradually sell to obtain better sales still. If farmer organizations can provide soft loans, then the farmer’s problem is no solution. The lowest selling price of patchouli oil, in general, can still cover the costs incurred by farmers (Table 2).

4. Conclusion
Patchouli oil is an exported commodity widely produced in Southeast Sulawesi province, especially in the District of Kolaka. Nevertheless, to realize sustainable production of patchouli oil, which is environmentally tolerable and economically feasible, efforts are needed to address problems that are not yet following the principles. Some problems in cultivation and distillation that must be addressed according to their activities are (1) the low suitability of available land, (2) limited availability of certified seeds, (3) low level of fertilization, (4) herbicides used in most of weeding, (5) pesticide application in most disease controls, and (6) immature leaves harvesting, (7) non-stainless steel kettles utilization; and (8) fluctuation of selling price of patchouli oil.

The probable solutions could be applying (1) the patchouli superior variety, which is suitable with coconut plants; (2) good agricultural practices in an intercropping pattern, including what is the most suitable crop for the intercropping pattern; (3) the intercropping pattern with the perennial crops also can be seen as income source diversification, so that it can help the farmers if the patchouli oil price is declining. These are important factors in realizing sustainable production of patchouli oil.

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