Sustainability of masoyi (Cryptocarya massoy (Oken) Kosterm) for essential oil industry materials

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Abstract. Excessive exploitation without cultivation caused harvest of masoyi (Cryptocarya massoy (Oken) Kosterm) from forest to be more difficult. Cultivation outside of natural habitat becomes important to ensure sustainable masoyi oil production. This research presents information on the prospects for cultivation and growth rates of masoyi plants outside natural habitats. The research method used a plot design conducted at three locations, namely (1) Haurbentes Research Forest, Bogor Regency, West Java Province; (2) Boalemo Protection Forest Management Unit (PFMU), Gorontalo Province; and (3) community land in East Lombok Regency, West Nusa Tenggara Province. The results showed that the soil characteristics in the Haurbentes Research Forest were more suitable for masoyi plant growth. This is because the Haurbentes area has a texture of clay dust, climate classification type A. However, the characteristics of growing areas in Boalemo and East Lombok showed that masoyi plants were still able to grow. Thus, masoyi plants have the potential to be cultivated outside their natural habitat.

1. Introduction

Essential oil is the result of distillation from plant parts (roots, stems, bark, rhizomes, leaves, fruits, seeds, and flowers) that are liquid and volatile [1]. This oil is classified as vegetable oil and has a distinctive aroma. Indonesia has around 500 types of essential oil-producing plants. At least 40 out of 80 types of essential oil-producing plants traded in the world grow in Indonesia [2]. Based on Minister of Forestry Regulation No. P. 35 of 2007 concerning Non-Timber Forest Products (NTFPs), masoyi (Cryptocarya massoy (Oken) Kosterm) is one of 20 types of NTFPs producing essential oils under the jurisdiction of the Ministry of Forestry. Masoyi oil produces a distinctive aroma (such as the aroma of coconut, caramel, milk) and high levels of lactone.

Masoyi is a tree species with a height above 30 m, the upright trunk is straight and untwisted. It has greenish-gray bark with 5-15 mm thickness [3]. Topul et al. [4] mentions that the hydro distillation from bark, wood core, and fruit parts of masoyi produces pale yellow oil, with the main components of bark and wood core oil being massoia lactone C-10 and massoia lactone C-12, while the main fruit oil constituents is benzyl benzoate (68.3%). Core wood also contains C-14 massoia lactone (1.4%) and saturated d-decalactone C-10 derivatives (2.5%). Massoia lactone is needed in the chemical industry, especially in the food industry, cosmetics as a flavoring agent and raw material for drugs. Massoia lactone (synonym 5 hydroxy 2 decenoic acid delta lactone cas No. 54814-64-1) meets regulation 872/2012/EC as a safe flavoring agent. Some research results mention that masoyi bark essential oil is...
a potential in vitro immunomodulator, anti-bio-film and antimicrobial (Hertiani et al., 2018; Permanasari et al., 2017).

Masoyi oil ranks 8th in the production of essential oils in Indonesia. The amount of masoyi oil production in 2016 has an average production value of 15-20 tons/year [2]. The selling price of masoyi oil is divided based on its lactone compound content, which is 50% lactone content (IDR 2.5 million/kg), 70% (IDR 4 million/kg) and 90% (IDR 9 million/kg) (personal communication, 2019). The high selling value has an impact on the high demand for raw materials in masoyi oil production.

Until now, the raw material for making masoyi oil is in the form of tree bark obtained through collection activities from nature in the masoyi endemic region, Papua Island. Exploitation was carried out by cutting down trees and directly skinning the trunk has accelerated the reduction of masoyi stands at the tree level. If the oil yield is assumed to be 2%, 750-1000 tons/year masoyi bark is needed to produce 15-20 tons/year of masoyi oil. If a 30 cm diameter masoyi tree produces 100 kg of masoyi bark [7], then in one year 7500-10000 masoyi trees will be felled. This condition threatens the continued availability of raw material for masoyi oil in Indonesia. This is evidenced from the research of Hutapea et al. [8] which shows the presence of masoyi at the pole and tree level is very low due to harvesting activities. To ensure the sustainability of the raw material for masoyi oil, the Research and Innovation Agency of the Ministry of Environment and Forestry has carried out masoyi development outside its natural habitat, namely Sulawesi Island (Boalemo), the West Nusa Tenggara Islands (Lombok Timur), and Java Island (Bogor). This paper presents information on the prospects for cultivation and growth rates of masoyi plants outside natural habitats to support the continuity of supply of essential oils. It is expected that research results can provide information on the potential of masoyi plants to be developed outside their natural habitat.

2. Materials and Methods

2.1. Materials

Data collection was carried out from three planting trials of masoyi in: 1) Haurbenties Research Forest, Bogor Regency, West Java Province, 2) Boalemo Production Forest Management Unit (PFMU), Boalemo Regency, Gorontalo Province, and 3) community land in Timbenuh Village, Pringgasela District, Lombok Timur Regency, West Nusa Tenggara Province.

2.2. Method

2.2.1. Characteristics of growth places

Characteristics of masoyi planting trials was collected through desk study from literature and reports from relevant agencies.
2.2.2 Trial planting of masoyi outside the natural habitat

Planting trials were carried out through three stages: (a) provision of planting material (seedlings), (2) planting, and (3) maintenance.

2.2.2.1. Seedlings

Fruit was collected from the masoyi population in the natural forests of Fak-Fak Regency, West Papua Province. The seeds were sown 2 weeks after harvesting. Before sowing, fruit flesh was discarded. Furthermore, the seeds were soaked 24 hours with water at room temperature. Seeds were then soaked in Dithane solution for 2 hours to kill the fungus carried by seeds. The seeds were sowed in a medium mixture of soil+charcoal+cocopeat in a greenhouse with 50% paranet shade. After the seeds produced seedlings with a number of leaves > 2 strands, seedlings were transplanted to polybags containing soil+sand+charcoal husks. Seedlings used for planting were 6 months old with a height of over 45 cm.

2.2.2.2. Planting

Masoyi planting is carried out in three locations as follows:

a. Haurbentes Research Forest, Bogor Regency, West Java Province.
   The plot was established in 2016. The initial condition land was shrubs. The observation form was in a path with a distance between plants in 2 m lane and a distance between path in 10 m lane (2 m x 10 m).

b. Boalemo Production Forest Management Unit (PFMU), Boalemo Regency, Gorontalo Province.
   The initial condition was unproductive natural forest production and dominated by shrubs. The research plot was built in 2015 with a spacing of 4 m x 5 m.

c. The community land of Timba Nuh Village, in East Lombok Regency, West Nusa Tenggara Province.
   The plot was built in 2018 which was planted along the boundaries of community land with a distance between plants of 5 m.

2.2.2.3. Maintenance

Maintenance carried out in the three research plots in the form of:

a. Basic fertilization with 2 kg of manure per planting hole 30 x 30 x 30 cm.

b. Weeding by removing the weeds around the 1 m diameter plant. Weeding was done 2x/year.

c. No fertilization was added.

2.2.2.4. Growth measurement

The observation plot was made by a line plot containing 20 plants. The number of plot in each location was as follows: Haurbentes Research Forest was 12 plots, Boalemo PFMU was 5 plots, and East Lombok was 19 plots. Variables of growth parameters included survival rate, height, and diameter. The diameter of the stem was measured at the base of the stem as high as 10 cm from the ground. Masoyi stand at Boalemo and East Lombok were measured once at 2 years old. Masoyi stand at Haurbentes was measured regularly each six months since plantation until 3 years old (6 measurements).

2.2.2.5. Data analysis

Data were analyzed to obtain the mean and standard deviation of height, diameter, survival rate, and MAI. Specifically for growth data at the Haurbentes Research Forest site, a regression analysis was performed to determine the relationship between diameter and height to plant age.

3. Results and Discussion

3.1. Results

3.1.1. Characteristics of the masoyi planting area

Based on the literature study, it showed that the masoyi planting trial area has a medium range of topography, but has different climate with wide variations and varied soil textures (Table 1).
Table 1. Land characteristics of masoyi planting trials

| Variables | Location                  |
|-----------|---------------------------|
|           | Haurbentes¹ | Boalemo² | Lombok Timur³ |
| Elevation (m) | 200-250 | 400-600 | 300-400 |
| Slope (%)   | 25-45    | 15-25    | 15-25 |
| Soil type   | Red yellow podsolik | Red yellow podsolik | Reddish brown latosol |
| Soil texture | Clay sandy dust | Dusty clay sand | Clay dust sand |
| Precipitation (mm/years) | 4276 | 1475 | 1100 |
| Wet season (months) | 11 | 7 | 6 |
| Dry season (months) | 1 | 5 | 6 |
| Minimum temperature (°C) | 23 | 21 | 20 |
| Maximum temperature (°C) | 28 | 34 | 30 |

Sources: ¹[9]; ²[10]; ³KPHL Rinjani Timur

The site condition provide a varied growth response. In general, the site condition in Haurbentes Research Forest has a sandy clay dust, while in Boalemo and East Lombok the texture of the land is dusty sand and clay dust sand. The soil texture in Boalemo and East Lombok tends to be higher in sand content than in Haurbentes Research Forest. Thus, soil conditions at the Boalemo and East Lombok research sites are more porous compared to at the Haurbentes Research Forest site.

Based on the Schmidt and Ferguson classification, the rainfall type in Haurbentes Research Forest area is type A and does not have a dry month (rain fall less than 60 mm/month) [9]. The climate type in Boalemo PFMU is type D, which is temperate and is influenced by the rainforest season [10]. The climate type in the Rinjani Timur KPH area is type D (moderate) and E (slightly dry), which is the condition of the region with rainfall between semi-dry to moderate.

3.1.2. Trial planting of masoyi outside the natural habitat

3.1.2.1. Seedlings

Masoyi seeds are semi recalcitrant, so the seeds were sown directly (2 weeks after harvesting). Single leaf emerged after 30-32 days. Rate germination was 70%. Seedlings were raised in the nursery for 6 months to reach a standard height of 45 cm for planting.

3.1.2.2. Growth

The growth of 2 years old masoyi in the three sites showed that the highest to lowest masoyi plant successively was in the Haurbentes Research Forest, East Lombok, and Boalemo. The average diameter of the largest to the smallest is in the Haurbentes Research Forest, Boalemo, and East Lombok. Planting trials in the three sites showed that the growth of the masoyi plants in the Haurbentes Research Forest was the best. Data recapitulation is presented in Table 2. Growth curves of height and diameter and picture of 2 years old masoyi can be seen in Figures 2, 3, and 4.

Table 2. The growth of 2 years old masoyi in three sites

| No. | Location                  | Diameter | Height | Survival (%) |
|-----|---------------------------|----------|--------|--------------|
|     |                           | Mean (cm) | SD (cm) | MAI (cm/years) | Mean (m) | SD (m) | MAI (m/years) | Mean | SD |
| 1.  | Lombok Timur, Nusa Tenggara Barat | 0.34 | 0.07 | 0.17 | 1.29 | 0.24 | 0.69 | 75.8 | 22.6 |
| 2.  | Boalemo, Gorontalo         | 0.83 | 0.80 | 0.42 | 0.82 | 0.27 | 0.41 | na  | -   |
| 3.  | Bogor, Jawa Barat          | 1.12 | 0.20 | 0.56 | 1.65 | 0.23 | 0.86 | 81.0 | 7.5 |

Remarks: SD = Standard of deviation; MAI = Mean Annual Increment, na= not available
Figure 2. Height growth of masoyi at three planting sites

Figure 3. Diameter growth of masoyi at three planting sites
Figure 4. Growth performance of 2 years old masoyi at three sites

3.2. Discussion

3.2.1. Characteristics of planting sites

Planting a species outside of natural habitat requires taking consideration the similarity of the site with its natural habitat. The parameters observed are the physical properties of the site (altitude and soil type) and climate (rainfall, temperature, humidity, and canopy cover).

The natural distribution of masoyi is spread throughout the provinces of West Papua and Papua (Figure 5). In West Papua province, it is found in Manokwari Regency, Ransiki District, Windesi, Teluk Wondama District (Wasior), Teluk Bintuni Regency, Fak-Fak Regency, Kaimana Regency, Sorong Regency (Sorong District, Moraid District), and Teminabuan Regency; whereas in Papua Province it is spread in Nabire Regency, Yapen Waropen Regency (South Yapen District), Biak Nunfor Regency (East Biak District, North Biak, West Biak, South Supriori), parts of Jayapura Regency and parts of Merauke Regency [11]. Hutapea et al. [8] mentioned the potential of masoyi in Teluk Bintuni Regency was 1593 individuals/ha, higher than the Kaimana District which was 871 individuals/ha. However, this potential was dominated by seedling (80-90%) and sapling (5-13%), and only 1 individual/ha at tree level. The low natural distribution and plant at tree level seem to be caused by the need for habitus and high exploitation of masoyi at tree level. Therefore the biophysical information of the masoyi natural habitat becomes important to be considered on the suitability of the edaphic factor for masoyi development.
Based on natural distribution of masoyi in three districts namely Nabire, Bintuni, and Manokwari, Yeny et al. [11] concluded that the masoyi natural habitat is on a fairly wide slope range of 2-60% and rainfall 1300-2500 mm/year, but has a narrow range in terms of elevation, soil type, soil texture, and effective depth. Furthermore Hutapea et al. [8] conducted a survey of the natural distribution of masoyi in Bintuni and Kaimana and stated that masoyi grew at an altitude of between 50-1100 masl, and grew scattered (not clustered). Based on the study of Yeny et al. [12], Hutapea et al. [8] and this study (Table 1) can be concluded that masoyi can adapt to climate types A (very wet regions), D (temperate regions), and E (slightly arid regions) according to the Schmidt & Fergusson classification, and elevation 200-475 masl. Masoyi can grow in areas with temperatures of 21-34°C. The results of masoyi planting trials until 3 years old indicate that masoyi are able to grow in the elevation range of 250-600 masl with rainfall between 1100-4276 mm/year (Table 1).

Based on the characteristics of three planting sites, the Haurbentes Research Forest area is most suitable for masoyi plantation compared to the two sites of Boalemo and East Lombok. This is presumably because the Haurbentes Research Forest has climate type A with wet months throughout the year, and texture conditions of sandy clay dust. However, in Boalemo and East Lombok the texture of the clay is dusty clay sand and clay dust sand with low rainfall. Soil and climate characteristics in Boalemo and East Lombok have higher sand content, the soil is more porous so it dries faster. More porous soil conditions with low rainfall result in slower growth of masoyi plants (Table 1). However, with the characteristics of growing places in Boalemo and East Lombok it turns out that masoyi plants still have a high survival rate, which is above 75%. Thus, masoyi plants have the potential to be developed outside their habitat on the terms of agro-climate and edaphis such as in the Haurbentes Research Forest, Boalemo, and East Lombok.

3.2.2. Trial planting of masoyi outside of natural habitat
Propagation of masoyi plants can be done by generative and vegetative. Vegetative propagation can be obtained through seeds and wildlings. Germination rate of seeds reach 70%. Since masoyi seeds are recalcitrant and seed sources/parent trees are rare, vegetative propagation should be forced. It can be done by cuttings and the rooting percentage reached 72% using mix media soil+sand (2:1, v/v) [13].

The study showed that Masoyi had better growth in Bogor than two sites. This is indicated by the MAI diameter and height of 2 years old masoyi in the Haurbentes Research Forest which are 0.65
cm/year and 0.86 m/year, respectively. Compared with other forest tree, the growth of masoyi is similar to the growth of *Vatica sumatrana, Hopea mangarawan, Dryobalanops lancelolata, Dipterocarpus* sp., with MAI diameter and plant height at 2 years old less than 1 cm/year and 1 m/year [14,15].

Planting trials showed that masoyi is a semi-tolerant plant. Therefore, masoyi is able to grow in open areas by gap planting. Masoyi also can be used as an enrichment plant in unproductive Log Over Area (LOA) forest by applying a line planting or gap planting.

Using vegetative propagation method, the production of masoyi seedlings can be performed in any places. Then, it allows masoyi as a noteworthy NTFPs in forest areas and community forests. Local people in Papua Island cut the masoyi tree with minimum diameter 15 cm, which is generally reached by trees aged 10 years. Based on masoyi growth up to 3 years old in Haurbentes Research Forest, the harvest age will be achieved at the age of 15 years. If one masoyi tree with a diameter of 15 cm produces 7.5 kg of masoyi bark, then to produce 20 tons of masoyi oil/year (same as production value in 2016) takes 133,333 trees/year. If the planting distance is 5 x 5 m, then planting and logging are needed with an area of 333 ha/year.

Masoyi is slow-growing tree species, so it requires a long observation time for predicting growth and yield of stands up to 15 cm in diameter. Therefore, observations will continue to predict the economic cycle of the masoyi stand. Masoyi economic cycle is the time length to produce an economic diameter of the masoyi tree for harvesting. Economic cycle information data is important because it deals with the prospects of masoyi plantation on a business scale. Other effort to be conducted is to develop improved masoyi by breeding to find faster growth of masoyi.

### 4. Conclusion

Masoyi showed better growth at Haurbentes site, Bogor Regency, than at the Boalemo and East Lombok sites. Site characteristics in the Haurbentes Bogor Research Forest are clay sandy dust texture with climate classification type A. However, masoyi is able to grow in the site characteristics of Boalemo and East Lombok. Thus, masoyi has the potential to be cultivated outside their habitats as long as the agro-climatic and edaphic conditions are the same type as natural habitat.

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