The use of improved cajuput seeds to encourage self-sufficiency in cajuput oil in Indonesia

Sumardi, N K Kartikawati, Prastyono, A Nirsatmanto and A Rimbawanto
Center for Forest Biotechnology and Tree Improvement, Jl. Palagan Tentara Pelajar Km.15, Purwobinangun, Pakem, Sleman, Yogyakarta, Indonesia
E-mail: sumardi_184@yahoo.com

Abstract. *Melaleuca cajuput* sub sp *cajuput* is an indigenous species in Indonesia which primarily used for the cajuput oil industry. The demand for cajuput oil is reported at around 3,500 tons/year, while the national capacity production is only around 600 tons years\(^{-1}\) due to lack of grower interest in planting and low productivity of the existing plantations. Following the success of the genetic improvement of cajuput in which oil yield and cineole content are improved, carried out by CFBTI, a program to increase oil production through developing plantations using genetically improved seeds was developed in six provinces. Five small-growers and one company were involved in the program covering 35 ha and 2000 ha of a plantation, respectively. This paper aims to report the progress of the program by focusing on the impact of the improved seed and people’s participation in developing cajuput plantations. The paper also discusses the projected impact for further development of the plantations, including government policy to support increased national production of cajuput oil as well as ensuring the market. The results showed that oil productivity varied among small-grower sites ranging from 93.75 to 171.6 kg ha\(^{-1}\) year\(^{-1}\), while for the company it could be increased to reach oil productivity of 175.5 kg ha\(^{-1}\) year\(^{-1}\) through innovative technology either in the plantation or in the distillation process. As compared to the previous system using ordinary un-improved seed, the oil productivity in the program increased around 62 – 116%. The program also revealed that the cajuput industry could be managed effectively and efficiently while maintaining the sustainability and continuity of high oil production so that Indonesia will become self-sufficient in cajuput oil.

1. Introduction

*Melaleuca cajuput* subsp. *cajuput* is an indigenous species in Indonesia, it has an economic value due to its essential oil content in its leaves that has been widely used as materials for medical or pharmaceutical products [1]. In Indonesia, it grows natively in Moluccas (Ambon, Seram, Buru Island, and surrounding small islands) and Timor Island [2]. Besides growing naturally in its place of origin, this plant has been cultivated as cajuput plantations in Java Island. There are more than 30,000 hectares of cajuput plantations in Java which are managed by Perum Perhutani and KPH Yogyakarta.

Indonesia is one of the countries with the biggest consumption of cajuput oil. Currently, the national production of cajuput oil is still insufficient as compared to the demand for raw material for the domestic cajuput oil packaging industry that is estimated at around 3,500 tons year\(^{-1}\) [3]. Although it was reported that around 30,000 hectares of cajuput plantation in Java and 120,000 hectares of cajuput natural stand in the Moluccas are existing, Indonesia’s national cajuput oil production is only about 600 tons year\(^{-1}\). Therefore, such shortfall of ± 3000 tons year\(^{-1}\) has triggered the fulfillment of raw materials through importing substitute eucalypt oil from China which is then mixed with local cajuput oil in
pharmaceutical industries [3]. The reason for this low supply includes less grower interest in planting and the low productivity of cajuput plantations. The existence of a large gap between the supply and demand for cajuput oil in the country does not trigger the development of cajuput plantations. This could be due to the lack of information about cajuput plants and their cultivation, there are no models of successful cajuput cultivation, or there is a mindset that importing substitute oils is more economically profitable [4].

Increasing production of cajuput oil can be achieved through simultaneous intensification (using superior seeds) and extensification (area expansion) of cajuput plantations [4]. Cajuput genetic improvement of cajuput by the Center for Forest Biotechnology and Tree Improvement (CFBTI), has provided the superior seed that potentially produces plants with high oil yields as well as high cineole content. The current average of oil yield from cajuput plantations in Java is only around 0.60 – 1.00%, while the superior seeds can produce more than 1.20% of oil [5]. Following the success of the genetic improvement of cajuput in which oil yield and cineole content are improved, carried out by CFBTI, a program to increase oil production through developing plantations using genetically improved seeds was developed in six provinces. In this program, genetically improved seeds and technical supervision were provided by CFBTI. Five small-growers and a company were involved in the program covering 35 hectares and 2000 hectares of plantation, respectively. Nonetheless, the opportunity for extensification remains promising, because cajuput is a species that grows well on marginal lands with low to moderate rainfall.

This paper aims to report the progress of the program by focusing on the impact of the improved seeds and people’s participation in developing cajuput plantations. The paper also discusses the projected impact for further development of the plantations, including government policy to support increased national production of cajuput oil as well as ensuring the market.

2. Materials and methods

2.1. Cajuput business framework

In this study, the development of cajuput plantations using genetically improved seeds was carried out on two different scales, namely a small scale by small-growers and a large scale by a national company in Indonesia. The small-scale cajuput plantation was carried out by 5 small-growers in 5 sites in Indonesia, namely Papua, Madura, Gunungkidul, Lampung, and Riau. The total area of the plantation for all farmers in the study location is about 35 hectares. Meanwhile, the large-scale cajuput plantation was carried out by a national company in Bima - West Nusa Tenggara. To date, the company has converted 2,000 hectares of bush and Savana into cajuput plantations.

To ensure the sustainability of cajuput oil production and market, a “core-plasma” concept was developed. Small-growers and a company that produces cajuput oil are the “plasma” and a pharmaceutical industry that collects and buys cajuput oil as the “core”. This concept is not only to guarantee the sustainability of production and the market but also to ensure the stability of competitive prices.

2.2. Study sites

Cajuput plantations are established in five small-growers in Papua, Madura, Gunungkidul, Lampung, Riau and and one company in West Nusa Tenggara.

2.2.1. Study site in Papua. The cajuput plantation in Papua is established in Kampung Rimbajaya, East Biak District, Biak Numfor Regency, in collaboration with Biak Numfor Forest Management Unit (FMU) in Papua Province. Geographically, the plantation is located at 1°08′21.7″ S - 136°12′56.8″ E at an altitude of about 60 m above sea level. The average rainfall in Biak Numfor in 2019 was 198 mm with the highest rainfall was recorded in June (318.5 mm), and the lowest was in August (102.7 mm). The average rain day in a month was 18 rain days.
2.2.2. Study site in Madura. The cajuput plantation in Madura is established in Kebun, Kamal District, Bangkalan Regency, East Java Province, located at 7°09′35.4″ S dan 112° 43′33.9″ E with an altitude of about 5 m above sea level. The average rainfall in Madura in 2019 was 108.33 mm with the highest rainfall occurring in December (251 mm), and the lowest was in August (0 mm). The average rain day in a month was 9 rain days.

2.2.3. Study site in Gunungkidul. The cajuput plantation in Gunungkidul is established in Plot 93, Playen District, Gunungkidul Regency, Yogyakarta Province. The site is located at 7°58′55.8″ S and 110°29′28.9″ E in an altitude of about 145 m above sea level. The average rainfall in Gunungkidul in 2019 was 153.08 mm with the highest rainfall occurring in March (527 mm), and the lowest was in June-October (0 mm). The average rain day in a month was 15 rain days.

2.2.4. Study site in Lampung. The cajuput plantation in Lampung is established in Sukamenanti, Bukit Kemuning District, North Lampung Regency, Lampung Province. The site is located at around 4°52′13.8″ S and 107°34′55.4″ E with an altitude about 700 m above sea level. The average rainfall in Lampung during 2019 was 153.36 mm with the highest rainfall was in February (412.8 mm), and the lowest was in September (0 mm). The average rain day in a month was 14 rain days.

2.2.5. Study site in Riau. The cajuput plantation in Riau is established in Karya Indah, Tapung District, Kampar Regency, Riau Province. The site is located around the geographic position of 0°32′41.9″ N and 101°19′15.6″ E with an altitude of about 51 m above sea level. The proportion of rainfall in Riau during 2019 was 164 mm with the highest rainfall was in January (449 mm), and the lowest was in June (26 mm). The average rain day in a month was 15 rain days.

2.2.6. Study site in Bima - West Nusa Tenggara. The cajuput plantation in Bima is established in Oi Katupa, Tambora District, Bima Regency, West Nusa Tenggara Province. The site is at 8°8′59.9″ S and 118°7′18.8″ E and it’s surrounded with an altitude of about 30-150 m above sea level. The average rainfall in Bima during 2019 was 164 mm with the highest rainfall was in January (449 mm), and the lowest was in June (26 mm). The average rain day in a month was 12 rain days.
2.3. Planting materials of improved cajuput
The results of the cajuput breeding program with local genetic sources have been able to increase the productivity of cajuput oil yield from 0.8% (an average) to 1.25% -1.5%. Superior cajuput seeds have been produced and are available to the public. This pilot project in five small-growers and a company were considered as a testing ground for the actual genetic gain of improved seed, as well as an attempt to introduce the cajuput industry on a home industry scale and larger scale.

3. Results and discussions
3.1. Pilot plantations of cajuput
Pilot plantations of cajuput were developed using superior seeds. The superior seed for this program was supplied by CFBTI as a product of the breeding program. The seeds were collected from SSO Paliyan, Gunungkidul Regency with a potential oil yield of 1.25% - 1.5% [6]. Preparation of seedling is one of the critical steps due to some difficulties, including the process of germination and prickling out. Nurseries were prepared at each site of the plantation to minimize the damage to the seedlings due to transfer.

The first small-scale plantations (10 hectares) of cajuput were established at Gunungkidul, in 2005-2006. Planting was carried out in two phases, the first phase was a 5 ha-plantation in Plot 93 Playen-Gunungkidul (2005) with a plant spacing of 1.5 x 4 meters (1,666 trees/ha), and the second one was in Plot 95 Paliyan-Gunungkidul (2006) with a plant spacing of 1 x 3 meters (3,333 trees/ha) in an area of 5 ha. The pilot plantation of cajuput in Gunungkidul was equipped with an oil distillation unit. This pilot project, however, was not run well because the interest and involvement of growers in the process of cultivation, harvesting, and distillation were limited. Currently, only about 15,000 trees were remaining in the two plantation sites.

The second pilot project of cajuput plantation was developed in Rimba Jaya Village, East Biak District, Biak Numfor Regency, Papua Province by small growers in 2015 in an area of 5 ha. Seedlings were planted in plant spacing of 4 x 1 meters to set the tree density of 2,500 trees per hectare. The trees were monitored periodically, -i.e. every six months-, to assess the tree productivity and anticipate any potential threats of pests and diseases. The plants showed excellent growth at this location, indicating that the soil and climatic conditions were suitable for cajuput. At 18 months of age, the average tree height was 6 meters with an average diameter of 7.2 cm [7]. Because of this outstanding growth, the leaves were first harvested after 18 months of planting, i.e. 6 months earlier than common practices in the commercial cajuput plantations in Java.

Following the pilot projects in Gunungkidul and Papua involving small-growers, in 2016 the pilot project of cajuput plantation involving a national company in Bima, West Nusa Tenggara was initiated targeting a 4,000 ha new plantation of cajuput. Planting started in 2016, so far, about 2000 hectares have been planted with a spacing of 2 x 1 meter, -a total of about 10 million trees-. Cajuput plantations in Bima were managed intensively (land preparation, planting, maintenance, and harvesting). Land preparation was done by tilling the soil, applying fertilizer and aquasorb gel in the planting hole to hold water longer. Watering with a large capacity water gun was also carried out to provide water to the plantation. The was equipped with infrastructure and an oil distillery containing 5 pots with a capacity of 3 tons of leaves. Thus the total capacity is 15 tons of cajuput leaves for a time of distillation process. The first harvest was also done at two years of age.

The success of the pilot project of cajuput plantations by small-growers in eastern Indonesia has inspired the development of cajuput plantations in western and central Indonesia, namely in Lampung, Riau, and Madura started in 2019. Cajuput plantations in Lampung, Riau, and Madura were established on an area of 5 hectares, 10 hectares, and 5 hectares, respectively, with a plantation space of 2 x 1 meter in Lampung and Riau and 4 x 1 in Madura. The number of trees varied between locations, namely 24,450, 42,000, and 12,500 for Lampung, Riau, and Madura, respectively.
3.2. Leaf biomass and oil production of cajuput

Oil productivity is influenced by oil yield and leaves biomass production. The higher oil yields and leaves biomass production will produce higher oil productivity of cajuput. All locations of the pilot plantations of cajuput in Gunungkidul, Papua, Bima, Lampung, Riau, and Madura used the same seed from seedling seed orchard (SSO) Paliyan Gunungkidul. The first harvesting of cajuput leaves is commonly practiced at two years of age considering the stability of essential oil produced and also the performance of trees for pruning. The coppice system was practiced during the first harvesting by cutting the main stem of the cajuput tree at around 1 meter above the ground. The second harvest onward of the coppice is done every 9 months.

Currently, 15,000 trees are remaining in the pilot plantations of cajuput in Gunungkidul. Production of leaves biomass in the first harvest was 9.41 tons ha\(^{-1}\), while in the second harvest it was 4.05 tons ha\(^{-1}\) with the assumption that the survival rate was 90%. The oil yield in the first and second harvests was 1.05% as the plants were still young (<3 years) [7]. When the plants were matured (>3 years) or in the third harvest, the oil yield reaches an optimal yielding of 1.3% and is assumed to be stable until the end of the cajuput biological cycle at 25 years of age [8]. The cajuput plantation in Gunungkidul has the potential to produce oil of 98.80 kg, 42.53 kg, and 52.65 kg ha\(^{-1}\) in the first, second, and third harvests until the 33\(^{rd}\) harvest at the end of the cycle (25\(^{th}\) year). Based on this figure of oil production, the 10 hectares cajuput plantation in Gunungkidul has the potential to generate revenue of IDR 247 million in the first year, IDR 106.3 million in the second year, and IDR 131.6 million in the third year onward, provided that the farm gate cajuput oil price was IDR 250,000 in 2018 [Director of Perum Perhutani 2019, pers. Kom.].

The pilot plantations of cajuput in Papua of 5 hectares with a total of 12,500 trees were able to produce cajuput leaves biomass at the first harvest of 16.65 tons ha\(^{-1}\) and 8.24 tons ha\(^{-1}\) in the second harvest. The potential oil yields from the cajuput plantations were 174.83 kg ha\(^{-1}\), 86.47 kg ha\(^{-1}\) and 107.06 kg ha\(^{-1}\) respectively at the first, second, and third harvests until the 33\(^{rd}\) harvest at the end of the cycle. The potential revenue from its plantations was IDR 218.5 million in the first year, IDR 108.1 million in the second year, and IDR 133.88 million in the third year onward. Financial analysis of the small-scale cajuput plantation in Papua showed that the NPV for 25 years at a 9.2% discount rate was IDR 757,171,972 (IDR 151,434,394.32 ha\(^{-1}\)), IRR of 72.74%, BCR of 1.77, and payback period after 2 years and 3 months [7].

A large-scale cajuput plantation by a national company in Bima in an area of 2,000 hectares with about 10 million trees of cajuput produced leaves biomass and cajuput oil larger than the cajuput plantations managed by small-growers. The production of leaves biomass for cajuput in the first harvest was 31.37 tons ha\(^{-1}\), while in the second harvest it was 13.5 tons ha\(^{-1}\). This is due to the intensive management of plants and optimization of plant spacing by the company. The cajuput plantation in Bima can produce cajuput oil of 329.33 kg ha\(^{-1}\), 141.75 kg ha\(^{-1}\), and 175.50 kg ha\(^{-1}\) in the first, second, and third harvests, respectively, until the 33rd harvest at the end of the cycle. The potential revenue of cajuput plantations in Bima was IDR 164.7 billion in the first year, IDR 70.9 billion in the second year, and IDR 87.8 billion in the third year onward.

Production of leaves biomass in Lampung in the first harvest was 30.67 tons ha\(^{-1}\), while in the second harvest it was 13.20 tons ha\(^{-1}\). Cajuput leaf distillation in Lampung was carried out using a distillation unit with a capacity of 100 kg of leaves. The average oil yield is 1.05%. Based on the total leaves biomass and yield, the cajuput plantation in Lampung were able to produce 322.09 kg ha\(^{-1}\) of oil in the first harvest and 119.07 kg ha\(^{-1}\) of oil in the second harvest and 119.07 kg ha\(^{-1}\). The potential income of a 5-hectare cajuput plantation in Lampung is IDR 402.6 million in the first year, IDR 173.3 million in the second year, and IDR 214.6 million in the third year and so on.

Meanwhile, the production of cajuput leaves biomass in Riau in the first harvest was 26.36 tons/ha, while in the second harvest it was 11.35 tons ha\(^{-1}\). Cajuput leaf distillation in Riau was carried out using a distillation unit with a capacity of 500 kg of leaves. Based on the total leaves biomass and yield, cajuput plantations in Riau were able to produce 276.64 kg ha\(^{-1}\) of oil at the first harvest and
ha\(^{-1}\) at the second harvest at 9 months after pruning. Oil production in the third harvest onward is 147.42 kg ha\(^{-1}\). The potential revenue of a 10-hectare cajuput plantation in Riau is IDR 691.6 million in the first year, IDR 297.7 million in the second year, and IDR 368.6 million in the third year onward.

The cajuput plantation in Madura has not been harvested even though it is 2 years of age because of the unavailability distillation unit. However, based on the seeds used for the establishment of cajuput plantations, the same as those used for Lampung and Riau locations, cajuput plantations in Madura are predicted to have the same potential leaves production per tree and oil yield. Thus, it can be predicted that the production of cajuput leaves biomass in Madura in the first harvest was 16.76 tons ha\(^{-1}\) while in the second harvest it was 7.21 tons ha\(^{-1}\). Based on the total leaves biomass and yield, the cajuput plantation in Madura can produce 175.93 kg ha\(^{-1}\) of oil in the first harvest and 75.72 kg ha\(^{-1}\) in the second harvest. In the third harvest onward, oil production in the cajuput plantation in Madura was 93.75 kg ha\(^{-1}\). The potential revenue of 5-hectares cajuput plantation in Madura is IDR 219.9 million in the first year, IDR 94.7 million in the second year, and IDR 117.2 million in the third year onward.

3.3. Contribution to national cajuput oil production

The results showed that oil productivity varied among small-grower sites ranging from 93.75 to 171.64 kg ha\(^{-1}\) year\(^{-1}\), while for the company it could be increased to reach oil productivity of 175.5 kg ha\(^{-1}\) year\(^{-1}\) through innovative technology either in the plantation or in the distillation process. As compared to the previous system using ordinary un-improved seed, the oil productivity in the program increased around 62 – 116%.

The total potential of cajuput oil production from five small-growers and one company at the pilot plantations of cajuput in Gunungkidul, Papua, Bima, Lampung, Riau, and Madura is 463.9 tons year\(^{-1}\). This amount contributes to the fulfillment of national cajuput oil needs by 13.26%. Furthermore, this amount represents 43.61% of the total national cajuput oil production.

The total cajuput oil production of 463.9 tons year\(^{-1}\) from the pilot plantations in the six provinces is equivalent to IDR 116 billion or equivalent to IDR 8.3 million USD (1 USD = 14,000 IDR). Thus, if the pilot plantations of cajuput are managed properly, it will be able to contribute to saving the country's foreign exchange of 8.3 million USD annually from imports of substitute oil in (eucalypt oil).

The long-term benefits of cajuput development program on a large scale in multiple locations in Indonesia include reducing dependence on imports of substituted oil, encouraging the development of domestic industry-based businesses, increasing community empowerment, increasing conservation of natural resources and the environment, saving foreign exchange, and even increase the country's foreign exchange through export potential. The program also revealed that the cajuput industry could be managed effectively and efficiently while maintaining the sustainability and continuity of high oil production so that Indonesia will become self-sufficient in cajuput oil.

4. Conclusion

Cajuput oil productivity can be increased through innovative technology either in the plantation or in the distillation process. The total potential for cajuput oil production in the pilot plantations of cajuput in six provinces is 463.9 tons year\(^{-1}\) (13.26% of domestic cajuput oil demand).

The pilot plantations of cajuput that have been developed prove that the cajuput oil industry can operate well and produce biomass leaves and oil yields by the potential of their superior seeds. These plantation models can be applied at other sites to accelerate cajuput oil self-sufficiency.

References

[1] Kartikawati N K, Naiem M, Hardiyanto E B, Rimbawanto A 2013 Improvement of seed orchard management based on the mating system of cajuput trees Indonesian Journal of Biotechnology 18(I) pp 26-35 (https://doi.org/https://doi.org/10.22146/ijbiotech.7865)

[2] Craven L A, Barlow B A 1997 New Taxa and New Combinations in Melaleuca (Myrtaceae) (Novon, 7 pp 113–119)

[3] Rimbawanto A 2017 Budidaya Tanaman Kayuputih (Minyak Kayuputih Dari Tanaman Asli Indonesia Untuk Masyarakat Indonesia) ed Hardiyanto E B and Nirsatmanto A (Yogyakarta,
Acknowledgments

The author is very grateful to Mr. Sunaryanto (Gunungkidul), Mr. Suroto (Gunungkidul), Mr. Aristoteles (Papua), Mrs. Anita (Papua), Mrs. Salma (Papua), Mr Jimmy Sumitro (Bima West Nusa Tenggara), Mr. Ari Wibowo (Lampung), Mr. Agus (Riau), Mr. Sampurno (Riau) and Mr. Mahfud (Madura, East Java) for their help and support on data collection.