Ebony (Diospyros celebica Bakh.) cultivation: A short review

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Abstract. Ebony (Diospyros celebica Bakh.) is an endemic tree species of Sulawesi. Based on the World Conservation Monitoring Centre, it is one of the protected tree species and listed in IUCN Red List under the category of vulnerable. This species is well known for its beautiful and luxurious wood. In practice, natural forests dominated by Diospyros can be managed using the Indonesian Selective Logging System (TPTI). The purpose of this paper was to determine the cultivation and management techniques of ebony plants in order to establish ebony plantations and their conservation strategy. Data were collected based on primary field observation and review of previous research written by other authors. Direct field observations were conducted to collect data on the management of seed, scarification techniques, germination, and seedling growth increment (height and diameter), while secondary data were collected from Diospyros-related studies. From the study, it was identified that the best time to produce fruit for the species was between September - November, with a germination rate, was up to 94.67%. The recommended parent trees should be over 20 years old. Seedlings were weaned when having 2 - 4 leaves with compost enriched with NPK as the best planting media. The seedling can be moved to the planting location after the age of 8 - 9 months with weeding as the initial treatment. The optimum growth for nine-year-old Ebony trees may reach 6.5 m in height and 6.63 cm in diameter and this growth may still be seen for 12 years old trees that showed 9 m in height and 12.81 cm in diameter. Based on this optimum growth, it is prospective to establish ebony plantation and or enrichment planting as long as the silvicultural aspect described in this study was used as a basic guideline.

1. Introduction
Ebony (Diospyros celebica Bakh.) is endemic species of Sulawesi. Its native or natural habitat can be found in South Sulawesi, Central Sulawesi, and West Sulawesi. Ebony in Sulawesi is distributed in South Sulawesi (East Luwu, Sidrap, Barru, Maros, and Gowa Regency), Central Sulawesi (Poso, Parigi, and Donggala Regency), and West Sulawesi (Mamuju Regency) [1, 2, 3]. Ebony is a fancy wood and much favored by consumers, both local and international, because it has a beautiful pattern [4] and durable wood [5]. Since the Dutch colonial era, ebony has become a commodity of trade, led to the production and the population reduction. Around 1990, the ebony wood production depleted, which led to the issuing of Minister of Forestry Decree No. 950/IV-TPHH/90, regarding the prohibition of felling ebony except by special permission from the Department of Forestry at the time. With the concern of its population condition, ebony has become one of the protected species of flora [6].
Ebony growth has its own characters; therefore, it is necessary to consider the properties of its natural growth. The nature of growth is slow, and the creation of a wooden terrace (black-colored part) with good quality requires a considerable amount of time. Along with the development of silviculture science and technology, we can devise a guideline in the cultivation of ebony plants both in natural forests and plantations. The purpose of this article is to review and discuss the cultivation techniques of ebony plants. The data in this study were collected from a field survey and secondary resources.

2. Methodology
Data and information of this article were obtained through field surveys (with direct observations and discussions) and secondary data collection (literature references, either electronic or printed media). A field survey was aimed to obtain data and current information about the stage of ebony cultivation, such as management of seed [7], scarification techniques [8], germination, and seedling growth increment (height and diameter) in the nursery [9, 10]. Direct measurements were done in the greenhouse and the nursery of Environment and Forestry Research and Development Agency of Makassar (BP2LHK Makassar). Discussions were held with lecturers or practitioners in ebony cultivation.

A literature review was done by collecting and reviewing the results of studies conducted in the Faculty of Forestry at Hasanuddin University, particularly by ecology and conservation lecturers with knowledge and experiences in ebony cultivation. The secondary data were generally obtained from scientific journals, proceedings, books, and academic papers (thesis, research report, etc.), which were published after the year 1990s.

3. Management of Ebony in Natural Forests
In the natural forests of Sulawesi island, Diospyros trees can be found with a height reaching 40 m, clear bole height of 10 - 21 m, and diameter up to 100 cm. The large trees might even have buttresses of 3 m high [11]. The formation of ebony stands was managed by the Indonesian Selective Logging System. In this system, natural regeneration ensued from [12], removing small trees that are less valuable to partially-open canopy cover. It is followed by clearing the undergrowth to reduce resource competition with other species. [2] Diospyros seedlings are shade tolerant, usually grow, and develop into saplings around the mother tree.

At the end of the fruiting season, the seedlings will be abundant if the condition coincides with the rainy season. Natural seedlings usually survive at the seedling stage. If there is competition for space and lighting, the natural seedlings may not survive. [11] as for surviving individuals, they are usually scattered or located far from the mother tree. Ebony requires shade to grow at its early phase in natural forest (in situ) [11]. While in ex situ condition, Ebony requires appropriate silvicultural techniques to optimize its growth.

Excessive forest harvesting, have resulted in the depletion of ebony stock in natural forests. An inventory of ebony populations in the Kalaena Nature Reserve found 28 individuals in the tree stage, 45 in the pole stage, and 910 and 2,599 individuals in the sapling and seedling stage, respectively. A different result is found in Ponda-Ponda Natural Reserve. Based on this inventory, the population of ebony was 46, 66, 383, and 2,314 individuals in the tree, pole, sapling, and seedling stages, respectively [13]. The differences in the individual components may be due to the availability of nutrients and seeds, and probability, but there is still very little information available on how regeneration occurs.

However, the growth of ebony in nature can be optimized. We can apply the ebony growth cycle (shade-tolerant when young, light-tolerant after matured) by the spacing setting between the young seedlings, shade settings, and horizontal-vertical trimming. [14] Vertical trimming by removing the upper part of the trees and canopies that shaded sapling, while horizontal trimming by cutting competitive plants around the seedling, at a minimum radius of one meter.

The ebony commodity is economically valuable. Therefore, it is crucial to use the best practice in preserving and cultivating ebony. These practices may be government policies or regulations on-field
actions for conservation such as planting activities in native (in situ) or outside (ex-situ) growing areas. [15] Several ex-situ conservation practices for ebony species has covered some issues such as plantation development, private and community forests, and garden plantation or reforestation.

[16] pointed out that ebony is a slow-growing, with Mean Annual Increment (MAI) of the volume was 0.5 m$^3$ ha$^{-1}$ year$^{-1}$, while the MAI of stem diameter was 0.5 cm ha$^{-1}$ year$^{-1}$. It was estimated that it would take 80 years to reach the volume of 40 m$^3$/ha/year. Experiment by [11] resulted that in Java island during the first 20 years, its diameter increment was 1.5 cm year$^{-1}$, then decreased to 0.5 cm year$^{-1}$.

The average height and stem diameter of nine years old ebony in Makassar was reported to be 6.5 m and 6.63 cm, respectively, with a diameter increment of 0.69 cm year$^{-1}$. In the same location, 12-years old trees showed an average of height up to 9 m, stem diameter reached 12.81 cm, and diameter increment of 1.59 cm year$^{-1}$. Furthermore, the growth of 12 years old ebony and 10 years old ebony in Palu City was reported as follows. The average height, stem diameter, and diameter increment of 10 years was 9.25 m, 6.53 cm and 0.66 cm year$^{-1}$, respectively. At the age of 12 years, the trees had reached 12 m high with stem diameter 9.08 cm, and increment diameter 0.76 cm year$^{-1}$. The growth of ebony in open environments such as urban forests or reforestation was more significant than in natural forests with high dense vegetation.

Regeneration of the sapling stage for ebony species was very low, i.e., one wilding per hectare with 1% distribution. In the logged-over forest, wildings of ebony species appeared to be in poor condition but still better than in the natural forest [12, 17]. Therefore, the management of logging rotation, minimum diameter tree for logging, and residual stand after logging is essential to set to ensure the availability of ebony trees in the nature. The most recommended logging rotation was 45 years by considering diameter cutting 35 cm [18], whereas trees with a diameter over 50 cm were rarely found due to their slow growth. Residual stand after logging should be at least 25 trees ha$^{-1}$ in good conditions with a stem diameter of 15 - 34 cm. Furthermore, enrichment planting is recommended after logging [16].

4. Ebony Cultivation
4.1. Management off fruit and seed
Ebony seedlings still derived mainly from natural regeneration, with low quality, and limited uniformity is still a weakness requiring the production of seedlings from the nursery. [4] stated that climatic conditions and growing places influence the fruiting season for ebony trees. The differences that occur result in different fruiting times.

Ebony trees have flower and bear fruit throughout the year, fruits ripe generally in September-November, but not all the trees in one group stand are fruiting every year [19]. Ebony trees are usually clustered. So that if there is a tree separated from other trees, it cannot bear fruit because it is not occurred in crossbreeding. Fruiting is generally had a dominant canopy, and fruiting on the branches are generally found in the outer canopy [20, 4, 11]. Procurement of ebony fruit for preparation of seeds should be obtained from mother trees that are more than 20 years old, with a straight trunk, cylindrical, good branching and canopy shape and healthy tree conditions [16].

The fruit is picked or climbed from the mother tree when making it as a seed. If the fruit falls, it is quickly damaged by fungi of the type Penicilliopsis clavariaeformis. The fruit of ebony has ten seeds, but only 20 - 80% become good seeds. The seeds are classified as recalcitrant seed (germinate quickly), so they cannot be stored for a long time. Based on direct observation, the color of ebony fruit is light green-brownish when immature and dark green-yellowish with brownish spots when mature. The seeds are dark brown. The average of fruit production is 16.37 kg tree$^{-1}$, which produces seeds ranging from 682 grains kg$^{-1}$ - 1,100 grains kg$^{-1}$ ([18], [21] and [16] reported: South Sulawesi averages 800 grains kg$^{-1}$ and Central Sulawesi averages 1,150 grains kg$^{-1}$). The characteristics of morphologically mature fruit can be seen in Figure 1.

[21] stated that the shade effect on the production of ebony is very influential. More flowers produced by the ebony tree without shade, with 11 fruits/branches. When without the effect of
shading, ebony may produce more fruit by 490 fruits/trees with average fruit weight 16.82 g fruit\(^{-1}\) and seed weight 1.13 g seed\(^{-1}\). Whereas the ebony tree is shaded with a shade intensity of 40% - 60%, only about 80% of the flowering part of the tree, and produces an average of six fruits/branches, fruit production 204 fruits tree\(^{-1}\), average fruit weight of 13 g fruit\(^{-1}\), and seed weight of 0.77 g seed\(^{-1}\). The information is crucial for practitioners or cultivators for planning in the production of ebony seed.

The fruit may be collected by climbing the mother tree for the preparation of the seed. Another technique is gathering mature fruit from a tree after the fruit has fallen down. The best practice for handling ebony seeds has been carried out directly in the laboratory. After fruit collection, the fruit is packed and extracted (the fruit is peeled to get it seeds) with ripened for 24 hours for easy stripping. Then wring the fruit to remove seeds. Furthermore, the seeds are washed with water and sterilized by soaking liquid fungicide for two hours. [18] This way to avoid fungal attack from *Peniulliopsis clavariaeformis*. Based on direct practice, the seeds must be dried in a room (temperature 28°C) for 12 hours. Then the seeds are selected to be used as good and healthy seeds. Procurement of ebony seeds [22], i.e., ripe fruit is peeled, then the seeds are washed and soaked in water with a solution of *dithane* for one hour, to avoid fungus seed, before planting.

A standard for the determination of healthy seeds was based on direct observation. Healthy seeds are blackish brown, medium-large size, not crinkly, be drowned when putting in water, and sometimes having radicle roots. Selected ebony seed should have a length of 2 - 5 cm, thickness from 0.5 to 1.5 cm, grain weight from 0.5 to 2.0 grams, or around ± 1,100 grains kg\(^{-1}\) or 480 grains liter\(^{-1}\).

During the storage period, ebony seeds experienced physiological changes of ebony seeds bear which decrease the seed moisture content and germination. The biochemical changes of ebony seeds increase fat and protein content and also decrease the levels of carbohydrate content along the storage period. Based on these physiological and biochemical reactions, the seed of ebony is categorized as recalcitrant seeds.

Germination of the ebony seed depends on the time and storage technique. Ebony seeds that are directly sown without being stored have seed viability of 90%. The mighty ebony seed loses its
viability 50 - 85% with interval 2 - 3-week storage in general. The germination with fresh seeds may reach 90%, while those which stored for 12 days in the refrigerator, the germination decrease to 20% [23]. Ebony seeds were stored using charcoal powder for 12 days have seed viability of 70%. In another report, the seeds should be wrapped in a moist gunny sack 80 - 90% for keeping seed viability above 50% [23, 18].

When the supply of ebony seeds is inadequate, it can take seedlings in nature (natural seedling). The growth of natural seedling appeared to be better than seedling in the nursery [24]. One of the factors was the environment adaptation during the process of seedling growth. The production of natural seedlings may reach 500 – 4,000 individuals at a radius of ± 5 m around the mother tree. In a radius of ± 10 m, only found ± 50 individuals. The farther away radius from the mother tree, the less the number of seedlings.

Natural seedlings are considered acceptable if they have 2 - 4 leaves. Natural seedling was taken by pull out gently from the ground, then wrapped with banana stem-midrib (the observation of result in the field and the greenhouse). The function of banana stem-midrib is maintaining natural seedling moisture stabilization on the transport process to the nursery. Half of the roots and lengths of the seedlings were cut before planting in a polybag. Cutting the roots as the guarantee of avoiding any folded roots that can cause rot or source of disease while cutting the leaves aimed to reduce evaporation. The natural seedlings are covered for approximately two months for the environmental adaptation process.

4.2. Nursery management

The stages and criteria for ebony nursery generally follow the principles of existing nurseries. Planting media for nursery must consist of a mixture of soil, sand and compost with comparison (3 : 1 : 1) and the addition of NPK base fertilizer (1 - 1.5 g/polybag). The size of the good polybag is 12 cm x 17.5 cm, with a media weight of ± 2 kg [21]. Sapling seeds are given routine maintenance such as watering, weeding, and eradicating pests and diseases if there are symptoms of an attack.

The treatment for ebony seedlings is different from natural seedling. The natural seedlings that have been taken are covered with clear plastic material to reduce evaporation. The lid is opened every morning between 08.00 - 10.00 am to facilitate circulation and reduce moisture in the lid room. [22] stated that natural seedlings might be maintained in the lid for 1-2 months for environmental adaptation. Natural seedling needs shading with the intensity of 50 - 75% when the lid has been removed and kept in the nursery for 7-10 months, and ready for planting when the seedling height reached 30 - 40 cm [25, 24]. The survival rate of natural seedlings decreased by 5 – 10% every seven days of storage and decreases up to 20% at three weeks of storage after tugging [26].

Layout arrangement of polybag seedlings significantly affecting the growth of seedlings in the nursery. In the case from direct observation found that tightly distance between the polybags is better than the width distance because the close distance produces higher humidity [27]. The close distance between the polybag is obtained plant height by 23.3 cm, stem diameter of 2.93 mm, Seed Quality Index (SQI) of 0.17. When the polybag given distance of 5 x 5 cm, acquired plant height of 20.9 cm, stem diameter of 2.70 mm, SQI of 0.145, and the ebony seedlings aged seven months.

![Figure 3. Conditions of ebony seedlings in the nursery.](Source: BP2LHK Makassar)
At the age of 8 - 10 months, ebony seedlings may reach a height of ± 20 cm, and the number of leaves is 8 - 10 strands. Silvicultural treatment by applying fertilizer of urea 0.5 g polybag\(^{-1}\), ebony seedlings can produce a growth height of 28.7 cm and a diameter of 4 mm at the age of 7 months in the nursery [28]. Furthermore, the addition of 0.5 grams of NPK /polybags can produce a growth height of 27.8 cm and a diameter of 4.9 mm at the age of seven months in the nursery [29]. Ebony seeds were soaked with indole hormone butyric acid as much as 3 mg/L, which promotes seedlings growth height of 12.3 cm and viability of 93% at three months in the nursery [30].

4.3. Planting management

Planting ebony in logged areas will give better performance when using a pathway-lined planting technique because ebony is semi-tolerant, which requires shade during seedling. In this technique the residual trees can be used as shade nursing or shade trees. The best characteristics of ebony are shade-growing and non-allelopathic species; hence lane of planting was cleared with a width of one meter. The distance between the lanes was adjusted by the specified spacing, 4 m in the lane and 5 m between lanes.

The best time to plant ebony is at the beginning of the rainy season. The planting hole was prepared at least ten days before planting, and the hole size is 30 x 30 x 30 cm (L x W x H). The provision of basic fertilizer was adjusted to the conditions of the soil at the planting location. Infertile soil was added with 20 grams of NPK fertilizer/hole, while less porous soil conditions added 3-4 kg of compost or charcoal powder/plant. The seedling could be planted under a seven years old eucalyptus stand with a spacing of 3 m x 3 m. Fertilizing of ebony plants with NPK as much as 30 g plant\(^{-1}\) can reach a height of 66.8 cm and a stem diameter of 9.2 mm at the age of 23 months in the field [31].

Initial maintenance for the ebony plant with weeding and making dishes (soil clumping around plants). Weeding of ebony was planned every three months, or plants can compete with weeds, or plant height ± 100 cm or age between 2-3 years. Replanting to replace dying plants can be done when the plant’s age is one month in the field, along with the evaluation of the percentage of life.

Ebony plants needed direct light after over two years old so that the planting in logged-over areas needs to be freed from shading. [32] stated that ebony plants at the age of three months after planting require shading of 70-80%, and after the age of six months, they require shading of 40-60%, then weeding need to be carried out gradually, until the plants are able to adapt to their environment. Another result showed planting of seedling with a height of 50 cm, requires only shade around 30% until the age of two years.

[33] and [14] stated that the ebony plants could grow well under the shade intensity between 76 - 85%. The shading gives the seedling height increase of 4.7 cm for one year. However, that result must be followed with horizontal-vertical clearance for lighting and removal of disturbing plants. Fertilization after planting is a part of ebony plant maintenance. The NPK fertilizer as much as 6 g/plant, then fribbing soil width of 50 cm, which can increase growth by 50% after four months of planting in the field [34]. The use of shade can influence the growth of ebony. Therefore, in the cultivation of ebony, this factor becomes very important to consider for farmers.

5. Conclusion

The ebony species (Diospyros celebica Bakh.) is one of the endemic species of Sulawesi. The ebony plantation has been done in several places both inside and outside the original site to preserve its sustainability. However, in many planted sites, the plantations were grown unsuccessfully. This failure is due to the planting project that have not been followed by the maintenance activities. The maintenance was done only in the first year after planting, so the growing percentage of ebony was low. By ensuring the needs of ebony, need for regeneration and good management, particularly the silvicultural knowledge and cultivation will support the preservation and production of ebony.
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