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Natural growing site and cultivation of Pongamia (*Pongamia Pinnata* (L.) Pierre) as a source of biodiesel raw materials

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Natural growing site and cultivation of *Pongamia* (*Pongamia Pinnata* (L.) Pierre) as a source of biodiesel raw materials

A Aminah and D Syamsuwida

Forest Tree Seed Technology Research and Development Centre, Jl Pakuan, Ciheuleut PO BOX 105 Bogor, Indonesia

Email: aamaminah515@yahoo.com

Abstract. *Pongamia* (*Pongamia pinnata* (L.) Pierre) is one of biodiesel source raw material plants. Natural site conditions and an appropriate planting technique of this species are necessary to be investigated. The purpose of this study was to assess the quality of natural growing site and the cultivation of *pongamia* through the plantation of seedlings based on provenances. The seedlings were originated from 5 different populations of Java Island. Soil was sampled at each location to determine the rate of soil fertility in natural habitat compared to soil sample at cultivation site. The plantation was carried out in Parungpanjang Research Forest with spacing of 3 m x 3 m. Characteristics of growth observed up to 6 months old were total height, stem base diameter, seedling survival percentage and leaf number. The results showed that *pongamia* in Java grows in less fertile natural habitats. The initial growth of *pongamia* provenance test in Parungpanjang showed that seedlings from Carita had the best growth of height (83.75 cm) and diameter (0.85 cm). *Pongamia* was able to adapt to the environmental conditions which are different from its natural conditions, indicated by the high percentage of survival i.e ranging from 88% (Kebumen) to 100% (Batukaras).

1. Introduction

Pongamia (*Pongamia pinnata* (L.) Pierre) known by local name of keranji or malapari is a prospective plant to be a source of biodiesel raw material [1]. This species has various habitat distribution and grow well at any condition. It's found usually in coastal areas, calcareous areas and corals, alongside of mangrove forests and tidal rivers. As a source of renewable energy raw materials, the cultivation of these plants should be encouraged to meet the material needs in the form of fruit. However, a review of the natural distribution of this species is necessary to determine the adaptability of its growth when it is planted outside the natural habitat.

Naturally, the growth of plants is influenced by environmental and genetic factors. The most effect of environmental factors on the plant growth are 1) soil nutrition and moisture, 2) sunlight and heat, 3) oxygen and carbon dioxide in the air [2]. [3] pointed out that tropical tree variation is determined by the combination between temperature and rainfall variation. The rise of temperature is negatively correlated with tree growth, the higher the temperature the growth rate will decrease. In addition, the specific soil characteristics will affect the types of plants that grow on it and this is reflected from the dominant species in the ecosystem concerned [4].

Related to the growth of seedling in the field, [5] mentioned that genetic and environmental factors strongly affect the seedling vigour and [6] stated that the ability of the plants to adapt to new growth sites indicated by the number of seedling survival. *Pongamia* requires warm and long summers (30-



40°C) during the day and warm at night (minimum 17 °C), and capable of growing on low-productivity farms, thus minimizing competition with food crops or the associated resources of fertilizers/water/land needed for food production and cattle fodder [7].

The available information indicates that for now there has been no research results that evaluate in detail the influence of growing site on the growth of pongamia seedlings gathered from various populations. Therefore, in this study, the quality of natural growing site and adaptability of pongamia seedling in Parungpanjang were conducted. The study was aimed to assess the quality of natural growing site and the cultivation of pongamia through the plantation of seedlings based on provenances.

2. Materials and Methods

2.1. Location and periods of the study

There were 5 locations of selected pongamia stands in Java Island i.e, Carita (Banten Province), Batukaras-Pangandaran (West Java Province), Ambalresmi- Kebumen (Central Java Province), Alas Purwo and Baluran National Park (East Java Province). The cultivation of pongamia was carried out in Parungpanjang Research Forest- Bogor positioned at 106°30'52,29" E.L and 6°22'53,53" S.L, at the altitude of 52 m a.s.l. Location of fruit collection was presented in figure 1. The study was started from September 2015 to September 2016.



Figure 1. Location of fruit collection from western to eastern Java, Indonesia. 1. Carita, 2. Batukaras, 3. Kebumen, 4. Alas Purwo and 5. Baluran (Source: [8]).

2.2. Materials and Equipment

The materials of pongamia seedlings, soil and organic fertilizers were used and the equipment were regular scale, hoe, ruler and calliper.

2.3. Procedures

2.3.1. Collection of field data

Field data collected were geographical position, rainfall, annual mean temperature, altitude and soil fertility. Soil was sampled from the depth of 10 – 20 cm under every sample tree (4 retrieval points). The samples were then composite for each population [9]. Soil samples from every population were analysed for its fertility in a laboratory of Soil and Plant of SEAMEO BIOTROP, Bogor, West Java.

2.3.2. Planting design

The spacing of 3 m x 3 m with the size of planting hole of 40 cm x 40 cm x 40 cm were used to grow the seedling. Three kg of organic fertilizer was put in a planting hole as a basic fertilizer which contains of 3.21 % N , P₂O₅, 1.57 % K₂O, 1.57 % Ca, 1.44 % Mg, 250 ppm Mn and 315 ppm Zn [10]. There were 25 seedlings grown for each population and replicated four times. The evaluated

growth characteristics were total height, stem collar diameter, seedling survival percentage and leaf number. The age of evaluated seedling was 6 months old.

2.4. Data analysis

Site characteristics were analysed descriptively. Completely randomized group design was used to analyse the growth characteristics in term of population and the significant different test was using distance test of Duncan. Data presentation in the form of a boxplot using internet online: display of distributions (<http://www.physics.csbsju.edu/stats/box2.html>).

3. Result and Discussion

3.1. Results

3.1.1. The site growing of pongamia

In the natural habitat, pongamia grows along the coastal with the altitude from 0 m to 20 m a.s.l. Grows in a group with rainfall from 1500 mm to 3950 mm per year, mean annual temperature of 20 °C to 34 °C and climate type of A – F [11]. In fact, pongamia is enable to grow well in Parung panjang of 52 m altitude where the location is not in the coastal area and the sand content of 28.8% is lower than in its natural habitat. In addition, pongamia could also grow at very acidic pH (4.3), even though in the natural habitat pongamia grows at neutral and somewhat alkaline pH (table 1).

Table 1. Site characteristics of pongamia in the natural and cultivation habitats

Parameters	Population					
	Carita	Batukaras	Kebumen	Alas Purwo	Baluran	Parung panjang
Altitude (m asl)	0 - 5	0 - 22	8	15	0 - 1	51,71
Rainfall (mm/tahun)	3950	3196	3787	1500	1600	2.500
Mean annual temp (°C)	23-32	25-30	20-34	20-34	27-30	25-28
Climate type (Schmidt dan Fergusson)	A	B	A-C	D-E	F	A
Soil chemistries:						
- H ₂ O pH	8.10	6.60	6.60	7.67	7.82	4.3
- CaCl ₂ pH	7.73	5.80	6.30	7.47	7.28	3.8
- organic C (%)	0.61	0.66	2.37	2.55	1.34	2.29
- total N (%)	0.10	0.09	0.24	0.36	0.17	0.37
- C/N ratio	6.33	7.33	10.00	7.15	7.86	6
- P ₂ O ₅ available (ppm)	32.83	38.57	124.17	54.63	85.90	8.9
- Ca (cmol/kg)	9.03	1.94	5.05	13.56	5.20	5.99
- Mg (cmol/kg)	7.34	3.64	4.32	7.79	12.31	12.89
- K (cmol/kg)	0.17	0.12	1.03	1.63	3.34	0,26
- Na (cmol/kg)	4.19	0.34	0.27	2.36	4.20	0,23
- Total Ca, Mg, K, Na	20.72	6.04	10.67	25.34	25.04	19,38
- Cation change capacity (cmol/kg)	6.03	2.86	11.04	8.76	10.70	27,90
- Saturated alkaline (%)	100	100	96.62	100	100	69,45
- Al ³⁺ (me/100g)	0.00	0.00	0.00	0.00	0.00	9,75
- H ⁺ (me/100g)	0.10	0.10	0.10	0.11	0.11	1,83
Texture:						
- Sand (%)	98,0	65,1	70,8	88,3	93,3	28,8
- Ash (%)	1,3	13,6	24,4	5,7	3,2	13,35

Parameters	Population					
	Carita	Batukaras	Kebumen	Alas Purwo	Baluran	Parung panjang
- Clay (%)	0,7	21,3	4,8	6,0	6,0	57,7

Based on assessment criteria of soil chemistry of [12], the results of soil structure and chemistry at each location showed that the level of soil fertility of pongamia site was in moderate to low category for the component of organic C, total N, C/N ratio, Ca, K and Cation Change Capacity (CCC). Meanwhile, component of P_2O_5 , Mg, Na and alkaline saturated were in high to very high category. Soil pH at each location was varied that is somewhat acid, neutral and slightly alkalis. The assessment criteria of soil chemistry are presented in Table 2.

Table 2. Assessment criteria of soil chemistry at five natural populations and cultivation of pongamia in Java.

Parameters	Population					
	Carita	Batukaras	Kebumen	Alas Purwo	Baluran	Parung Panjang
Organic C (%)	SR	SR	S	S	R	S
Total N (%)	R	SR	S	S	R	S
C/N Ratio	R	R	R	R	R	R
P_2O_5 (ppm)	T	ST	ST	ST	ST	SR
Ca (c mol/kg)	S	SR	R	T	R	S
Mg (c mol/kg)	T	T	T	T	ST	ST
K (c mol/kg)	R	R	ST	ST	ST	R
Na (c mol/kg)	ST	R	R	ST	ST	R
CEC(c mol/kg)	R	SR	R	R	R	T
Alkaline saturated	ST	ST	ST	ST	ST	T
pH	slightly alkalis	slightly acid	slightly acid	Neutral	Neutral	Very acid

Remarks: SR = very low, R = low, S = moderate, T = high, ST= very high CEC = Cation exchange capacity

3.1.2. Initial growth evaluation of seedling

The measurement of pongamia seedling growth of 6 months old achieved from variables of height, diameter, leaf number and seedling survival percentage are presented in Figure 2. It is revealed that seedling from Carita possesses highest average of total height (83.75 cm), diameter (0.85 cm) and leaf number [12].

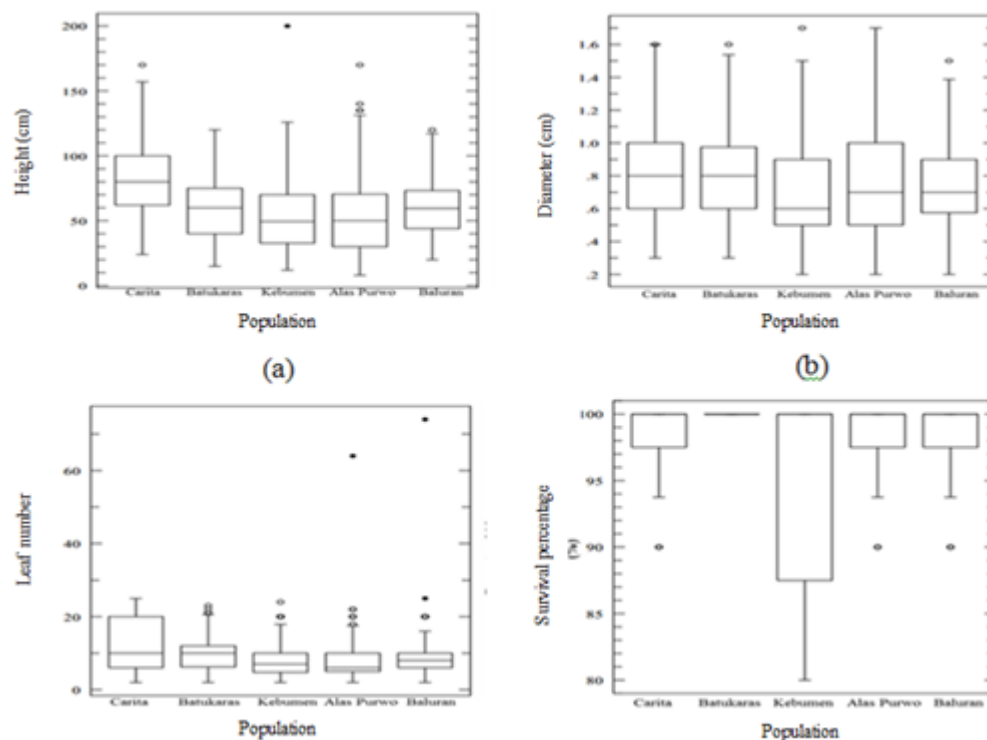


Figure 2. The growth of pongamia seedling from various populations at 6 months old in Parungpanjang (a) seedling height (b) seedling diameter (c) leaf number and (d) seedling survival percentage.

3.2. Discussion

3.2.1. The Growing site of Pongamia

Considering the differences of natural growing sites and cultivation in Parungpanjang, it is suspected that pongamia is a plant that has high adaptability to the site condition which are not the same as their natural habitat. Thus, it can be recommended to be planted on marginal lands where are less fertile or ex-mine lands.

Pongamia which grows on Java Island in its natural habitat such as in Carita, Batukaras, Kebumen, Alas Purwo and Baluran is at a low fertility level. As a result of soil chemical measurements, the soil fertility rate of Alas Purwo shows the highest content of organic C, total N, Ca and total Ca, Mg, K, Na. In addition, the dominant soil texture in all locations of pongamia is sand, because all plants grow on the coastal area. However, this species also grows well on clay texture like in Parungpanjang-Bogor and enable to flower and produce fruit at the age of 5 years old [13].

The high content of P₂O₅ in all the population of pongamia natural site is related to the availability of phosphor within the soil. Phosphor (P) is an essential nutrition that play a role in capturing and converting solar energy into compounds that are very useful for plants, so that the plants can grow, develop and produce well [14].

The other component that has a high value is Mg. The main role of Mg is in the process of photosynthesis, because this element is part of chlorophyll, thus the plant cannot grow perfectly without it. Mg moves inside the phloem, so it will rapidly move towards the top of plants or young leaves that lack of Mg from the old leaves [15].

The content of sodium in the population of Carita, Alas Purwo and Baluran is categorized as high. This might be happened due to the growing of pongamia are in the coastal areas. The sea is the main

source of sodium. Sodium is one of the main elements of mineral crust, sediment and sea waters. Sodium is one of the main causes of suppressed plant growth [16].

The very high values of the base saturation in all the natural population indicates that the rate of soil base saturation influences the easiness of cation to be absorbed by the plants. In addition, the rate of soil fertility and pH are highly correlated to the base saturation [17]. The rise of base saturation will decrease the rate of acidity and increase soil fertility, hence will affect the growth of plants.

Pongamia is bioresource as biodiesel more promising in the near future, compare to nyamplung, jarak, oil palm, etc because this plant can produce fruit at the age of 3 years. As well as, the productivity of pongamia of 29 tons ha/year to 5.000 biodiesel/ha [18].

3.2.2. The Evaluation of seedling growth

The best growth of seedlings in Parungpanjang come from Carita population. It perhaps due to the similarity of climate condition in Parungpanjang and Carita which the distance geographically is close enough (138,6 km) [11]. Based on Schmidt and Ferguson climate type, Parungpanjang and Carita are classified as A climate type, besides that it has similar mean annual temperature (table 1). In association with carbohydrate content, the seeds of pongamia from Carita have a highest percentage of carbohydrate i.e. 57.21% in average that affected the growth quality of seedling eventually [11].

The characteristic of leaf plays important role to assess the growth of the plant. The number of seedling leaves from population of Baluran, Batukaras, Kebumen and Alas Purwo were less than the leaves number from Carita. This is due to an attack by pathogens and insects. The type of pathogen that attacks pongamia is *Phytophthora sp* while the type of insects is grasshopper (figure 3). Although the leaves were eaten by the insects, the plants can eventually recovery, so it does not cause seedlings mortality.



Figure 3. Healthy seedling of pongamia a) Seedling attacked by leaf-eating insect (b)

The highest seedling survival percentage was seeds collected from Batukaras (100%) and the lowest were those from Kebumen (88%). The result of this study was higher than those reported by [19] that the initial growth of pongamia at conservation plots showed the number of seedlings survived was ranging from 40% to 60%. This might be caused by many factors, one of them was related to the implementation of the planting of the seedlings.

In the implementation of the seedlings in the field, many aspects should be paid attention to get good stands of the plants, among others are field preparation, seedlings transportation, cropping pattern determination, planting time, soil conservation and seedling age. The right cropping pattern

starts from setting the spacing and mounting the stakes and holes. The right planting system will make the plants easy to grow and produce good stand of plants.

The successful of provenance trial of 5 populations at Parungpanjang was very interesting because it moved the genetic potential of pongamia from a height of 0 – 22 m above sea level to 52 m above sea level. However, the successful of adaptation would be more complete when the pongamia has flowered and produced fruit (at the age of 3 years old).

4. Conclusion

Pongamia in Java Island grows in less fertile natural habitats. The initial growth of pongamia provenance trial in Parungpanjang showed that the seedlings from Carita had the highest growth of total height (83,75 cm in average) and diameter (0.85 cm in average). The seedlings of pongamia had a great adaptability at a cultivation site indicated by the high seedling survival percentage ranging from 88% (Kebumen) up to 100% (Batukaras).

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