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Seed morphology and germination of *Macadamia (Macadamia integrifolia)* from North Sumatra

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Abstract. Macadamia is an endemic species in Queensland's rainforest and known as one of high economical nut producer. In Indonesia, makadamia cultivated in some research garden in West Java and East Java also can be found in Aeknauli Forest Research in Sipiso-piso. As valuable nut producer, macadamia can be adopted as one of targeted species for restoring Lake Toba through agroforestry scheme. For supporting the successfulness of restoring program using macadamia trees, information on species and seed character was needed, especially about its propagation strategy. But this information still very limited in Indonesia. Therefore, our research was conducted to get information on seed morphology of makadamia and its seed germination process. For seed morphology, data on seed part was quantified through direct observation and measurement. The germination process was quantified through direct observation and its occurrence process. The result on seed morphology showed that macadamia fruit was round shape on ripe condition. The fruit has 2.20 cm diameter average and 8.58 of fruit weight. The seed and endosperm thickness were 0.38cm and 1.54 cm respectively. Macadamia has hypogeal germination type and takes 5-6 months for germinating.

1. Introduction

Macadamia integrifolia was the broadleaf tree, native in Australia with local name Queensland nut, macadamia nut, Australian bush nut [1]. This species has wide range habitat and not specific growth so have been cultivated in many countries in the world. In Thailand, Macadamia has been tested and cultivated in highland areas for more than 40 years. The main area of macadamia nut plantations is located in northern Thailand [2]. In Indonesia macadamia has not been cultivated as an agricultural commodity even though the tree can be found in several places in Indonesia. Macadamia can be found in Indonesia at some research location and Cibodas Botanical Garden. In North Sumatra, macadamia can be found in Sipiso-piso forest.

Macadamia was the prospective product for social economy development in North Sumatra and also promising trees for lake Toba restoring and rehabilitation through agroforestry scheme. Macadamia nut has a high price in the international market as direct consumption and also many utilizations. Macadamia can be utilized as food combination, apiculture purpose, fuel, tannins, lipids, and essential oils. Macadamia oil also containing a high antioxidant which is good for the skin [3]. Macadamia oil has a high value for cosmetics and can be used safely for cosmetic products [4].



In considering with prospective utilization, the high price of nut and ecological benefit of this species, Ministry of environment and forestry also have been chosen this species as one of the targeted species for restoring Lake Toba. Although have many economic and ecological benefit, the information of this species in Indonesia still very limited, especially about seed phenology, seed morphology, and its germination.

As known that, seeds were basic of plant life stage. Seed also genetically and physiologically able to determine the successfulness of the cultivation process. Macadamia seed characterized as semi recalcitrant with very erratic and low, and also not simultaneous germinate [5]. Semi recalcitrant seed characterized by short storage period, sensitive to removal of water and drying process, usually morphologically have larger shape and seed coat. Seed morphology was an important aspect for studies because it can assist generative propagation, dormancy breaking effort and determined the stage and process of germination [6]. Therefore, our research was conducted to determine seed morphology and germination type of macadamia for future breeding and large scales plantation purpose.

2. Materials and Methods

The seed for this research was fresh mature seeds of *M. integrifolia* originate from identified materials in Sipiso-piso Seed Orchard belongs to Aeknauli Forest Research Agency, Merek Subdistrict, Karo District, North Sumatra. This research was carried out at Silviculture laboratory and the seed germination test was carried out at Greenhouse of Aeknauli Forest Research Agency. The initial step of this research was selecting trees using to identified the fruiting trees. The fruit was directly harvesting from identified trees by threshing fruit, picking fruit, and collecting fruit on the forest floor.

Ten ripe fruit was used for morphological observation of seed. Seed morphology measurement conducted through direct measurement of seed part those were seed diameter, seed coat, seed weight, and endosperm condition. Digital caliper and scale were used for this purpose. The morphological observation was conducted through primary observation of whole outer and inner seed part those were fruit colour, shape, endosperm, cotyledon, epicarp colour and endocarp colour. The method for seed morphology observation was following previous research on forest seed.

Germination process was conducted through germinated the seed into the prepared medium (sand: soil). The seed germinated by submerging half the seeds based on seed radicle position. Germination process was observed a measured after the seed was germinated and the seed coat was opened. The stage of seed development was identified based on morphological differences.

3. Results and Discussion

3.1. Seed morphology

Botanically, the fruit of macadamia identified as follicle [7]. Some researcher named as a nut for described the part of kernel and nut in the shell as complete seed. Macadamia kernel consists of two large cotyledons [8] and covered by a single layer of epidermis cell. And when the cotyledon separates during processing, two half kernels was formed.

Our observation on macadamia fruit showed that ripe fruit has dark green pericarp colour, nearly round shape and smooth surface (Figure 1a & b). This same colour and shape also in accordance with previous research on macadamia fruit from Australia. Macadamia cotyledons shape are near round but are looking the same with onions shape (Figure 1c). The top part and bottom of macadamia shell have a different shell thickness and a different colour (Figure 1d). The thicker part was brown, but the other side was yellowish. Testa consisted of the fertilized integument of mature ovule (Figure 1c).

The macadamia seed in pericarp (husk) has several parts [8] those were tannin coated endocarp as interior part, open testa with enamel layer in the inner surface, micropyle at the end of enamel, hilum in the opposite end and embryo that located in testa with cotyledon apex extending towards micropyle. On the inner testa, there were 2 different layers, the half of testa near hilum has dark brown colour and, near micropyle has a light-cream colour (Figure 1d). This testa morphological feature was the important characteristic to describe macadamia seed. The nut of macadamia was difficult to crack and need

extraction and considered forced for extracted the kernel. In spite of the kernel was hard to extract, the testa has the main function as effective embryo protector from predation agent and also prevent the seed from some unfavourable condition of damage [9].

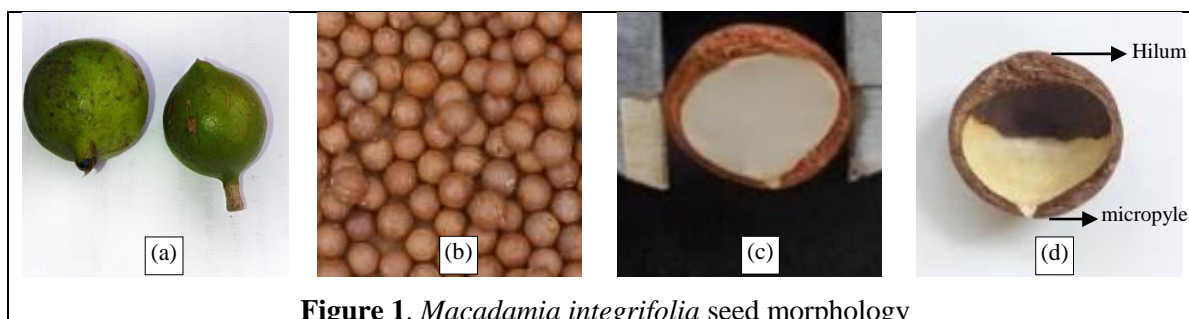


Figure 1. *Macadamia integrifolia* seed morphology

The measurement on fruit, seed, and cotyledon can be shown in Table 1. Macadamia fruit has a round shape with an average of diameters was 2.20 cm and an average of weight was 8.58 g. It's composed seed shells thickness 0.19 - 0.48 cm and the average of endosperm thickness was 1.54 cm. Different research showed, a whole ripe macadamia fruit has a round shape with outer diameters of 25 to 40 mm, Macadamia seed has a spherical shape with outer diameters between 22 and 27 mm, the thickness of the shell wall varies considerably between 1 and 4 mm depending on the specific region of measurement, and seedling (cotyledon) has almost spherical shape with diameters 12 - 24 mm. Its shows, the size of Macadamia planted in Indonesian are not significantly different with other [5].

Table 1. *M. integrifolia* fruit diameters, weight, seed shell thickness, outer diameters, and cotyledons diameters

Seeds	Fruit diameters (cm)	Weight (g)	Seed coats thickness (cm)		Outer diameters (cm)	Cotyledons (cm)
			Up	Down		
1	2.77	14.01	0.48	0.24	0.32	2.03
2	2.5	10.54	0.42	0.22	0.38	1.76
3	2.65	12.08	0.40	0.27	0.40	1.88
4	2.32	8.61	0.39	0.19	0.42	1.62
5	1.55	6.37	0.30	0.23	0.37	0.97
6	1.73	6.31	0.43	0.21	0.35	1.21
7	1.65	5.75	0.40	0.25	0.34	1.17
8	2.25	7.19	0.38	0.23	0.24	1.58
9	2.40	8.36	0.36	0.25	0.42	1.65
10	2.19	6.56	0.31	0.28	0.36	1.56
Mean	2.20	8.58	0.39	0.24	0.36	1.54

3.2 Seed germination

Germination was complex, crucial and basic process on the plant. Physically, the visible sign of germination is usually indicated through the penetration of structures surrounding the embryo by the radicle. It called visible germination [10]. Our observation showed that fresh macadamia seed (without storage) takes 20 days - 115 days after planting to germinate. Whereas the storage seed (2 weeks to 12 weeks) require 23 days - 150 days after planting to germinate. Previous research conducted [11], shows that the process of germination of *M. integrifolia* takes 45-140 days to reach a stable and produces a percentage of germination of 71.5%. It showed that the seeds of *M. integrifolia* take a long time to germinate. It might be caused by shell thickness as a physical barrier for germination. This phenomenon also stated by [12]. Seed dormancy might be caused by a hard and impermeable seed coat. It becomes

a mechanical barrier to for water and gas entry point into the seeds. Dormancy is a mechanism of seeds to survive, but it inhibits seed production on a large and uniform scale. To overcome seed dormancy, the scarification process was needed. The scarification able to soften the hard seed coat, so that it becomes permeable to water and gas.

The hard macadamia shell structure can inhibit germination due to being able to prevent water imbibition and gas exchange. The thickness of macadamia five times higher compared to other types of nuts such as nuts, hazelnuts, walnuts, and almonds [13]. Macadamia seeds have seven layers those were the epidermal layer, outer sclereid layer, sclerenchyma tissue layer, deep sclereid layer, inner layer (consisting of 2 layers, creamy layer, and brown layer, deep testa layer (non-sclerenchyma tissue), vascular vessels. To break the macadamia seed, need 1800-4000 Newton forces.

The germination process is the initial stage of forming new individuals in seed plants. The initial germination process of macadamia seeds was indicated by shell breaking and the appearance of whitish radicle on seed apex hole. After the radicle was emerged, the operculum will open and allowing the seed plug to part. Our observation showed that there was five stage of makadamia seed germination those were radicle emergence (fig 2.a), hypocotyl emergence (2.b), cotyledon emergence (2.c), cotyledons opening (2.d), first leaves an opening (2.e).

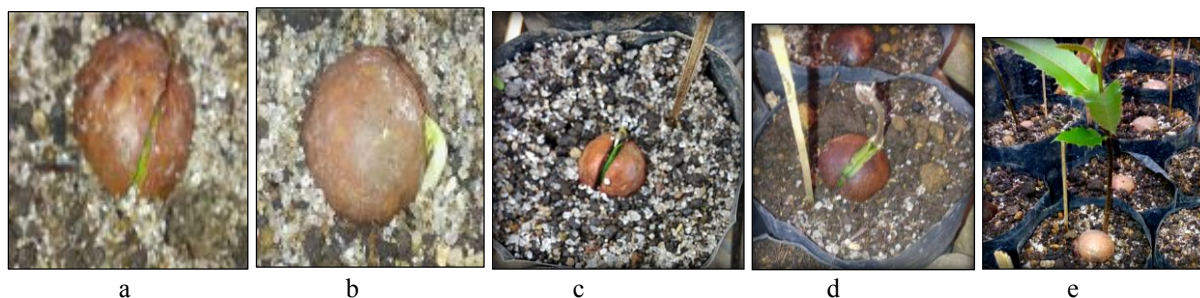


Figure 2. Germination process on makadamia seed: radicle emergence (a), hypocotyl emergence (b), cotyledons emergence (c) cotyledons opening (d) first leave opening (e)

Based on observation on cotyledon emergence, the germination of makadamia seed classified as hypogeal. It indicated by the cotyledons remain beneath the soil surface, where they have been deposited [14]. On the type of hypogeal germination, the appearance of radicle followed by elongation of plumula, hypocotyl does not extend above the soil surface while cotyledons remain in the seed coat below the soil surface. This type also common in some forest trees species.

4. Conclusions

Ripe macadamia characterized by a round shape of fruit with diameters average was 2.20 cm diameter and 8,58 g on weight. The fruit coated with hard testa and the thickness average was 0.38 cm. The fruit also consisting of endosperm with the thickness average was 1.54 cm. Germination process of makadamia takes 15-115 day after sowing. The germination process has five stage those were emergence of radicle following by emergence of hypocotyl, emergence of the cotyledon, the opening of cotyledons and the opening of firs leaves. Based on cotyledon emergence, makadamia seed germination classified into hypogeal.

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