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A review of sapodilla beneficial use, production status, and propagation technique in Indonesia

Abstract. *Manilkara zapota* (L.), commonly known as sapodilla, is one of the tropical plants originating from Central and South America that is still less popular in Indonesia than banana, citrus, mango. To gain its popularity, it is crucial to review the beneficial uses, existing production status, and propagation techniques of sapodilla. In general, sapodilla is used for either as table fruit or derivative food. Additionally, it contains various bioactivities in its fruit, stem, and leaves, such as antioxidant, antimicrobe, and antitumor activity; thus, it becomes very potential for pharmaceutical purposes. The existing production data of sapodilla determine the West Java Province as the biggest production area in Indonesia, with more than 20% contribution to the national level (38.250 tons annually). In more detail, the top production area at the village level with a local sapodilla cultivar, Sukatali sapodilla, is found in Sukatali village in Situraja Subdistrict, Sumedang District, West Java Province. Sapodilla can be propagated by using both reproductive system and vegetative methods. Vegetative propagation of grafting is commonly used to produce shorter juvenile and uniform seedlings. However, it highly depends upon the grafting type, season, and scion diameter. Literature search on grafting recommended modified cleft grafting in June-July, using *Chrysophyllum lanceolatum* and *Manilkara hexandra* as rootstock, and scion with a diameter of 5.02 mm, as the best practice of sapodilla propagation.

Keywords: Antioxidant · Grafting · *Manilkara zapota* · Rootstock · Sukatali

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Introduction

Sapodilla (*Manilkara zapota*) is an important horticulture commodity worldwide, although sapodilla's center of origin is recorded in tropical Central and South America (Gilly, 1943; Fayek et al., 2012). *Manilkara zapota* (L.) have various synonyms, such as *Achras sapota*, *Achras zapota*, *Manilkara achras*, *Manilkara zapotilla* and *Mimusopus manilkara* (Mohidin et al., 1992; Quattrocchi, 1999). The tree is tolerant to shade and can be used for edible sweet fruit and latex for gum production (Toledo-Aceves et al., 2009).

Its fruit is commonly found in several countries, with different vernacular names, such as dilly in Bahamas, sapoti in Brazil, sapote in Cuba, sapatiha in Dutch West Indies, chiku in India, sawo in Indonesia, chikoo in Malaysia, chicozapote in Mexico, nispero in Puerto Rico, lamoot in Thailand, ciku in Singapore, sapodilla in UK and USA (Karle & Dhawale, 2019). The sapodilla fruit is composed of nutritious soft and sweet flesh, thus it will be attractive to be consumed as a fresh fruit. The fruit was popularly known as the source of vitamin C (Kusmiyati et al., 2014), amino acids in the form of aspartic and glutamic acid (Hall et al., 1980), and flavonoids such as quercitrin, myricitrin, catechin, epicatechin, gallocatechin (Ma et al., 2003).

In Indonesia, the popularity of sapodilla as a table fruit is still less than other tropical fruit such as citrus, banana, and mango (Efendi and Budiarto 2022). Additionally, there are limited researches to investigate the uses and popularity of sapodilla. A previous study by Kusmiyati et al. (2014) reported the applied culture practice and production of sapodilla locally in three subdistricts in Java. Kusumiyati et al. (2017) also stated that the quality of sapodilla fruit is in response to post-harvest handling.

One of the locally famous varieties of sapodilla is Sukatali sapodilla, which refers to the name of the village of Sukatali, Situraja Subdistrict, Sumedang District as the center of its development (Saepuloh et al., 2022). Sukatali sapodilla is a local superior agricultural commodity that can be used as a supporting component for ecotourism (Setiawati & Yunita, 2020; Djuwendah et al., 2017). The further development of Sukatali sapodilla is still widely open to fulfil the need of domestic and international markets. Moreover, this variety has equipped with geographical indication certification, which potentially become its strength in entering the high-level market, such as the modern or international market (Setiawati & Yunita 2020).

The effort to develop the production of Sukatali sapodilla should be achieved by research activity, such as the enrichment of sapodilla information database that elaborates on any aspect regarding sapodilla in general or even Sukatali sapodilla in specific. Thus, the present study was aimed to review the beneficial use and production status of sapodilla in Indonesia.

Discussion

Beneficial Use. Sapodilla is mainly served as table fruit in fresh raw form (Yee & Shukkoor, 2020). This fruit can be found in both modern and traditional markets. The tree bears flowers all year round; thus, sapodilla fruit can always be regularly found in the market. Sapodilla fruit is generally slightly oval, with relatively rough skin, brown, soft flesh, and sweet taste. Sapodilla fruit is rich in nutrients that are beneficial to human health (Padmavathi, 2018; Mehnaz and Bilal, 2017), such as sugar, protein, dietary fiber, tannin, saponin, minerals (copper, potassium, iron) and vitamins (ascorbic acid, niacin, folate, and pantothenic acid) (Miranda, 2022; Bangar et al., 2022). Consuming sapodilla fruit is reported to improve the walking capacity of older people due to its rich vitamin C and vitamin A content, which positively affects the body's antioxidant status (Leelarungrayub et al., 2019). It also improves body immunity, and help to maintain digestive and cardiovascular health (Miranda, 2022).

The sapodilla fruit pulp is previously reported to have a high antioxidant potential content (Karle et al., 2021; Leong & Shui, 2002). The post-harvest handling of sapodilla fruit highly affects the antioxidant level, especially storage treatment (Shui et al., 2004). Aside from fruit pulp, sapodilla's fruit peel has a high antioxidant potential (Karle et al., 2021). An earlier report also showed that fruit peel contains more bioactive compounds than its pulp (Gomathy et al., 2013). Moreover, the unripe fruit of sapodilla fruit could be used to treat diarrhea, after being smashed and diluted with water, and then used to treat diarrhea

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(Mohidin et al., 1992). The presence of bioactivity in sapodilla fruit is related to its physicochemical compounds, such as tannins (Matthew & Lakshminarayana, 1969; Pontes et al., 2002; Shui et al., 2004), triterpenes (Hart et al., 1973), and flavonoid (Ma et al., 2003).

In addition to the mentioned beneficial uses of fruit, the stem of sapodilla can also be use as gummy latex for chewing gum production (Ma et al., 2003) and pharmaceutical material. The stem bark of sapodilla possesses several bioactivities, such as antitumor activity (Osman et al., 2011a), antibiotic, astringent (Kaneria et al., 2009), and antimicrobial against several pathogenic bacteria (*Bacillus subtilis, B. megaterium, B. cereus, Sarcina lutea, Escherichia coli, Shigella sonnei, S. shiga, S. dysenteriae,* and *Salmonella typhi*) and fungi (*Aspergillus flavus, Vasianfactum sp,* and *Fusarium sp.)* (Osman et al., 2011b).

Not only fruit and stem but also the sapodilla leave is reported to have beneficial bioactivities, such as an antioxidant (Chanda & Nagani, 2010), antimicrobe (Nair & Chandra 2008; Kaneria et al., 2009), antitumor (Rashid et al., 2014), analgesic (Jain et al., 2011), antihyperglycemic and hypocholesterolemic (Fayek et al., 2012). The leaves are previously reported to treat cold, cough, and diarrhea (Ma et al., 2003). Kaneria et al. (2009) reported the presence of less alkaloid, less flavonoid, high tannin, moderate phlorotannins, high triterpenes, no steroid, moderate saponin, and less cardiac glycosides in the leaf of sapodilla.

Production status. Sapodilla's production status in Indonesia is illustrated in Figure 1 (BPS, 2020). Numerous provinces throughout Indonesia produce this fruit. The top five lowest sapodilla production in 2020 was found in North Sulawesi (2 tons/year), North Maluku (7 tons/year), Papua (20 tons/year), Maluku (31 tons/year), and Aceh (46 tons/year). On the opposite, the top five highest sapodilla production was achieved by West Java (38.250 tons/year), North Sumatra (19.886 tons/year), East Java (19.898 tons/year), Lampung (19.371 tons/year), and Central Java Province (19.294 tons/year). In 2020, there was a total of 186.706 tons/year of sapodilla produced by Indonesian, and 21% of them is the contribution of West Java Province (BPS, 2020). One of the production districts in West Java province was Sumedang. The top four sapodilla production subdistricts in 2012 were Situraja (6886 tons), Darmaraja (5168 tons), Cisitu (4881 tons), and Ganeas (3861 tons) (BPS Kabupaten Sumedang 2012). Situraja, the highest sapodilla production subdistrict, is popular with its local sapodilla variety, Sukatali sapodilla.

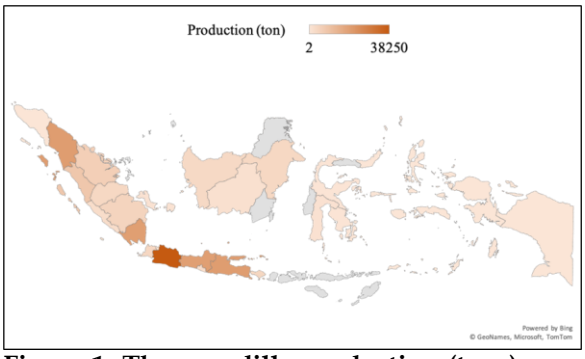

Figure 1. The sapodilla production (tons) map throughout Indonesia (BPS, 2020).
Note: Brown color gradiation implied the sapodilla fruit production (tons) data throughout Indonesia in 2020

Culture practices. Sapodilla can be cultured in monoculture and polyculture system. Earlier study used to mix sapodilla cropping with ginger and turmeric (Pandey et al., 2016). In contrast, previous research by Kusmiyati, et al. (2014) has reported the local monoculture practice of sapodilla cultivation in Trirenggo Village, Bantul Regency, Yogyakarta Province. Traditionally, traditional cultivation practices begin with seeding, land preparation, planting, maintenance, and harvesting. Air layering propagation techniques prepare seedlings of sapodilla. The mother plant used for air layering is a local sapodilla tree grown around the village. Land preparation and planting are conducted during the rainy season by making planting holes measuring 50 cm in length x 50 cm in width x 50 cm in depth (Kusmiyati, et al. 2014). Sapodilla seedling is transplanted amid the local garden that accommodates a polyculture system. Local farmers need to use regular plant spacing. Farmers carry out watering, organic fertilization, and less intensive pest-disease control at the maintenance stage (Kusmiyati, et al. 2014). To control weed invasion and growth, farmers of sapota can apply soil cover (Reddy & Khan, 2000). Integrated nutrient management to improve sapota growth is recommended in the form of NPK fertilizer (1000:1000:1500 g NPK tree-1), vermicompost, and activated effective microorganism (Tasleema et al., 2019). Plant growth regulator in form of paclobutrazol could

stimulate the increase of fruit yield of sapodilla (Reddy & Khan, 2001). Harvesting is usually done in a period of 1-2 weeks. Marketing rests on the existence of the middleman. The annual productivity of sapodilla plants is around 50-70 kg of fruit per tree, with the selling price at the farmer gate around IDR 100,000 per tree.

The uniqueness of sapodilla fruit is found in its extremely susceptible character to perishability on ripening (Singh et al., 2021). Thus, post-harvest handling is crucial to indicate the quality of fruit by farmers or collectors. Post-harvest is one of several critical points in sapodilla fruit production. The less accurate post-harvest handling caused a significant loss of sapodilla fruit in terms of quality and quantity. One of several essential issues in sapodilla is how to prolong the shelf life of sapodilla fruit (Raesi, 2013).

Sapodilla fruit can only be stored for 6 days at room temperature (27-29^{o}C, Rh 65-75%); however, chitosan coating treatment with a concentration of 1.5 – 3.0% can extend the shelf life 2 days longer (Kurniawan et al., 2013). Combining chitosan and 20% beeswax is recommended to extend sapodilla fruit shelf-life (Foo et al., 2018). In addition, Hasmoro et al. (2014) reported that fruit immersion in a solution of 4% and 6% of $CaCl_2$ could prolong up to 10 days.

Product diversification is also applicable to sapodilla to improve the likeliness of sapodilla and give added value to sapodilla fruit commodities. Sapodilla can be processed as jam, syrup, and vinegar to increase its shelf life and value-added (Raesi, 2013).

Propagation techniques. Sapodilla propagation can be carried out in both sexual and vegetative methods. Fertilization is required between male and female flower organs, to produce sapodilla fruit containing seeds for planting material. In contrast to reproductive methods that produce less uniform and labile genotypes with a longer juvenile period, the vegetative method has more uniform and stable planting materials with a shorter juvenility (Kaur et al., 2020). Various techniques to vegetatively propagate sapodilla can be achieved in the form of grafting and air layering, while cutting could be more effectively applied even with the plant growth regulators supplementation (Chadha, 1992). Air layering is a more effortless and quicker method; however, it produces shallow-rooted plants prone to falling when exposed to high wind. In contrast, grafting is a promising method that has a deeper root structure due to the presence of rootstock.

The rootstock is crucial for grafting because it determines the scion canopy's growth and harvested yield (Mukherjee & Litz, 2009). Several rootstocks are commonly used to support the production of sapodilla-grafted seedlings, namely *Chrysophyllum lanceolatum* (Kalesh et al., 2005) and *Manilkara hexandra* (Kaur et al., 2020). In a particular case, the seed of Manilkara hexandra requires seed priming treatment to improve the seed germination response (Bhanuprakash et al., 2008; Reddy & Khan, 2002). One of the popular seed-priming chemicals to increase seed vigor is gibberellic acid (Kaur et al., 2020; Bajaniya et al., 2018; Ballantyne, 1991) which regulates starch mobilization used for respiratory substrate (Shah, 2007) and then boosts the biosynthesis of proteolytic enzymes like alpha-amylase (Prasad & Prasad, 2009) and ribonuclease to hydrolyze starch in the endosperm providing the sugars for the initial germination processes (Copeland & Mc Donald, 1995).

Aside from plant growth regulator like gibberellic acid, numerous previous studies revealed the crucial factor of grafting type and season in determining the success of grafting in sapodilla. Islam et al. (2004) decided that modified cleft grafting as the best type of grafting rather than cleft and veneer grafting, with a mean of graft survival of about 94%, 89%, and 78%, respectively. While Shirol et al. (2005) recommended the inarching method due to its maximum graft success, especially in June-July, due to the minimum fluctuation of relative humidity and temperature during that period. Similarly, softwood grafting performs the best in July with the best graft survival rate (Wazarkar et al., 2009; Ghosh et al., 2010), whereas the minimum graft survival rate is recorded in September-October (Ghosh et al., 2010). Maske, et al. (2010) also confirm poor graft survival rate on plants grafted from November to April. The culture of softwood sapodilla grafting seedlings under moderate shading results in the number of days to bud sprout data, ranging from 14 to 18 days (Kalalbandi et al., 2014). Nitish et al. (2019) reported a faster sprout coming when the grafting is performed in July rather than August. Numerous studies also said the best growth on seedlings as the effect of grafting in July (Nitish et al., 2019; Ghritlahare & Ashutosh, 2018;

Niranjan, 2011; Wazarkar et al., 2009). Aside from seasonal variation, earlier studies also reported the effect of the scion diameter on the success of sapodilla grafting. The scion with a diameter of 5.02 mm was recorded to have a greater graft success rate than 4.63 mm, 4.38 mm, and 4.02 mm scion diameter (Tanjua & Thippesha, 2016). These results shows that more food reserves in the scion, with a large scion diameter indicator, increase the success of post-grafting recovery growth and *vice versa*.

Conclusion

Sapodilla has numerous beneficial uses, such as table fruit and pharmaceutical material, due to the various bioactivities in its fruit, stem, and leaves, such as antioxidant, antimicrobe, and antitumor activity. The production of sapodilla is found in numerous provinces in Indonesia, with West Java as the top production area. Sukatali Village in Situraja Subdistrict, Sumedang District, West Java, is determined as the top production area at the village level with a local sapodilla cultivar, namely Sukatali sapodilla. Sapodilla can be propagated by using both sexual reproduction and vegetative methods. Vegetative propagation of grafting is commonly used to produce shorter juvenile and uniform seedlings, and it is highly dependent upon the grafting type, grafting season, and scion diameter.

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