Research Article

Anatomy of Mangosteen Root (*Garcinia mangostana* L.) from Bengkalis Island which can grow in flooded areas

Anatomi Akar Manggis (Garcinia mangostana L.*) Asal Pulau Bengkalis Yang Mampu Tumbuh di Daerah Tergenang*

Vebrita Sari[1]*, Syamsul Bachry[1], Febri Ayu[1]

[1] Department of Biology, Faculty of Life Sciences, Pahlawan University, Tuanku Tambusai No.23, Bangkinang, Kec. Bangkinang Kampar, Riau 28412

*email: ayi.vebritasari@gmail.com

Recived: September 2023
Accepted: December 2023
Published: December 2023

p-ISSN: 2723-7974
e-ISSN: 2723-7966
doi: 10.52045/jca.v4i1.561

Website: https://ojs.untika.ac.id/index.php/faperta

Abstract: Bengkalis Island is a lowland area that often experiences periodic flooding, such as flooding due to "Pasang keling" every December. In Bengkalis Island, Riau Province, there are many good quality mangosteens. The ability of mangosteen from Bengkalis Island to adapt to flooded areas is thought to have a special root system that has never been reported. This study looks at the anatomical structure of mangosteen roots from Bengkalis Island that grow in flooded and non-flooded areas. Samples of mangosteen roots were taken in 4 villages for location I (flooded) and three villages for location 2 (not flooded) on Bengkalis Island. Sampling using the survey method and analyzed descriptively. Preparation of root anatomy using paraffin method with double staining. Observations were made using a photomicrographic microscope. The anatomy of mangosteen roots from Bengkalis Island that grow in flooded areas differs from those in typical habitats (not flooded The anatomy of mangosteen roots in the flooded location has a thicker epidermis, aerenchymal tissue, and Ca oxalate crystals are found. Mangosteen roots growing in normal habitat (not flooded) generally do not have aerenchyma. The discovery of differences in root morphology in both locations indicates that mangosteen from Bengkalis Island has a mechanism to tolerate flooded conditions.

Keywords: Aerenchyma, root anatomy, Bengkalis, mangosteen

Abstrak: Pulau Bengkalis merupakan daerah dataran rendah yang sering mengalami kondisi tergenang secara periodik, seperti banjir karena "Pasang keling" setiap bulan Desember. Di Pulau Bengkalis Provinsi Riau banyak ditemukan manggis yang berkualitas baik. Kemampuan manggis asal Pulau Bengkalis beradaptasi di daerah tergenang, diduga karena memiliki sistem perakaran yang khusus dan belum pernah dilaporkan sebelumnya. Penelitian ini bertujuan untuk melihat struktur anatomi akar manggis asal pulau Bengkalis yang tumbuh di daerah tergenang dan tidak tergenang. Sampel akar manggis diambil di 4 desa untuk lokasi I (tergenang) dan 3 desa untuk lokasi 2 (tidak tergenang) di Pulau Bengkalis. Pengambilan sampel dengan metode survei dan dianalisis secara deskriptif. Pembuatan preparate anatomi akar menggunakan metode paraffin dengan pewarnaan ganda. Pengamatan menggunakan mikroskop fotomigrografi. Anatomi akar manggis asal Pulau Bengkalis yang tumbuh di daerah tergenang berbeda dengan akar manggis pada umumnya yang tumbuh pada habitat normal (tidak tergenang). Anatomi akar manggis pada lokasi tergenang mempunyai epidermis yang lebih tebal, jaringan aerenkim, dan terdapat kristal Ca oksalat. Akar manggis yang tumbuh pada habitat normal (tidak tergenang air) umumnya tidak mempunyai aerenkim. Ditemukannya perbedaan morfologi akar di kedua lokasi mengindikasikan bahwa manggis asal Pulau Bengkalis memiliki mekanisme toleran terhadap kondisi tergenang.

Kata kunci: aerenkim, anatomi akar, Bengkalis, manggis,

Citation:
Sari V, Bachry S, Ayu F . 2023. Anatomy of Mangosteen Root (*Garcinia mangostana* L.) from Bengkalis Island which can grow in flooded areas . *Celebes Agricultural*. 4(1): 21-29. doi: 10.52045/jca.v4i1.561

INTRODUCTION

Mangosteen (*Garcinia mangostana* L.) is one of Indonesia's native tropical fruit commodities with high economic value and is a leading export fruit. Mangosteen is known as the Queen of Tropical Fruits and The Finest Fruit of Tropic because it has many features: beautiful skin color, refreshingly sweet and sour taste, and high nutritional content. The xanthone chemicals in the rind and roots of mangosteen are important in pharmaceutical and healthcare (Ahmad et.al, 2010). Market demand for mangosteen fruit continues to increase in domestic and foreign markets (exports). To meet market demand, it is necessary to develop cultivation land, both public land and marginal land such as flooded land; for this reason, it is necessary to have the availability of mangosteen seeds that can adapt to this environment.

The Directorate of Fruit Crops reported that there are ± 10,771 ha of mangosteen plantations in Bengkalis Island, Riau Province. Bengkalis Island is a low-lying area of swamps and peatlands that often experience seasonal (periodic) flooding. Flooding due to "Pasang keling" in December (Personal communication with residents), tides in the seaside area every full moon, and flooding that occurs when rainfall is high because it is at an altitude of 7-9 m above sea level, in this area there are many good quality mangosteen trees. Mangosteen from Bengkalis Island is different from mangosteen in general, which grows well on non-flooded soil and at an altitude of 460-610 m above sea level (Gunawan, 2007; Reza, 2001; Rukmana, 1998). In addition, mangosteen flowers are faster (5 years old) than mangosteen from other regions (10 years old), and the flowering period is earlier (March-June) than mangosteen in Java Island (August-November).

Flooded soil conditions cause soil O_2 content to be low, <4% (hypoxia), and even close to 0% (anoxia) (Colmer, 2003). Based on the ability to adapt to environments with low O_2 conditions (hypoxia-anoxia), grouping plants into two, namely flooding-sensitive plants and flooding-tolerant plants. Plant adaptation mechanisms in flooded conditions are very complex. These adaptations give plants unique characteristics that are important to study and explore. Plant adaptation mechanisms in flooded conditions are very complex. One form of plant anatomical adaptation to flooded conditions is by forming aerenchymal tissue. Aerenchyma is a parenchymal tissue with large intercellular spaces that facilitate intercellular gas exchange (oxygen and ethylene) and as a storage of limited oxygen (Jung et al. 2008 and Videmšek et al. 2006).

Mangosteen (*Garcinia mangostana* L.)

Aerenchyma formation in plant roots has been widely reported in dicotyledonous and monocotyledonous plants, but aerenchyma is usually found in aquatic and mangrove plants (Evans 2004). These adaptive capabilities give plants unique characteristics important to study and explore. Haryanti et al. (2001) and Witiyasti (2006) stated that the adaptability of plants to their environment is closely related to changes in their anatomical structure. As with mangosteen roots from Bengkalis Island, it is thought to have a unique root anatomical structure that is different from other mangosteen roots so that it can live and produce well in flooded areas. For this reason, it is necessary to research the anatomical structure of mangosteen roots to obtain basic information on the structural resistance of the roots using anatomical characteristics. This information is very important in cultivating and breeding mangosteen plants.

The adaptability of plants to their environment is closely related to changes in their morphological structure (Witiyasti, 2006). As with mangosteen roots from Bengkalis Island, it is thought to have a special root morphology different from other mangosteen roots to live and produce well in flooded areas. Research on mangosteen is still primarily focused on improving quality and fruit production. Information on the morphology of mangosteen roots that can grow in flooded areas is needed as basic information for developing superior seeds. Many of Riau's indigenous germplasm collections must be explored and published, including mangosteen from Bengkalis Island, Riau. Research on mangosteen roots was conducted to obtain basic information on root resistance using anatomical characteristics. In cultivating and breeding mangosteen plants, such information is very important. Mangosteen is a fruit plant that is widely cultivated by people as a fruit plant that has medicinal properties.

MATERIALS AND METHODS

This research was conducted in June 2023. Samples were taken at two locations on Bengkalis Island, Riau Province (Figure 1).

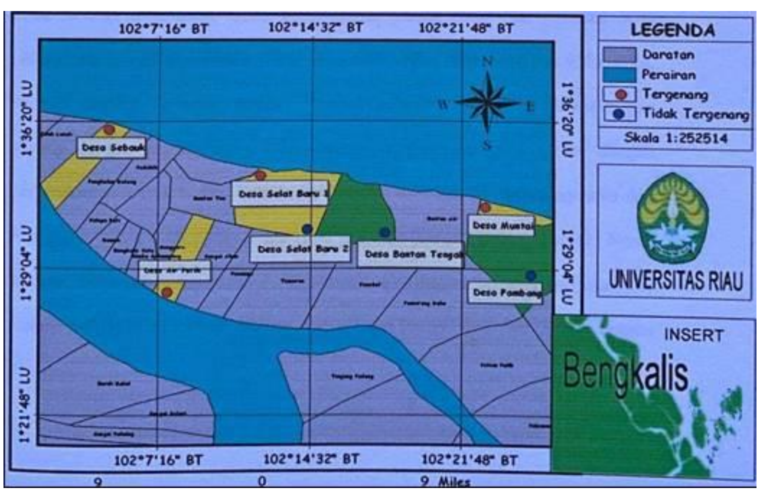

Figure 1. Map of mangosteen root sampling locations on Bengkalis Island.

Location 1 is an area that experiences periodic flooding conditions with four replicate villages, namely Selat Baru 1, Sebauk, Air Putih, and Muntai. In comparison, location 2 is an area that does not experience flooding conditions with three replicate villages, namely Selat Baru 2, Pambang, and Bantan Tengah. The research stages include sampling, preparation, observation, measurement of environmental factors and data analysis.:

Sampling

Sampling was conducted using a survey method in two locations on Bengkalis Island, Riau Province (Figure 1). Samples were taken in the form of saplings with three replicates in each place, and for uniformity, the saplings taken were saplings that had 6-12 leaves (3-8 buds) aged about 1-2 years (Gunawan, 2007). The method of taking root samples is by digging and pulling the plant carefully to obtain it up to the tip of the main (primary) root.

Environmental Factors Measurement

The environmental factors measured at both locations in each sampling event were as follows:

1. Measurement of soil moisture content using the National Standardisation Agency method

$$w = ((W1 - W2)/ (W2 - W3)) \times 100\%$$

Description:

w = moisture content (%)
W1 = weight of plastic and wet soil (gram)
W2 = weight of plastic and dry soil (gram)
W3 = weight of plastic (gram)

2. Measurement of the height of the sampling site using a GPS device.

Anatomical Preparations

Preparation was made using the paraffin method (Johansen 1940) by going through several processes. Initially, the root sample is fixed in 50% FAA solution for 24 hours. Samples were washed and dehydrated after 24 hours of fixation with graded alcohol solutions (50%, 70%, 80%, 95%, and 100%) alternately for 30 minutes each. Then, the samples were de-alcoholized in a mixture of alcohol: xylol 3:1, 1:1, and 1:3 to xylol I and II alternately for 30 minutes each. Next, the samples were made into paraffin blocks by infiltrating the samples in a 1:9 xylol: paraffin mixture solution and pure paraffin in an oven (58°C) for 24 hours. The samples were then embedded in pure paraffin for one hour to form paraffin blocks. The blocks were cut transversely using a rotary microtome with a thickness of 8 µm. The pieces of paraffin tape were then glued to the object glass using Mayer's adhesive solution and dripped with distilled water. Furthermore, it was heated on a heating board (45°C) until the paraffin tape stretched; the staining process was carried out after the paraffin tape stretched. The staining used is double: safranin 1% in distilled water and fast green 0, 1% in 50% alcohol. The last process is mounting; a sample is stained and covered with a cover glass previously given an entering, then dried on a heating board (45 ° C). The dried preparations were then labeled on the right side of the object glass.

Observations

Observations of the anatomical structure of mangosteen roots from both locations were made under a light microscope and photographed using a photomicrographic microscope (Olympus CX 41 equipped with a Digital Camera). Parameters observed were differences in root anatomy, namely: (1) Whether or not aerenchymal tissue is formed, the area of aerenchymal tissue formed (by measuring the longest part) and the initial place of formation (the tip, middle or base of the root); (2) The constituent tissues of the roots in the two locations include: (a) Epidermis: counted the number of cell layers and cell shape, (b) Cortex: measured the thickness, (c) Endodermis, (d) Pericellicle, (e) Cambium, (f) Vascular tissue: phloem and xylem.

Data Analysis

Observation data were analyzed descriptively with observate the tissues comprising mangosteen roots from the two locations by using optiblab. Observation data is presented in the form of pictures.

RESULTS

The anatomical structure of mangosteen roots from the two locations (flooded and non-flooded) can be seen in Figure 2.

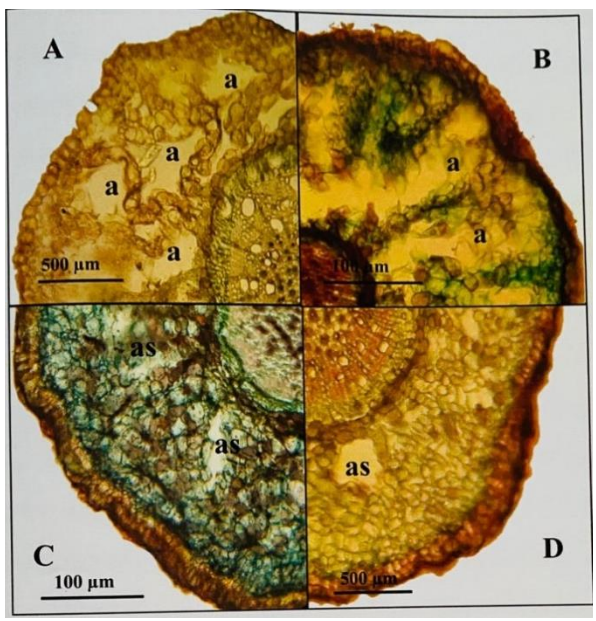

Figure 2. Cross-sections of mangosteen roots in both locations. Description: Site 1 (Flooded): (A) Sebauk Village and (B) Muntai Village, (a) Aerenkim perfect Site 2 (Non-inundated): (C) Pambang village and (D) Selat Baru village 2, (as) narrow aerenchyma.

Soil texture also affects the formation of lateral roots and root hairs. In contrast, soil conditions in both locations on Bengkalis Island tend to be water-saturated, namely the water content in the flooded location of 67.18% and the non-flooded location of 28.99% (Table 1), so that lateral roots and root hairs are not formed. Soil is water-saturated if the soil's pores are filled with water by >20-30%.

Table 1. Measurement results of environmental factors where mangosteen root samples were collected from Bengkalis Island, Riau Province.

No	Environmental factors	Location 1 (Flooded) Village				Location 2 (Not Flooded) Village		
		Selat Baru 1	Sebauk	Air Putih	Muntai	Pambang	Bantan Tengah	Selat Baru 2
1	Altitude (± above sea level)	7	6	7	7	9	9	9
2	Soil Water Content (%)	73.58	80.85	59.78	54.34	32.32	24.06	30.60
		67.18				28.99		

DISCUSSION

The anatomical structure of mangosteen roots from both locations shows differences with the roots of dicotyledonous plants. In general, the constituent tissues of mangosteen roots from both locations are not different, namely consisting of epidermal tissue, cortex, endodermis, pericellicles, and xylem and phloem vessel networks. The difference lies in modifying the structure of the epidermal tissue and the cortex-formed aerenchyma tissue, which differs from both locations. The epidermis of mangosteen roots in flooded locations consists of one layer of cells, while in non-flooded locations, it consists of two layers. Epidermal cells in flooded locations are round (tubular), while in non-flooded locations, in addition to being round, they are also rod-shaped. The second layer is indicated as a periderm layer formed to replace the function of epidermal tissue if the epidermal tissue is damaged due to the more complex soil texture.

The epidermis of mangosteen roots in flooded locations still functions correctly, so it has not been replaced by periderm. In contrast, the epidermis of mangosteen roots in non-flooded locations has begun to be replaced by periderm. Esau (1977) reported that the epidermis in certain parts of the plant will continue to function during its life but can be replaced by other protective tissues, namely the periderm. According to Esau (1977), epidermal tissue has a variety of structures and specific functions, which can be associated with its role as a layer of cells that are directly related to the environment.

The cortex structure of the two locations also showed differences. The mangosteen root cortex in flooded locations is thicker than the mangosteen root cortex in non-flooded locations. The difference in thickness is because the mangosteen root cortex in the flooded location has a perfect aerenchymal (extensive) (Figure 2). In contrast, the cell structure is denser (compact) with a narrower aerenchymal network in the non-flooded location. The formation of aerenchyma in the results of this study is by Kozlowski (1997), Stevens et al. (2002), and Malik et al. (2003), which reported that aerenchyma tissue formed by plant roots is a form of adaptation to flooded conditions. Aerenchyma is a tissue with large intercellular spaces (large air cavities) formed through lysigenous or schizogenous processes (Evert 2006) because the roots experience oxygen deficiency (hypoxia-anoxia) due to soil pores filled with water. Videmsik et al. (2006) also reported that aerenchyma in roots is a more efficient oxygen transport pathway and a place to store oxygen from the root tip.

Mangosteen roots in flooded locations form aerenchymal networks as an adaptation mechanism to survive in low oxygen conditions due to water-saturated soil. In contrast, the narrow aerenchyma formed in mangosteen roots in non-flooded locations is likely due to soil conditions that tend to be saturated with water, so it contains little oxygen but is not as low as in flooded locations. The area of aerenchyma network formed in the flooded location is much broader than the area of aerenchyma in the non-flooded location. This difference is caused by different soil conditions, with the average soil moisture content in the flooded site at 67.18%, while in the non-flooded site it is 28.99% (Table 1). The high soil moisture content in the inundated sites is due to periodic flooding that occurs at least twice a year, namely keling tides in December, sea tides, and flooding during the rainy season (personal communication from residents). Aerenchyma in mangosteen roots from Bengkalis Island is indicated to be secondary aerenchyma because mangosteen is a dicotyledonous plant. Secondary aerenchyma is formed from phellogen tissue, usually found in dicotyledonous plants (Evans 2004). However, judging from the structure of the aerenchyma, the intercellular spaces produced come from lysed cortex cells. According to Evans (2004), aerenchyma formation can differ even at the same species level, as different habitat conditions also influence it.

Aerenchyma in mangosteen roots in both locations was formed through a lysigenous process (cell death) because it was indicated to be formed due to adaptation to flooded conditions (low oxygen), which is not its normal habitat. Waterlogged conditions cause low oxygen content, so the roots lack oxygen and synthesize ethylene, which stimulates the process of cell death (cell lysis) (Evans 2004). In addition, the discovery of narrow aerenchyma tissue in non-flooded sites (Figures 2 C and D) also indicates that mangosteen from Bengkalis Island already has genetic resistance to flooded conditions influenced by the environment. The widest aerenchyma was found in the roots of mangosteen from Air Putih Village (Figure 2 B), and the smallest aerenchyma was found in the roots of mangosteen from Pambang Village (Figure 2 C). In the middle root cortex, ergastic objects were found, namely sand-shaped Ca oxalate crystals. Ca oxalate crystals are residual products of secondary metabolism deposited in cell vacuoles, and their function is as a source of calcium supply if plants lack calcium ions, as a form of plant protection from herbivore attacks, and as an additional mechanism in strengthening cells (Evert 2006). Different root constituent tissues such as endodermis, pericellicle, and xylem and phloem transport bundles of mangosteen roots from both locations are not found (Figure 2).

CONCLUSIONS

The anatomy of mangosteen roots in the flooded location has a thicker epidermis, aerenchymal tissue, and Ca oxalate crystals are found. Mangosteen roots growing in normal habitat (not flooded) generally do not have aerenchyma. Due to differences in soil conditions, soil moisture content, and altitude, there is a more comprehensive aerenchymal network in mangosteen roots in flooded locations. The discovery of differences in root anatomy in the two locations indicates that mangosteen from Bengkalis Island has a mechanism to tolerate flooding conditions. This difference is due to environmental conditions in the two locations, such as soil moisture content (28-67%) and altitude (7-9 m above sea level).

REFERENCES

Ahmad I, Ghazali, GEC Lian and RDA Ghani. 2010. Chemical constituent from roots of *Garcinia mangostana* L. *International Journal of Chemistry*. 2(1):134-142. https://doi.org/10.5539/ijc.v2n1p134

Colmer TD. 2003. Long distance transport of gases in plants: A perspective on internal aeration and radial oxygen loss from roots. *Plant, Cell and Environment*. 20(26): 17-36. https://doi.org/10.1046/j.1365-3040.2003.00846.x

Dewi N. 2005. Studimorfologi, anatomi dan analisis RAPD bibit manggis (Garcinia mangostana L.) karena iradiasi sinar gamma [Thesis]. Departemen Budidaya Pertanian, Fakultas Pertanian. IPB. Bogor. Program Pascasarjana.

Esau K. 1977. *Plant Anatomy: Anatomy of Seed Plant, 2nd Edition*. Jhon Wiley & Sons Inc. Canada

Evans D. 2004. Aeremchyma formation. *New Phytologist*. 161:35-39. https://doi.org/10.1046/j.1469-8137.2003.00907.x

Evert RF. 2006. *Plant Anatomy, 3th Edition*. A Jhon Wiley & Sons Inc. New Jersey.

Gunawan E. 2007. Hubungan agroklimat dengan fenofisologi tanaman manggis (Garcinia mangostana L.) dan kualitas buah manggis di lima sentral produksi di Pulau Jawa. [Thesis]. Departemen Budidaya Pertanian, Fakultas Pertanian. IPB. Bogor. Program Pascasarjana.

Haryanti S, Rini BH, Endah DH, Yulita N dan Jackson. 2001. Adaptasi morfologi fisiologi dan anatomi eceng gondok di berbagai perairan tercemar. [Skripsi]. Jurusan Biologi FMIPA. UNDIP. Program Sarjana

Jung J, SC Lee and HK Choi. 2008. Anatomical patterns of aerenchyma in aquatic and wetland plants. *Journal of Plant Biologuy*. 51(6). 428-439. https://doi.org/10.1007/BF03036065

Johansen DA. 1940. *Plant Microtecnique*. McGraw Hill Book Company Inc. New York.

Kozlowski, TT. 1997. Responses of woody plants to flooding and salinity. *Tree Physiology Monograph*. 1(13): 678-685. https://doi.org/10.1093/treephys/17.7.490

Malik AI, Colmer TD, Lambers H and Schortemeyer M. 2003. Aerencyma formation and radial O_2 loss along adventitious roots of wheat with only the apical root portion exposed to O_2 deficiency. *Plant , Cell and Environtment*. 10 (26): 1713-1722. https://doi.org/10.1046/j.1365-3040.2003.01089.x

Reza H. 2001. Memilih Biji Manggis Untuk Bibit. *Trubus* (355):122-130.

Rukmana R. 1998. *Budidaya Manggis*. Kanikus. Yogyakarta.

Sari V, Gafur A, Sari DR. 2023. Efektifitas Minyak Serai Sebagai Bioinsektisida Nyamuk. *JES-TM Social and Community Service*. 3 (1). 28-36.

Sari V. 2017. Keragaman Genetik Bawang Merah (*Allium cepa* L.) Berdasarkan Marka Morfologi dan ISSR. *Indonesian Journal of Agronomy*. 45 (2). 175-181. https://dx.doi.org/10.24831/jai.v45i2.11665

Sari V. 2023. Morfologi Akar Manggis (*Garcinia mangostana* L.) Asal Pulau Bengkalis Yang Mampu Tumbuh di Daerah Tergenang. *Metrik Serial Teknologi dan Sains*. 4 (1). 9-15

Sari V, F. Ayu, M Aulia. 2023. Penyuluhan Pembibitan Ikan Patin (*Pangasius hypothalamus*) Skala Mikro di Kelurahan Sialang Sakti, Pekanbaru, Riau. *JES-TM Social and Community Service.* 1 (2). 10-16.

Witiyasti I. 2006. Studi Banding Sifat Ketahanan Struktural Terhadap Kekeringan Antara Varietas Padi Sawah dan Padi Gogo Berdasarkan Anatomi Daun. [Skripsi]. Prodi Biologi FMIPA. ULM.

Videmšek U, Boris T, Dominik V. 2006. Root Aerenchyma formation and function. *Acta Agriculturae Slovenica*. 87: 445-453. https://doi.org/10.14720/aas.2006.87.2.15124