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Review

Impact of Pest and Diseases on Mangrove Forest Rehabilitation in Indonesia: A Review

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Abstract: Mangroves are the constituent plants of tropical and subtropical intertidal regions of forest communities, comprising a biotic and abiotic environment for ecosystem services. Biotic factors greatly affect the health of mangrove forests, the decline in health in mangrove ecosystems is caused by pests and diseases on the leaves. The presence of pests and diseases that attack mangrove plants resulted in failure in forest rehabilitation efforts. This review investigates the types of pests found on mangrove leaves and the utilization of bioactive compounds in mangrove leaves that can suppress disease development. Its impact on mangrove forest rehabilitation efforts was discussed in this review. The knowledge and application from this review provided a guide in maintaining and conserving mangrove forests in Indonesia as one of the solutions in adaptation and mitigation to climate change.

Keywords: Conservation, Mangrove Leaf, Pest, Deaseas, Rehabilitation

Introduction

Mangroves are the constituent plants of tropical and subtropical intertidal forest communities. Among them are woody trees, shrubs, herbaceous plants, epiphytes and ferns (Kusmana *et al*., 2013). Indonesia has 43 species of true mangroves consisting of several genera such as *Aegiceras*, *Avicennia*, *Bruguiera*, *Ceriops*, *Excoecaria*, *Lumnitzera*, *Rhizophora*, *Sonneratia*, *Xylocarpus*, etc., (Kusmana, 2014; Basyuni *et al*., 2022). Based on the zone where they grow, mangroves have different growth mechanisms at hyper and low salinity concentrations. Parida and Jha (2010); Basyuni *et al*. (2012; 2014) showed that each mangrove species has a distinctive anatomical structure, namely salt glands on its leaves to secrete salt, for example, *Avicennia marina*. Other species are also able to ultrafiltrate the root cell membrane to secrete salt or accumulate salt in cells and tissues and then prevent damage to the efficient absorption of ions in vacuoles in the leaves, then translocated to the outside of the leaf, the cuticle, exemplified by *Rhizophora stylosa*. Transpiration and leaf turnover in releasing salt become more efficient. It is this ability that mangroves have to withstand fluctuating salinity conditions in tidal environments.

The ecological function of mangroves in a biotic and abiotic environment is to provide habitat for birds, fish and invertebrates (Nguyen *et al*., 2021; Sumarga *et al*., 2024). Mangrove forests play an important role in coastal protection from hurricanes, sea level rise, flooding and erosion. In addition, mangrove ecosystems are also globally recognized as one of the most fragile ecosystems with enormous potential for species degradation (Duke *et al*., 2020). Abiotic factors that affect the health of mangrove forests include hurricanes, lightning strikes, sea level drops, salinity and flooding. In addition, biotic factors that greatly affect the growth and development of mangroves are stress to opportunistic pests and diseases caused by pathogen attacks, especially on mangrove leaves (Van and Duke, 2017). In addition, molecular works assisted in preventing pests and diseases in mangrove plants (Osorio *et al*., 2017; Karthi *et al*., 2020) and contributed to enhancing biodiversity and conservation (Basyuni *et al*., 2024)

Damage to mangrove forests that occur due to forest conversion results in decreased forest function. The decline in the health of mangroves that have been exploited will result in increased attacks of pests and diseases in mangrove ecosystems because there are no longer any natural enemies controlling these attacks (Sibero *et al*., 2023). Pests and diseases that attack leaf

tissue in mangroves are very diverse. This is attributed mostly to mangrove leaves that are rich in nutrients because they obtain substances from the surrounding water and soil. Besides that, mangrove leaves also contain bioactive compounds that can be used to suppress the growth of pests and diseases on mangrove leaves.

Research related to pests and diseases in mangrove ecosystems in Indonesia has not been widely studied, therefore it is very important to conduct a review to estimate the impact of pests and diseases in efforts to rehabilitate forests. This review examines the types of mangrove pests and bioactive compounds in mangrove leaves that can suppress diseases in mangrove ecosystems. The purpose of this review is to illustrate the impact of pests and diseases on mangrove leaves in the process of mangrove forest rehabilitation.

Methods

We conducted a search for data related to pests and diseases found on mangrove species. Papers were collected by one person to avoid bias in collecting information. A comprehensive review was conducted on the online scientific platforms and databases of Web of Science, Scopus and google scholar using predetermined keyword combinations of "mangrove pests", "mangrove diseases", "rehabilitation", "bioactive compound" "mangrove metabolism", "mangrove molecular" and then collected data regarding secondary metabolism, the impact of the presence of pests, damage caused by diseases. The authors assessed, evaluated and interpreted the selected articles. This perspective reflects the authors' opinions on the role of bioactive compounds of mangrove leaves in preventing the increase of pests and diseases in mangrove forests so that the health of mangrove ecosystems can be successfully rehabilitated.

Mangrove Peast and Leaf Diseases

Mangrove Forest Rehabilitation

Mangrove forest rehabilitation or restoration is important in Indonesia, especially as the impacts of mangrove forest destruction become evident in the form of loss of productivity in coastal fisheries, livelihoods of coastal communities, as well as life-threatening natural disasters (Kusmana, 2017; Basyuni *et al*., 2022; Sasmito *et al*., 2023). Planting mangrove seeds in suitable habitats is a conservative mangrove ecosystem rehabilitation strategy and sustainable management efforts will result in healthy mangrove ecosystems.

Distribution of Mangrove Pest Species

Mangroves are ecosystems that are widespread throughout the coast to river areas that are influenced by tides. As an ecosystem that is used as a place to grow and live various types of flora and fauna (Srikanth *et al*., 2016) make mangroves an ecosystem with a high level of species diversity. Mangrove forests are inhabited by a variety of species from the open coast zone, mid-zone and landward zone. Each species can grow and live based on different salinity levels such as Rhizophora and Avicennia species that live in high salinity and can usually be found in the open coast zone to the riverbank.

One of the insect pests in Indonesia is the *Ophiuse melicerta* borer. Most of the pests recorded affect the establishment stage and have threatened mangrove cultivation Table 1. Pests are generally found living attached to mangrove stems and leaves as well as on the substrate surface. In the study of Vazirizadeh *et al.*, (2011) classified the fauna in mangrove ecosystems based on habitat are epifauna, infauna and tree fauna. Pest infestations are a major cause of unsuccessful mangrove rehabilitation, and these critical steps should be clearly documented when assessing the success or failure of an initial mangrove planting or replanting effort at a site or set of sites (Portillo *et al*., 2017).

Table 1: Mangrove pest distribution in Indonesia

Species	Symptoms	Pest	Location	Reference
Rhizophora apiculata and *R. mucronata*	Black spots and wilting on leaves	*Oecphylla, Lepidoptera*	Rambut Island, Seribu Island, Jakarta	Kusmana and Rifana (2023)
Lumnitzera littorea	Holes in the centre of leaves and white spots	*Lepidoptera: Acrolohidae*	Banda Aceh, Aceh	Putri Maulida and Agustuna (2022)
Xylocarpus granatum	Tepi daun berlubang	*Apicoterminitie and Portinuidae*	Pesisir Selatan, West Sumatera	Pramono *et al*. (2021)
R. apiculata	Perforated leaf edges	*Polistes* sp., *Sexava* sp., *Orgyia postica, Dasychira inclusa*	West Kalimantan	Utari *et al*. (2017)
R. apiculata	Rolled leaves, brown dry patches, holes in leave	*Cassidula angulifera*	Banda Aceh, Aceh	Putri Maulida and Agustina (2022)
Excoecaria agallocha	Damage to leaf margins to leaf veins	*Ophiuse melicerta*	Belawan, North Sumatera	Gumilang (2018)
Sonneratia	White spots on leaves	*Lymantria galinatia*	Sungai Barito,	Gumilang (2018)

Table 1: Countinue

caseolaris			South Kalimantan	
Sonneratia alba	Canopy loss death of brances	*Nephopterix syntaractis and Hyblaea puera*	Probolinggo, East Java	Gumilang (2018)
A. alba	White spots and holes On the lower surface Of leaves	*Pagodiella* spp. *Acanthopsyche* spp.	Kubu Raya, West kalimantan	Haneda and Suheri (2018)
A. marina	Sooty-mold	*Peocilips fallax and mealybugs*	Pangkep, South Sulawesi	Gumilang (2018)

Under environmental conditions of pest and disease stress, mangrove leaves require specific morphological adaptations as a form of defense mechanism. These adaptations will produce glands on the leaves for salt secretion and pneumatophores (specialized roots) for aerobic soil respiration. Gilbert and Sousa (2002) explain that high salt concentrations on the leaves of Avicennia species can inhibit fungal growth and subsequent disease incidence. However, regular environmental stress can lead to mangrove disease and death.

Mangrove plants are currently experiencing a decline in ecological quality, resulting in a decrease in the number of mangrove plants. Mangrove plant health is closely related to the condition of mangrove tree damage. The health of the mangrove forest is not only indicated by its density but also free from pests. Physical internal factors that we find are the presence of pests and diseases on mangrove leaves that can inhibit the growth process of mangroves. Morphological damage to the leaves caused by these pests varies greatly. Considering the ecological importance of mangroves and the high rate of damage to mangroves, it is ironic that very little research has considered the impact of disease on mangroves in Indonesia. This is even more so when one considers the substantial level of research conducted on mangroves and the efforts made to protect mangrove areas. Mangrove vegetation plays an important role in the balance of terrestrial ecosystems. The slightest fragmentation will certainly disrupt ecological processes (Lekito and Tambing, 2018). Based on the zonation where they grow, each mangrove species has different characteristics and forms, both morphologically and physiologically, as well as the biochemical compounds produced. Nutrients contained in each tree tissue have significant differences in leaves, stems and fruits in the metabolic processes carried out. Both leaf-feeding insects and stem borers have been found to damage mangrove trees and in some cases, this damage resulted in the death of affected trees (Osorio *et al*., 2017).

Bioactive Compound of Mangrove Leaves

Mangrove species have great opportunities in the development process for various fields. This is because mangroves have an extraordinary abundance of ecosystems. Bioactive compounds obtained from mangrove plants include polyphenols, flavonoids, alkaloids, carotenoids, tannins, saponins, steroids, amino acids, carbohydrates, proteins, vitamins, terpenes and glycosides (Dahibhate *et al*., 2019). Mangrove leaves, in particular, can produce various types of secondary metabolite compounds that have extraordinary benefits, especially as antibacterials, antioxidants and antipathogens and play a role in suppressing the growth of pests and diseases. These secondary metabolites have various mechanisms that can influence and target pathogen metabolic processes. Plants produce secondary metabolites as a form of self-defense and self-protection, for example, terpenoids, from safety checks that occur in their environment (Inafuku *et al*., 2018). These toxins come from bacteria, fungi, insects and even other pathogens. Mangroves can be categorized as plants whose ecosystems are rich in various organisms. In fact, inhibiting all other anatomical parts of mangroves can also produce various secondary metabolites such as leaves, roots, stems and aerial roots in mangroves. Most of these secondary metabolites are produced in the leaves and have been proven to be widely used for various health needs. Previous studies (Parthiban *et al*., 2022; Khalil *et al*., 2021; Mitra *et al*., 2021) proved that mangrove leaves can produce various bioactive components in the form of flavonoids, terpenoids, alkaloids, tannins and polysaccharides. Apart from that, mangroves can also produce various other chemical compounds such as lipids, carotenoids and amino acids.

Alkaloid

This compound is an organic compound that is also widespread and found in various types of higher plants. Alkaloid compounds in mangrove plants can be said to be quite abundant, especially in the leaves. These alkaloids are mostly found to be alkaline. Alkaloids contain one or more nitrogen atoms in cyclic form for the base part, while the general structure contains carbon, hydrogen, nitrogen and oxygen atoms (Uzor, 2020). The content of various elements in alkaloids causes its role to be very important in physiological and pharmacological effects. The types of alkaloids in each plant are of course different. Mangrove plants in Indonesia have been widely used to prevent pests and plant health. Research shows that the mangrove species *Aegiceras corniculatum* has one of its active components, an alkaloid, which is useful as an antibacterial, antioxidant and anti-inflammatory (Nugraha *et al*., 2023). The alkaloid compounds most commonly found are new types of alkaloid compounds in the form of penibenzophenones and the synthetic α,β-unsaturated

amide alkaloid (E)-tert-butyl (3-cinnamamidopropyl) carbamate, obtained from the isolation of mangrove plants in the mangrove forests of southern China, namely *Bruguiera sexagula* var. Rhynchopetala where the compound can show cytotoxic activity against human A549 with an IC50 value of 15.7 μg/mL and shows antibacterial properties against *Staphylococcus aureus* (Zheng *et al*., 2019).

Phenol

Phenolic compounds have a Hydroxyl group (-OH) attached to a benzene ring and are included in aromatic organic compounds. This phenol has variations in content in plants which are influenced by plant organs in the form of internal factors and nutrients in the form of external factors. Specifically, this phenol is synthesized via the shikimic acid pathway, which is located on the side of the chloroplasts in the leaves (Santos-Sánchez *et al*., 2019). In the *S. caseolaris* mangrove plant, phenol is found in the leaves, while in some mangroves it can be found in the roots and fruit (Dores *et al*., 2014). The role of phenol is mostly as a compound that exhibits antioxidant properties. When exposed to high temperatures, namely ultraviolet radiation, mangrove plants rely on phenolic compounds for protection, so there will be an increase in phenolic compounds if conditions occur that threaten their continued growth. Most of these phenolic compounds are included in the group of important antioxidant compounds. Types of natural antioxidant compounds are tocopherols, flavonoids and phenolic acids. In mangrove plants, this compound is used as a response to biotic stress. *A. marina* is also reported to contain phenolic compounds which are used as antibacterial agents for *P. pseudomonas*, where this pathogen has a bad effect on the survival of some plants (Yoswaty *et al*., 2023).

Flavonoid

Flavonoids are compounds whose benzene structure is substituted with OH groups, these compounds are the largest compounds found in nature and are also contained in roots, stems, leaves and flowers. Flavonoids generally function as antioxidants and have high bioactivity as drugs. In mangrove plants, some species such as *R. aculata* produce flavonoids that can play a role in bactericides to control *A. hydrophila* bacterial disease. However, most flavonoids act as antioxidants, because they have contents that are good acceptors of free radicals, such as hydrogen peroxide and superoxide (Izzati *et al*., 2020). Its role as an antioxidant has several mechanisms, starting with slowing the formation of Reactive Oxygen (ROS), breaking down ROS and regulating or protecting with antioxidants (Arulkumar *et al*., 2020). Flavonoids can also be used as antibacterials, for example in *A. marina* species whose leaves can be used to suppress the growth of *Vibrio parahaemolyticus* bacteria in shrimp (Azis *et al*., 2022). In addition, flavonoids also play a role as antibacterials for gram-positive bacteria, this compound is found in the leaves of the mangrove plant *B. cylindrica*l.

Biological Activities of Mangrove Leaves

Mangrove biological systems are special coastal territories known for their wealthy biodiversity and critical environmental parts. Among the different components of these biological systems, mangrove clears have earned logical intrigue due to their different organic and pharmacological properties (Eswaraiah *et al*., 2020). This study investigates the multifaceted benefits of mangroves, focusing on their potential applications. This segment focuses on the antibacterial, antioxidant and specific antibacterial activities that mangroves perform against pathogens, highlighting their potential applications in restorative and biotechnological areas. Mangrove takes off are stores of different bioactive compounds, including alkaloids, flavonoids, tannins, saponins, phenol, steroids and polyphenols. These compounds contribute to the leaves' striking antioxidant, antimicrobial and anti-inflammatory exercises (Sumardi *et al*., 2018). Various studies have been conducted to utilize these bioactive compounds. Mangroves have been well-investigated for their antibacterial properties, as they have exceedingly bactericidal activities against a wide assortment of pathogens. Because of the abundance of auxiliary metabolites in these plants, antibacterial and antioxidant movements have been observed *in vitro* (Kalasuba *et al*., 2023). Table 2 shows the bioactive roles of mangrove leaves, derived from mangrove species such as *S. alba* (Wijaya *et al*., 2023), *S. caseolaris L*. (Siswanto Syamsul *et al*., 2022), *A. ilicifolius* (Saptiani *et al*., 2021) and *A. marina* (Sumardi *et al*., 2018; Rahman *et al*., 2023), can be used as antibacterial and antioxidant agents. Other species of mangroves also produce compounds that can inhibit or kill pathogens that cause diseases in plants (Syafitri *et al*., 2017).

Terpenoid

Terpenoids are secondary metabolites that have functions in physiological processes in plants as a class of hydrocarbons containing oxygen molecules that are built through biochemical modifications (Pandey *et al*., 2016). Mangroves are known to be rich sources of triterpenoid and phytosterol compounds, these compounds can be utilized as anti-bacterial compounds. Basyuni (2016) explained that terpenoid compounds in mangrove plants have the potential to be used as medicine properties and anti-salt stress components (Basyuni *et al*., 2012; Inafuku *et al*., 2018). Leaf extracts of *Avicennia marina* species can be used as natural antimicrobial compounds that can significantly inhibit the growth of microorganisms. The phytochemical content has many bioactive compounds-flavonoids, tannins and alkaloids-that may be responsible for the observed antimicrobial activity (Sarkar *et al*., 2023).

Table 2: Recent research on bioactive compounds of mangrove leaves

Species	Bioactive compounds	Bioactivity found	References.
Sonneratia alba	Tannins, phenols and steroids	Antioxidant	Wijaya *et al*. (2023)
S. caseolaris L.	-	Antioxidant	Siswanto Syamsul *et al*. (2022)
Achantus ilicifolius	Phenol	Antibacterial	Saptiani *et al*. (2021)
A. marina	-	Antibacterial against *Stenotrophomonas maltophilia*	Sumardi *et al*. (2018); Rahman *et al*. (2023)
A. marina	-	Antibacterial agents against *Virgibacillus marismortui and Micrococcus luteus*	Ulmursida and Trianto (2017)
R. apiculata	Flavonoids, alkaloid, tannins	Bactericides to control *A. hydrophila* bacterial disease	Mulia *et al*. (2023)
Bruguiera gymnorrhiza	Saponin and tannin	Antibacterial against *Escherichia coli*	Kholis *et al*. (2020)
Ceriops tagal	Antochyanin and phenolics	Antibacterial and antifungal	Kovvada *et al*. (2019)
A. corniculatum	Alkaloid, saponin, flavonoid, triterpenoid, steroid, tannin and quinone	Antioxidant, anti-inflammatory, and antibacterial	Nugraha *et al*. (2023)
R. mucronata	-	Antibacterial Againsts *Vibrio* spp.	Baskaran and Mohan (2012)
A. alba	Alkaloids, tannin, saponin, flavonoids, sulfated polysaccharide, terpenoid, polyisoprenoid	Anti-coagulants	Sumardi *et al*. (2018); Rusyiana *et al*. (2021)
Antibacterial *B. gymnorrhiza*	Flavonoids and tannins, saponins, alkaloids and steroids	Inhibited the growth of *A. salmonicida, A. hydrophila and E. ictaluri,*	Sumardi *et al*. (2018); Syawal *et al*. (2021)
A. ilicifolius	Propanethiol, Trimethylphosphine, Pentanoyl chloride, Dimethylhydroxymethylphosphine and Propanedinitrile, ethylidene	Antibacterial Anti-pathogenicity	Sravya *et al*. (2023)

Antibacterial

Mangroves display broad-spectrum antimicrobial action, successful against an assortment of pathogens, counting microscopic organisms, organisms and infections. The nearness of flavonoids and tannins is especially critical in repressing the development of destructive microorganisms, making mangroves clear out a potential source of characteristic antibacterial operators. Antibacterials can interfere with the growth or even kill bacteria by disrupting metabolism, thereby having a detrimental impact on bacterial cells. The mechanism of action of this antibacterial compound is by inhibiting cell wall synthesis, then inhibiting bacterial cell permeability and inhibiting protein and nucleic acids (Santoso *et al*., 2015). This antibacterial property is often found in several plants that are classified as benefiting from secondary metabolite compounds. This can be produced when there is a threat to the environment of some plants. This characteristic is often found in mangrove plants, such as in the *A. ilicifolius* plant which contains phenol. Apart from that, there are many other types of mangroves that can produce these properties to suppress the growth of pests and diseases, which can be seen in Table 2. The *Avicennia* sp. mangrove is a mangrove species that has quite a lot of antibacterial content, because of the various bioactive ingredients in it. A study by Alhaddad *et al*., (2019) showed that leaf extract dissolved with n-hexane, ethyl acetate and ethanol was proven to show a clear zone when tested on several species of microorganisms, making this species potentially used to control pathogenic bacteria.

Antioxidant

Antioxidants have the ability to scavenge free radicals, which cause many degenerative diseases. Mangroves can produce secondary metabolites based on their bioactivity and chemical structure such as antioxidants (Zhou *et al*., 2018). Many mangrove species were identified as being rich in antioxidants. According to a previous study, the leaf extracts of the mangrove plant *Phoenix paludosa*

contain bioactive compounds and have been reported for cytotoxicity and antioxidant activity (Samarakoon *et al*., 2016). The mangrove plant species namely: *A. illicifolia*, *E. agallocha* and *R. apiculata* contain bioactive molecules having anticancer and antioxidant activity (Miranti *et al*., 2018). Young leaves will produce higher levels of antioxidants compared to old leaves, this is due to the different concentrations of antioxidants. Free radicals are detrimental and can cause various deadly effects on living things, therefore antioxidants play a role in reducing these effects. This circumstance is supported by the work of Hanin and Pratiwi (2017) which reported that the spore sample showed a flavonoid content of 2.32 mg/mL and antioxidant activity with an IC50 value of 23.25 ppm. Thus, the ethanolic extract of sea fern leaf spores showed the highest flavonoid content and could be categorized as a powerful antioxidant. In Table 2, it is shown that several species of mangroves produce powerful antioxidant properties. Some of these species are *A. corniculatum*, *S. alba* and *S. caseolaris*. Phenols and flavonoids are the bioactive compounds that contribute the most to this feature. Other research also showed the existence of antioxidant-based products from mangrove plants in the *R. apiculata* species which is the dominant species in the mangrove area of Indonesia (Miranti *et al*., 2018).

Mangrove ecosystems are a type of forest with muddy and waterlogged growing conditions, making it difficult to reach all sides of the forest. The condition of the forest that is difficult to reach is a limiting factor in preserving the forest from various physical threats such as logging, exploitation of flora and fauna and handling damage caused by pests and diseases. Therefore, the government has implemented a rehabilitation program by restoring mangrove forests. Replanting seedlings and propagules at degraded locations is a conservative measure in rehabilitating mangrove forests (Amelia *et al*., 2023). Fig. 1 demonstrates the conservative pathway that needs to be followed for forest rehabilitation to be sustainable. In addition, there needs to be monitoring and alternative solutions to answer the challenges of mangrove forest rehabilitation in the future (Sasmito *et al*., 2023), one of which is a study related to the use of mangrove leaf extracts that contain bioactive compounds and can be implemented to prevent the presence of pests and diseases in mangrove ecosystems.

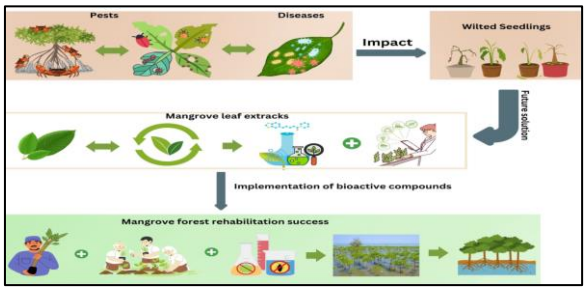

Fig. 1: Successful mangrove forest rehabilitation

Concluding Remarks and Future Direction

Currently, the successful rehabilitation of mangrove forests provides great benefits to coastal communities. The community can process and utilize the available natural resources so that the economic output can increase. Mangrove rehabilitation programs continue to be carried out with careful planning and implementation, taking into account ecological, social and economic aspects. The main priority in the mangrove rehabilitation program is inseparable from the government's efforts to restore the function of healthy forests and have high species diversity (Fauzi *et al*., 2022).

Maintenance and monitoring are very important for mangrove seedlings that have been planted to grow and live for a long time and be able to withstand extreme environmental stress. The success of rehabilitated mangrove maintenance depends on the threat of existing disturbances, such as pests, diseases, pollution, livestock and others (Amelia *et al*., 2023). The threat of pests and diseases in mangroves is an important concern in the rehabilitation process. Pests found on mangrove trees will interfere with the growth process of mangroves ranging from seedlings to trees. The presence of pests and diseases on mangrove leaves causes physical damage such as perforated leaves, black and white spots and ticks attached to the surface of the leaves. Inhibition of the process of photosynthesis and respiration in the leaves affects the metabolic process of plant growth, the lack of nutrients in the place of growth is a major factor in increasing the attack of pests and diseases. A very large pest attack will bring disease so mass damage will occur in the mangrove ecosystem.

Research related to the utilization of bioactive compounds in mangrove leaf extracts has been widely carried out, thus requiring adequate development in its management and application. Bioactive compounds of mangrove leaf extract can be used as a solution in suppressing the development of fungi that can invite the presence of pests and diseases in mangroves. The findings of our studies based on published papers confirmed that mangrove leaves contain bioactive compounds that can suppress the presence of pests and inhibit diseases on mangrove leaves, the results of extraction can be developed and mass-produced so that it can be used in the process of rehabilitation of mangrove ecosystems.

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Author's Contributions

Andi Aznan Aznawi: Conceived and designed the analysis. Collected the data. Wrote the manuscript draft.

Mohammad Basyuni: Design research on the impact of pests and diseases in mangrove forest rehabilitation, reviewed and finalized the manuscript.

Diana Sofia Hanafiah: Design a secondary metabolism and active compounds in mangrove leaves.

Siti Halimah Larekeng: Reviewed the drafting and final of the manuscript.

Sari Puspitha Mulya Sari: Collected the data and compiled a paper.

Ethics

This article is original and contains unpublished material. The corresponding author confirms that all of the other authors have read and approved the manuscript and that no ethical issues are involved.

Competing Interests

The authors report no conflicts of interest regarding this study.

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