

REVIEW ARTICLE

POTENTIAL OF ACACIA MANGIUM, ANACARDIUM OCCIDENTALE, AND SWIETENIA MAHAGONI LEAF EXTRACTS AS BIOCONTROL AGENTS AGAINST *Xanthomonas Oryzae* Pv. *Oryzae*: A REVIEW

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ABSTRACT

Bacterial leaf blight (BLB), caused by *Xanthomonas oryzae* pv. *oryzae* (Xoo), remains one of the most destructive diseases of rice in Southeast Asia, including Malaysia, where yield losses can reach 70%. The extensive reliance on synthetic bactericides has raised concerns regarding environmental contamination and the emergence of resistant pathogen strains, highlighting the need for sustainable disease management alternatives. This review evaluates the biocontrol potential of leaf extracts from *Acacia mangium*, *Anacardium occidentale*, and *Swietenia mahagoni* against Xoo, with emphasis on their phytochemical composition and antibacterial mechanisms based on published *in vitro* studies. Available evidence indicates that *A. mangium* exhibits the strongest antibacterial activity, including pronounced bactericidal effects and inhibition of Xoo biofilm formation. *A. occidentale* demonstrates moderate antibacterial activity, supported by a broad spectrum of bioactive phenolic compounds and antioxidant properties. In contrast, *S. mahagoni* shows limited or pathogen-specific antimicrobial activity, with no consistent inhibition of Xoo reported, suggesting variable effectiveness against different target pathogens. Collectively, these findings highlight the potential of selected plant extracts, particularly *A. mangium* and *A. occidentale*, as promising candidates for further development as plant-based biocontrol agents. Future research should focus on formulation optimisation and *in vivo* validation to support their integration into integrated pest management (IPM) strategies for sustainable rice disease control.

KEYWORDS

Xanthomonas pv. *oryzae* oryzae; plant-based biocontrol; *Acacia mangium*; *Anacardium occidentale*; sustainable agriculture

1. INTRODUCTION

Rice (*Oryza sativa* L.) is a staple food for over half of the world's population. In Malaysia, rice is classified as a primary crop in terms of cultivation area and production (Wahab, 2018). The rapid growth of the human population in Asia has led to estimates of a 70% increase in rice production required to meet future demands (Rajamoorthy et al., 2015). According to the predictions, people in Malaysia consume about 80 kg of rice annually, which accounts for to 26% of their daily caloric intake. Malaysia's rice production faces a structural deficit, with local production approximately 1.68–2.28 million tonnes, which meets only about 56%–70% of local demand.

Like other crops, rice production faces challenges from climate change, high production costs, ageing farmers, pests and diseases, and a lack of acceptance of new technologies, all of which contribute to reduced productivity. Each year, biotic stresses such as diseases, weeds, and insect pests cause losses in rice crops worldwide (Patra et al., 2018). Despite ongoing government support and initiatives, rice self-sufficiency remains below optimal levels, with 37.4% of demand met through imports (Omar, 2022; Firdaus et al., 2020). Currently, 67% of rice is produced domestically, and the remaining 33% are coming mostly from imports

from Thailand, Vietnam, and Pakistan. Among the challenges faced, the most significant constraint to rice production is the outbreak of bacterial leaf blight (BLB), caused by *Xanthomonas oryzae* pv. *oryzae* (Xoo), which can reduce rice yields up to 70% under severe infection conditions, including in major rice-growing regions (Naqvi, 2019; Mohd Din et al., 2023). This disease not only affects Malaysian rice production but is also reported in other Southeast Asian countries. In India, rice yield loss has been reported to reach up to 81.3 % of due to this disease, and in Japan, the yield losses were reported to range between 20-30 % and can reach up to 50 % of rice production (Gnanamanickam et al., 1999; Veena et al., 2000; Ou, 1985).

2. BACTERIAL LEAF BLIGHT

Rice Bacterial Leaf Blight disease is caused by *Xanthomonas oryzae* pv. *oryzae*, is reported to be one of the oldest and most dangerous rice diseases (Chukwu et al., 2019). This disease was initially discovered in Japan in 1884, and in 1885 it was found in other rice-growing countries (Gnanamanickam, 2009). BLB was first identified in Malaysia in 1960 and has since become a persistent threat to rice cultivation. In the early 1980s, a small-scale BLB infection was initially recorded in Peninsular Malaysia's rice fields (MOA, 2018).

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2.1 Epidemiology

Currently, this disease has spread rapidly, and under moderate weather conditions, it causes crop losses of 10% to 20%; however, under favourable conditions, crop losses can reach 50% (DOA, 2019). Recent outbreaks have affected over 12,000 hectares of rice fields all over Malaysia, with reported yield losses ranging from 30% to 70% (DOA, 2019; Mohd Din et al., 2023). These losses pose a significant threat to national food security and to farmers' livelihoods. According to a study, *X. oryzae* pv. *oryzae* is a seed-borne and seed-transmitted disease (Veena et al., 2000). Infected seeds lead to poor germination and affect plants during the tillering and flowering stages, resulting in the formation of chaffy seeds. This disease not only directly reduces yield but also adversely affects the seed quality through seed discolouration. *Xanthomonas oryzae* pv. *oryzae* (Xoo) spreads rapidly through rain splashes, irrigation water, wind, infected seeds, and contaminated farm tools. Favourable environmental conditions, such as high humidity, standing water, and temperatures between 25°C and 34°C, exacerbate disease incidence (Aftab et al., 2022; Naqvi, 2019). The transmission of the disease is further increased by strong winds that may injure rice plants (Sharma et al., 2017). Furthermore, BLB severity is further favoured by rice cultivars' vulnerability to high nitrogen fertilisation (Kiran et al., 2015).

2.2 Symptomology

A rice plant may be infected at any growth stage, which may begin from the seedling to the mature plant stages. The bacterium invades plants through wounds or water pores (stomata and hydathodes). The hydathodes facilitate water percolation; thus, the lesions normally start at leaf margins on the upper part near the top area. The symptoms start with small, water-soaked lesions that eventually turn yellowish-white and expand from both ends, forming elongated, sometimes uneven lesions. Lesion edges then coalesce and display the disease's distinct symptom: wavy margins. As the disease progresses, lesions coalesce, leading to leaf drying and rolling, in severe cases, plant death (Suma et al., 2016; Niño-Liu et al., 2006). Figure 1 displays a close-up of symptomatic rice leaves, clearly illustrating typical BLB lesions caused by *Xanthomonas oryzae* pv. *oryzae*.



Figure 1: Typical symptoms of bacterial leaf blight on rice leaves caused by *Xanthomonas oryzae* pv. *oryzae*. Bacterial blight symptoms on rice leaves [Photograph]. Note. From *PlantVillage*, Pennsylvania State University, 2018, <https://plantvillage.psu.edu/diseases/bacterial-blight-2c3e7c50-6320-4bf7-802a-27dceb60e63d>

Disease development and emergence in the field were significantly influenced by the environment. The disease can be divided into two primary stages: the leaf blight phase and the "Kressek phase," the most devastating stage of the disease (Reddy and Ou, 1976; Ou, 1985; Pranamika et al., 2017).

2.3 Leaf Blight Phase

In temperate regions of rice-growing countries, this disease phase appears very early, with the first symptoms appearing on the leaf blades after tillering reaches its peak position. It typically starts in the lower parts of plants and progressively spreads upward (Goto, 1992; Cha, 1982). Severe symptoms of the disease can be observed on susceptible cultivars when grown under excessive nitrogen fertilisation. According to a study the disease was so severe that the upper part of the leaf or the entire leaf blade

turned pale yellow before drying up (Mizukami and Wakimoto, 1969). In severe cases, yellow to white stripes developed immediately along the leaf blade margins, and these stripes eventually turned pale yellow and necrotic (Ou, 1985).

2.4 Kressek Phase

The word "Kressek" is derived from the Vernacular term in Java, meaning "the sound of dead leaves" (Wakimoto, 1969). The "kressek" phase is the highly destructive seedling wilt stage of bacterial leaf blight (BLB) in rice. It appears 1–3 weeks after transplanting from nursery to the field, and sometimes it also occurs on mature plants (Goto, 1992; Watanabe, 1975). On seedlings, infected leaves turn greyish green and roll up. As the disease progresses, the leaves turn yellow, then straw-coloured and eventually wilt, leading whole seedlings to dry up and die.

3. LIMITATIONS OF CURRENT CONTROL STRATEGIES

Conventional management of BLB rice disease includes the use of resistant rice varieties, cultural practices such as field sanitation, and the application of chemical treatments, including copper-based bactericides and antibiotics like streptomycin (Kim et al., 2022; Nasir et al., 2019). Seed treatments with hot water and bleaching powder are employed to reduce pathogen load. No doubt, chemical bactericides are highly effective in controlling BLB; however, prolonged use of these agents has led to the emergence of resistant Xoo strains, rendering some treatments less effective (Nga et al., 2021). Moreover, excessive reliance on agrochemicals contributes to soil and water contamination, harms non-target organisms, and increased production costs, all of which are contrary to the principles of sustainable agriculture. The limited efficacy, high costs, and ecological risks associated with current strategies underscore the need for alternative solutions that are both environmentally friendly and economically viable. Given the limitations of chemical treatments and the emergence of resistant varieties, research has shifted toward identifying natural and sustainable biocontrol strategies. In this context, plant-based biocontrol agents offer a sustainable alternative due to their biodegradability, low toxicity, and ability to enhance plant defence (Gnanamanickam, 2009; Yasmin et al., 2017). This review examines three promising candidates, *Acacia mangium*, *Anacardium occidentale*, and *Swietenia mahagoni* leaf extracts which all exhibit bioactive profiles that are suitable for controlling Xoo.

4. PLANT-DERIVED EXTRACTS AS BIOCONTROL AGENTS AGAINST XOO

Plant-derived extracts are rich in secondary metabolites, including phenolics, flavonoids, alkaloids, and terpenoids, which collectively confer broad-spectrum antimicrobial activity. These compounds exert antibacterial effects by disrupting bacterial membranes, inhibiting biofilm formation, and interfering with essential microbial metabolic pathways (Makhuvele et al., 2020; Omokhua et al., 2018; Tian et al., 2022). Due to their biodegradability, low environmental impact, and cost-effectiveness, plant-based products represent promising alternatives to synthetic bactericides in sustainable agriculture and rice disease management (Mandiriza et al., 2018; Makhuvele et al., 2020).

Several tropical plant species have demonstrated inhibitory activity against *Xanthomonas oryzae* pv. *oryzae*, the causal agent of bacterial leaf blight (Naqvi et al., 2019; Shabani et al., 2018). In addition, plant extracts such as *Azadirachta indica*, *Allium sativum*, *Curcuma longa*, and *Mentha piperita* have been widely reported as effective biocontrol agents, exhibiting broad-spectrum activity against phytopathogenic fungi and bacteria (Makhuvele et al., 2020; Naqvi et al., 2019). The following sections highlight the specific biocontrol properties of three such species with promising activity against *Xanthomonas oryzae* pv. *oryzae*. The antibacterial activity of selected plant extracts against *Xanthomonas oryzae* pv. *oryzae*, based on previous studies, is summarised in Table 1. The major phytochemical constituents and their proposed antibacterial mechanisms against *Xanthomonas oryzae* pv. *oryzae* are presented in Table 2.

Table 1: Summary of Antibacterial Activity of Selected Plant Extracts Against *Xanthomonas oryzae* pv. *oryzae*

Plant	Extract type	MIC	Activity	Reference
<i>Acacia mangium</i>	Methanol	3.13 mg/mL	Strong	Shafiei et al., 2021
<i>Anacardium occidentale</i>	Ethanol	2.5-5 mg/mL	Moderate	Pham et al., 2023
<i>Swietenia mahagoni</i>	Methanol, ethanol, aqueous	12.5-25 mg/mL	Weak	Khamis et al., 2023

Table 2: Major Phytochemical Compounds and Their Proposed Antibacterial Mechanisms Against <i>Xanthomonas oryzae</i> pv. <i>Oryzae</i>			
Plant	Phytochemicals	Mechanism	Reference
Acacia mangium	Phenolics, tannins, flavonoids	Membrane disruption and enzyme inhibition	Shafiei et al., 2017; Makhuvele et al., 2020
Anacardium occidentale	Flavonoids, phenolic acids, triterpenes	Membrane disruption and metabolic interference	da Silva et al., 2016; Ajileye et al., 2015
Swietenia mahagoni	Saponins, alkaloids, phenolics	Membrane disruption and protein denaturation	Syame et al., 2022; Khamis et al., 2023

5. BIOCONTROL POTENTIAL OF ACACIA MANGIUM

Acacia mangium, a fast-growing leguminous tree, has attracted attention for its potent antimicrobial leaf extract. Methanolic extracts of *A. mangium* inhibited Xoo biofilm formation and disrupted mature biofilms, with minimum inhibitory concentration (MIC) values as low as 3.13 mg/mL (Shafiei et al., 2021). The antibacterial activity is associated with the presence of phenolic acids, tannins, and terpenoids, as confirmed by GC-MS analysis (Shafiei et al., 2017).

Figure 2 presents the typical leaves of *Acacia mangium*, which serve as the source material for these biocontrol extracts. Additionally, aqueous extracts demonstrated comparable activity to that of methanolic extracts, suggesting their feasibility for large-scale, eco-friendly applications (Mondal et al., 2017). The antibacterial activity of *A. mangium* is attributed to its rich phytochemical profile. GC-MS and phytochemical analyses have



Figure 2: Leaves of *Acacia mangium* are used as source material for leaf extract preparation. *Acacia mangium* – bottlebrush-like white inflorescence [Photograph]. Note. From NParks Flora & Fauna Web, by National Parks Board, 2010, <https://www.nparks.gov.sg/florafaunaweb/flora/2/6/2695>

6. BIOCONTROL POTENTIAL OF ANACARDIUM OCCIDENTALE

Anacardium occidentale, commonly known as the cashew tree, is widely recognised for its antimicrobial properties and rich phytochemical composition. Leaf extracts of *A. occidentale* have demonstrated strong antibacterial activity against a range of Gram-positive and Gram-negative bacteria, including *Escherichia coli* and *Bacillus subtilis*, with reported minimum inhibitory concentration (MIC) values ranging from 2.5 to 5 mg/mL (Pham et al., 2023).

Ethanol extracts of *A. occidentale* leaves also showed bactericidal activity against multiple clinically and agriculturally relevant bacteria including *Staphylococcus aureus*, *Escherichia coli*, *Streptococcus mutans*, and methicillin-resistant *Staphylococcus aureus* (da Silva et al., 2016). The antimicrobial efficacy of *A. occidentale* leaf extracts is closely associated with their phytochemical profile, which includes phenolic acids (notably anacardic and gallic acids), flavonoids, triterpenes, and xanthones.

These compounds disrupt the bacterial membrane and interfere with metabolism, thereby inhibiting growth. In addition, *A. occidentale* leaf extracts exhibit notable antioxidant activity, with free-radical scavenging

identified phenolic compounds, tannins, flavonoids, and terpenoids in *A. mangium* leaf extracts (Shafiei et al., 2017). These secondary metabolites are known to disrupt bacterial cell membranes, interfere with enzymatic activity, and inhibit essential metabolic processes, resulting in growth suppression or cell death. In addition to BLB of rice, *A. mangium* extracts have shown efficacy against other plant bacterial diseases.

Tannin-rich extracts from *A. mangium* bark have been shown to significantly inhibit *Pectobacterium carotovorum* (formerly *Erwinia carotovora*), the causal agent of bacterial soft rot in vegetables such as potatoes and cabbage (Sinaga et al., 2021). Moreover, aqueous and organic solvent extracts of *A. mangium* have demonstrated antibacterial activity against *Ralstonia solanacearum*, a major pathogen responsible for bacterial wilt in solanaceous crops, indicating a broader antibacterial spectrum (Mondal et al., 2017).

In addition to Xoo, other bacteria have also been reported, suggesting potential applications against leaf spot and blight diseases in various crops. Notably, aqueous leaf extracts of *A. mangium* exhibited antibacterial activity comparable to that of methanolic extracts, supporting their feasibility for environmentally friendly and large-scale agricultural applications (Mondal et al., 2017).

This is advantageous for sustainable crop protection, as water-based formulations reduce solvent-related toxicity and environmental risks. Consistent with these findings, results from the present thesis demonstrated that *A. mangium* leaf crude extract exhibited the lowest MIC and MBC (5000 ppm) against *Xanthomonas oryzae* pv. *oryzae*, with complete bactericidal activity and significant reduction of BLB severity under greenhouse conditions (Zubir et al., 2025). Collectively, these studies indicate that *Acacia mangium* possesses broad-spectrum antibacterial activity against multiple plant bacterial pathogens, supporting its potential integration into integrated pest management (IPM) strategies as a sustainable alternative to chemical bactericides.

capacity comparable to quercetin, suggesting an additional role in mitigating oxidative stress in infected plant tissues (da Silva et al., 2016). Broad-spectrum antimicrobial activity of *A. occidentale* has been consistently reported. Methanolic leaf extracts inhibited several bacterial pathogens, including *Klebsiella pneumoniae*, *Staphylococcus aureus*, *Bacillus subtilis*, *Salmonella typhi*, and *Escherichia coli*, as well as the yeast *Candida albicans*, with inhibition zones ranging from 13 to 22 mm (Ayepola and Ishola, 2009). Bioassay-guided studies further identified flavonoids such as agathisflavone and quercetin glycosides as key bioactive constituents, exhibiting MIC values as low as 0.25 mg/mL against selected bacterial strains (Ajileye et al., 2015). In the context of plant disease management, the present study found that *A. occidentale* leaf crude extract exhibited antibacterial activity against *Xanthomonas oryzae* pv. *oryzae*, resulting in reduced bacterial growth and suppression of bacterial leaf blight severity under greenhouse conditions, although its efficacy was lower than that observed for *Acacia mangium* (Zubir et al., 2025). This suggests that the antimicrobial efficacy of *A. occidentale* may be pathogen-specific, with greater potential against non-vascular or soil-borne pathogens, although further targeted studies are required to confirm this.



Figure 3: Leaves of *Anacardium occidentale* (cashew tree) are utilised for antibacterial screening. *Anacardium occidentale* [Photograph]. Note. Photograph by J. Teo, 2017, from NParks Flora & Fauna Web, <https://www.nparks.gov.sg/florafaunaweb/flora/2/7/2709>

7. BIOCONTROL POTENTIAL OF SWIETENIA MAHAGONI

Swietenia mahagoni is a tropical tree species known for its medicinal value and rich secondary metabolite profile. Phytochemical analyses of *S. mahagoni* leaves have identified alkaloids, flavonoids, phenolic compounds, saponins, and tannins, which are associated with antimicrobial activity (Syame et al., 2022). Previous studies reported antibacterial activity of *S. mahagoni* leaf extracts against selected Gram-positive and Gram-negative bacteria, with minimum inhibitory concentrations (MICs) ranging from 12.5 to 25 mg/mL, depending on the solvent system and target pathogen (Khamis et al., 2023; Syame et al., 2022). The antibacterial effects have been attributed to membrane disruption by saponins and the synergistic action of phenolic compounds such as catechin, gallic acid, and rutin.

In addition to antibacterial activity, *S. mahagoni* extracts exhibited antifungal effects against soil-borne phytopathogens, including *Rhizoctonia solani* and *Fusarium equiseti*, which cause damping-off, root rot, and wilt diseases in various crops (Syame et al., 2022), indicating a potential dual antimicrobial role in crop protection. However, the present study found that *S. mahagoni* leaf crude extract did not inhibit *Xanthomonas oryzae* pv. *oryzae* under *in vitro* conditions, in contrast to *Acacia mangium* and *Anacardium occidentale* (Zubir et al., 2025). This suggests that the antimicrobial efficacy of *S. mahagoni* is pathogen-specific and influenced by extraction methods and target organism. Overall, while *S. mahagoni* demonstrates antimicrobial activity against several bacterial and fungal pathogens, its limited effectiveness against bacterial leaf blight indicates greater potential for managing soil-borne and fungal diseases within integrated pest management (IPM) system



Figure 4: Leaves of *Swietenia mahagoni* are used for the preparation of extracts. *Swietenia mahagoni* [Photograph]. Note. From Leon Levy Native Plant Preserve, by Freid, E. 2022, <https://levypreserve.org/plant-listings/swietenia-mahagoni/>

8. CONCLUSION

The rising resistance to synthetic agrochemicals necessitates a shift toward eco-friendly plant-based alternatives. Extracts from *Acacia mangium* and *Anacardium occidentale* show promising in vitro antibacterial activity against *Xanthomonas oryzae* pv. *oryzae*, with *A. mangium* demonstrates the highest efficacy, while *Swietenia mahagoni* exhibits limited or pathogen-specific antimicrobial effects.

Among these, *A. mangium* appears most potent, especially against biofilm-forming Xoo strains. Future research should focus on standardising extraction methods and dosages, conducting greenhouse and field trials, investigating synergistic formulations with other biocontrol agents, and developing commercially viable biopesticide products. The integration of these botanicals into integrated pest management (IPM) frameworks offers a promising avenue for sustainable rice disease management.

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DECLARATION OF INTEREST

The authors declare no competing interests.

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