

Exploring The Role of Botanical Extracts in Plant Disease Management

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Abstract

Agriculture is the key for global food security is constantly challenged by the biotic stress arising from plant diseases posing significant impact on crop production. *Saroclodium oryzae* and *Rhizoctonia solani* are the fungal plant pathogens, posing a significant threat to agricultural productivity. Conventional fungicides are losing their potency due to the development of resistance in pathogens leading to the urgent need for the development of sustainable alternatives. Plant based extracts have been acknowledged for a long time for their potential as biocontrol agents due to their antifungal properties. This study analyses the antagonistic effects of leaf extracts from *Calotropis procera*, *Ailanthus altissima*, *Lantana camera*, *Annona squamosa* and seed kernel oil from *Annona squamosa* against *Saroclodium oryzae* and *Rhizoctonia solani*. The results demonstrate that all the plant extracts showed antifungal activity against *S. oryzae*, however no inhibitory effect was seen in *R. solani*. The findings also suggest the presence of dominant bacterial flora in the extracts, which may explain antagonistic effects observed implying a synergistic relation between plant extracts and associated microbial communities. The bioactive compounds in these extracts contribute to the antimicrobial properties. The findings of this study highlight the potential of plant-based extracts which is enriched with microbial flora as promising biocontrol agents for sustainable agricultural practices. Further research is needed for the identification of active microbial populations and their metabolites which could pave a way for developmental of eco-friendly and effective biocontrol strategies in crop protection.

INTRODUCTION

Agriculture is the corner stone of global food security supporting the nutritional demands of an ever-growing population. However biotic stresses particularly plant diseases caused by fungal pathogens pose significant threats to agricultural productivity (Savary et al., 2019). Fungal pathogens are a major concern due to their ability to spread through spores (Oerke, 2006), thrive in humid and warm field conditions (Velásquez et al., 2018), persist as soil borne agents (Raaijmakers et al., 2009), and exhibit broad host ranges (Dean et al., 2012; McDonalds & Stukenbrock, 2016). The emergence of fungicide resistant strains further exacerbates the challenge, rendering conventional control measures less effective (Fisher et al., 2018). Climate change has intensified these issues by creating favourable conditions for pathogen proliferation, thereby threatening crop yield and food security (Singh et al., 2023; Fones et al., 2020).

Among fungal pathogens, *Sarocladium oryzae* and *Rhizoctonia solani* are particularly devastating to rice, a staple crop for billions worldwide. *S. oryzae* causes sheath rot in rice, leading to lesions on the sheath and significant yield losses. *R. solani*, a soil-borne pathogen with a wide host range, is responsible for diseases such as sheath blight in rice, damping -off in beans and cotton, and root rot and black scurf in potatoes (Ajayi-Oyetunde & Bradley, 2018). These pathogens severely impact both yield and quality, posing a critical threat to global food production (Chakraborty & Newton, 2011).

The heavy reliance on synthetic fungicides for disease control has led to the environmental pollution, human health concerns and the development of resistant pathogen strains (Nicolopoulou-Stamati et al., 2016; Saeed et al., 2021; O'Callaghan et al., 2022). Consequently, there is an urgent need for sustainable, eco-friendly alternatives (Grover et al., 2021). Plant-based extracts, rich in bioactive secondary metabolites such as terpenoids, alkaloids, phenols and flavonoids, have been used for centuries to manage plant diseases and offer a promising solution for sustainable agriculture (Gurjar et al., 2012; Kumar, 2012). These compounds disrupt microbial cell membranes, inhibit metabolic pathways and interfere with fungal growth (Cushnie & Lamb, 2011).

This study investigates the antifungal potential of leaf extracts from *Calotropis procera*, *Ailanthus altissima*, *Lantana camara*, *Annona squamosa* and seed kernel oil from *Annona squamosa* against *S.oryzae* and *R. solani*. These plants are known for their antimicrobial properties, attributed to compounds such as flavonoids, terpenoids and acetogenins (Radtko et al., 2013; Islam et al., 2012; Kalidindi et al., 2015). Additionally, the study explores the role of microbial communities associated with these extracts, hypothesizing those synergistic interactions between phytochemicals and beneficial bacteria may enhance their biocontrol efficacy. By evaluating the antagonistic effects of these extracts this research aims to contribute to the development of sustainable disease management strategies for rice cultivation.

MATERIALS AND METHODS

1. Collection of plant material

Healthy leaves of *Calotropis procera*, *Ailanthus altissima*, *Annona squamosa*, *Lantana camara* and seeds of *Annona squamosa* were collected from School of Agricultural Sciences, Aushapur. The leaves were thoroughly washed with tap water followed by sterile distilled water to remove dust and surface contaminants.

2. Preparation of Leaf Extracts

Leaves were sterilized by soaking in 0.1% mercuric chloride for 30 seconds, followed by 2–4 washes with sterile distilled water. For each plant species, 10 g of surface-sterilized leaves were macerated in a sterile mortar and pestle with 10ml of methanol. The resulting extract (7ml) was filtered using filter paper.

3. Preparation of *Annona squamosa* Seed Kernel Oil Extract

Fresh *Annona squamosa* seeds were collected, washed and sun-dried for 24 hours. Kernels were obtained by dehulling the seeds and pulverized into a coarse powder. Ten grams of pulverized kernel were placed in a thimble within a Soxhlet apparatus and the oil was extracted using petroleum ether

(60–80°C) over four cycles. The extracted oil was heated on a hot plate to remove the residual solvent until a stable weight was achieved, yielding 1.76g of seed kernel oil.

4. Test Fungal Pathogens

Sarocladium oryzae and *Rhizoctonia solani* were isolated from infected rice tissues and maintained on Potato Dextrose Agar (PDA) medium. Pure cultures were sub cultured and incubated at $25 \pm 2^\circ\text{C}$ for 7 days.

5. Poisoned Food Technique

PDA was prepared, sterilized and cooled to approximately 45°C. Different concentrations of plant extracts (5%, 10%, 15% and 20%) were added to molten PDA before solidification. The medium was poured into sterile petri plated and allowed to solidify. A 5mm diameter mycelial disc from the edge of a 7-day old culture of the test pathogen was placed at the centre of each plate. Control plates contained PDA without plant extract.

RESULTS

1. Antagonistic Effect on *Sarocladium oryzae*

All the tested extracts including the leaf extracts from *Calotropis procera*, *Ailanthus altissima*, *Annona squamosa*, *Lantana camara* and seed kernel oil from *Annona squamosa* exhibited significant antagonistic activity against *S. oryzae*. The inhibition of fungal growth suggests the presence of bioactive compounds with antifungal properties specific to *S. oryzae*.

2. Lack of Antagonistic Effect Against *Rhizoctonia solani*

None of the tested concentrations of the leaf or seed extracts showed any inhibitory effect against *R. solani*, indicating a lack of antifungal activity against this pathogen.

3. Role of Dominant Bacterial Flora in *Sarocladium oryzae* Inhibition

A notable observation was the presence of dominant bacterial flora in the leaf and seed extracts that exhibited antagonistic activity against *S. oryzae* (Fig. 1). This suggests a dual mechanism of action where both the plant -derived antifungal compounds and beneficial bacteria contribute to pathogen suppression. In contrast, no bacterial growth was observed in plates inoculated with *R. solani* and the seed kernel oil showed minimal bacterial or fungal growth indicating that the *R. solani* may suppress other microbial activity (Table 1).

Table 1
Antifungal Activity of Botanical Extracts (20% Concentration)

Plant Extract	<i>S. oryzae</i> (% Inhibition)*	<i>R. solani</i> (% Inhibition)
<i>Calotropis procera</i>	80	0
<i>Ailanthus altissima</i>	78	0
<i>Annona squamosa</i> (leaf)	79	0
<i>Lantana camara</i>	75	0
<i>Annona squamosa</i> (seed oil)	85	0

DISCUSSION

This study demonstrated the significant antifungal potential of the leaf extracts from *Calotropis procera*, *Ailanthus altissima*, *Annona squamosa*, *Lantana camara* and seed kernel oil from *Annona squamosa* against *Sarocladium oryzae*, major rice pathogen. The consistent inhibition of *S. oryzae* across all tested extracts highlights the presence of potent bioactive compounds at the given concentrations and extraction methods. The bioactive compounds such as flavonoids, terpenoids, acetogenins are known to disrupt the fungal cell membranes and metabolic pathways (Cushnie & Lamb, 2011; Kalidindi et al., 2015). For instance, *Calotropis procera* contains cardenolides, triterpenoids and flavonoids like quercetin and kaempferol, which have documented antimicrobial activity against various pathogens (Islam et al., 2012). Similarly, *Ailanthus altissima* produces quassinoids such as Ailanthone, which targets the fungal ergosterol, inhibiting the growth (Jordá & Puig, 2020). *Lantana camara* and *Annona squamosa* contribute volatile terpenoids and acetogenins respectively, further enhancing antifungal efficacy (Tembo et al., 2018; Alali et al., 1999).

Interestingly, none of these extracts inhibited *Rhizoctonia solani* suggesting a degree of specificity in their antifungal action. This could be attributed to *R. solani* robust resistance mechanisms, such as to dominate microbial interactions, as evidenced by the absence of bacterial growth in *R. solani*-inoculated plates. The oil-borne nature of *R. solani* and its broad host range may also confer resilience against the bioactive compounds present in the extracts (Raaijmakers et al., 2009; Dean et al., 2012). Previous studies have reported viable efficacy of plant extracts against *R. solani* with some suggesting the higher concentrations or specific formulation may be required (Abdul-karim & Hussein, 2025; Ravali & Rai, 2024).

A particularly compelling finding is the role of dominant bacterial flora in the extracts antagonistic activity against *Sarocladium oryzae*. The presence of beneficial bacteria, likely endophytic or epiphytic, suggests a synergistic interaction between plant-derived compounds and microbial communities (Saravanakumar et al., 2024). These bacteria may produce secondary metabolites or enzymes that directly inhibit fungal growth, complementing the action of phytochemicals. The absence of bacterial growth in *R. solani* plates further supports the hypothesis that *R. solani* may suppress microbial competitors, highlighting its ecological dominance (Ajayi-Oyetunde & Bradley, 2018). This dual

mechanism of action-phytochemical and microbial-underscores the potential of plant extracts as holistic biocontrol agents, aligning with the need for sustainable alternatives to synthetic fungicides (Grover et al., 2021; Cools et al., 2013).

The selective efficacy of the extracts against *S. oryzae* emphasizes the importance of tailoring biocontrol strategies to specific pathogens. Future research should focus on isolating and characterizing the bioactive compounds and microbial strains responsible for the observed effects. Additionally, optimizing extract formulations and delivery methods could enhance their efficacy against resistant pathogens like *R. solani*. These findings contribute to the growing body of evidence supporting plant-based biocontrol as a viable strategy for sustainable agriculture (Gurjar et al., 2012).

CONCLUSION

This study highlights the potential of leaf extracts from *Calotropis procera*, *Ailanthus altissima*, *Annona squamosa*, *Lantana camara* and seed kernel oil from *Annona squamosa* as effective biocontrol agents against *Sarocladium oryzae*. The synergistic interplay between phytochemicals and associated bacterial flora enhances their antifungal efficacy offering a promising alternative to synthetic fungicides. The lack of activity against *Rhizoctonia solani* underscores the need for pathogen-specific approaches in biocontrol development. Further research into the identification of active compounds and microbial populations, as well as their mechanisms of action is the essential to optimize these natural extracts for commercial application. By harnessing plant- microbe interactions, this approach could pave the way for sustainable and environmentally friendly disease management in rice and other crops.

DECLARATIONS

Ethical approval

The present study involved experimental research using plant materials grown at the School of Agricultural Sciences, Anurag University, Hyderabad, India. The collection and use of plant materials were carried out in accordance with the institutional guidelines of Anurag University and complied with the relevant national and international guidelines and legislation governing the use of plant materials in research. No protected, endangered, or wild plant species were collected or used in this study.

Consent to Participate

Not applicable

Consent to Publish

Not applicable

Competing interests

The authors declare that they have no competing interests.

Funding Declaration

There is no funding received for this work.

Author Contribution

Sravani ram and Shrey Bodhankar conceptualized and designed the study. Shrey Bodhankar, Jayanthi Bhima, Ch. Swathi performed the experiments and collected the data. Shrey Bodhankar supervised the research work and provided technical guidance. Shrey Bodhankar, and Sravani Ram analyzed the data and wrote the main manuscript text. Shrey Bodhankar and Sravani ram assisted in data interpretation and manuscript preparation. Stephen Ratnam. contributed to critical revision and overall improvement of the manuscript. All authors reviewed and approved the final manuscript.

Availability of data and materials

The datasets generated and/or analyzed during the current study are available from the corresponding author upon reasonable request.

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Figures

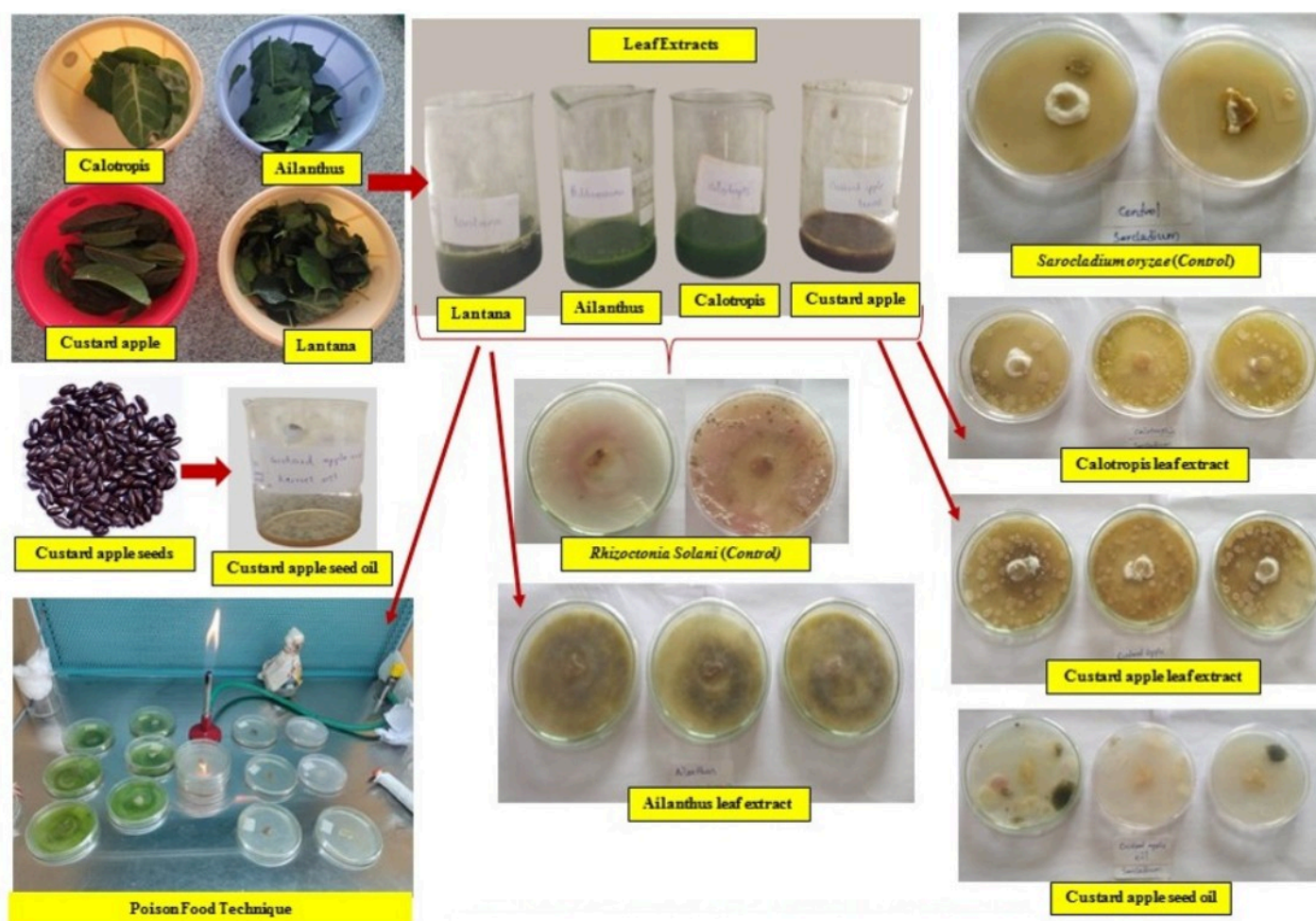


Figure 1

Legend not included with this version.