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The effectiveness of melaleuca essential oil (*Melaleuca alternifolia* Cheel) in the preventive control of diseases in bean cultivation

A eficácia do óleo essencial de melaleuca (Melaleuca alternifolia Cheel) no controle preventivo de doenças no cultivo de feijão

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RESUMO

Este estudo aborda a aplicação do óleo essencial de Melaleuca (*Melaleuca alternifolia Cheel*) no controle de doenças na cultura de feijão. Considerando a importância global e econômica do feijoeiro, a pesquisa investigou o potencial da *M. alternifolia*, conhecida como árvore-do-chá, para suprimir patógenos. Testes *in vitro* foram conduzidos, revelando que o óleo essencial (OE) inibiu o crescimento de fungos e bactérias a partir de 0,5%. Experimentos *in vivo*, com delineamento estatístico casualizado, demonstraram uma redução significativa na incidência e severidade das doenças a partir de 0,5%. Os resultados sugerem que o OE de Melaleuca pode ser uma alternativa eficaz no controle fitossanitário do cultivo de feijão, destacando seu potencial para promover a sustentabilidade e produtividade agrícola.

PALAVRAS-CHAVE: *fitossanidade; sustentabilidade agrícola; manejo integrado; fitopatogênicos; potencial antimicrobiano.*

ABSTRACT

This study looks at the application of Melaleuca (Melaleuca alternifolia Cheel) essential oil to control diseases in bean crops. Considering the global and economic importance of the bean crop, the research investigated the potential of M. alternifolia, known as the tea tree, to suppress pathogens. In vitro tests were conducted, revealing that the essential oil (EO) inhibited the growth of fungi and bacteria from 0.5%. In vivo experiments, using a randomized statistical design, showed a significant reduction in the incidence and severity of diseases from 0.5%. The results suggest that Melaleuca EO can be an effective alternative for phytosanitary control of bean crops, highlighting its potential to promote sustainability and agricultural productivity.

KEYWORDS: plant health; agricultural sustainability; integrated management; phytopathogenics; antimicrobial potential.

INTRODUCTION

Bean cultivation *(Phaseolus spp.)*plays a crucial role in Brazilian cuisine, culture, and economy, serving as a key source of nutrients and forming a central part of the national diet. With countless farmers engaged, bean cultivation plays a vital role in Brazil's food security and agricultural economy (ASSUMPÇÃO et al. 2023, NAVARINI et al. 2009). Beans, belonging to the *Phaseolus* genus with about 55 species worldwide, are nutritionally significant due to their rich content of proteins, complex carbohydrates, dietary fiber, B vitamins, iron, calcium, and other essential minerals. Furthermore, culture plays a crucial role in nitrogen fixation in the soil (DUTRA et al. 2017, PEDRO et al. 2012).

According to CONAB's 2024 report, Brazil's bean production for the 2023/24 harvest reached about 3.03 million tons. According to EMBRAPA ARROZ E FEIJÃO (2023), the estimated average apparent per capita consumption of common beans in 2021 was 12.2 kg per person. In Brazil, 80% of the consumed beans are common beans (Phaseolus vulgaris), while the remaining 20% are cowpeas (Vigna unguiculata). Regarding common beans, their distribution across the country is as follows: 56% is pinto bean, 21% is black bean, and 3% are specialty varieties.

Despite its significance, bean cultivation faces substantial hurdles due to various pathogens, including fungi, bacteria, and viruses. Among these pathogens, the fungus *Colletotrichum lindemuthianum,* which causes anthracnose, and the bacterium *Xanthomonas axonopodis pv*. *phaseoli*, responsible for common bacterial blight, are notable. Both can lead to significant crop losses (SIQUEIRA et al. 2019, TELAXKA et al. 2018).

Additionally, angular leaf spot in beans, caused by the fungus *Pseudocercospora griseola*, poses another significant threat, potentially causing up to 80% yield losses. Chemical control is often used to manage these diseases, despite environmental and human health concerns (TOILLIER et al. 2010). Given this situation, sustainable alternatives for disease management in bean crops are being sought, with a promising approach being the use of plant-derived substances, such as essential oils. In this context, tea tree essential oil (*M. alternifolia*) has garnered attention due to its remarkable antimicrobial properties (CASTRO et al. 2005). Despite these known properties, few studies address their specific application in controlling the aforementioned diseases in bean plants (SOUZA et al. 2015, Simões 2002).

This study aimed to evaluate the *in vitro* and *in vivo* effects of *M. alternifolia* essential oil in controlling bacterial blight, anthracnose, and angular leaf spot, as well as analyze the efficacy of its emulsion in protecting bean plants. The pursuit of sustainable alternatives aims to enhance environmental health and maintain agricultural productivity in this vital crop.

MATERIALS AND METHODS

This research was carried out at the Plant Pathology Laboratory and greenhouse facilities of the Federal University of Southern Frontier, Laranjeiras do Sul Campus, Paraná, Brazil (25° 24' 28'' S, 52° 24' 58'' W, elevation 840 meters), a temperate region with annual rainfall averaging 1800-2000 mm. Melaleuca essential oil from Australia, diseased bean samples of the IPR TUIUIÚ variety from bean crops in Laranjeiras do Sul, Paraná, and Tween 80 for emulsification were used. The essential oil composition, as determined by technical analysis, comprises the following components: α-terpinen-4-ol (40%), cineole (1%), α-terpinene (3%), α-pinene (4%), γ-terpinene (22%), α-terpinene (11%), α-terpinolene (3%), and p-cymene (3%). Plant specimens exhibiting disease symptoms were gathered and the causal pathogens were identified using light microscopy and specialized culture media. For the *in vitro* tests, an initial emulsion with a concentration of 10,000 µl/mL of essential oil was prepared. In greenhouse trials, the initial emulsion had an essential oil concentration of 1000 µl/mL. Evaluation of EO emulsion on *Pseudocercospora griseola, Xanthomonas axonopodis pv. phaseoli, and Colletotrichum lindemuthianum* at various concentrations (0.0%, 0.05%, 0.1%, 0.5%, 1%, 2%, and 3%).

Greenhouse bioassays *in vivo* conducted with varying concentrations (0.0%, 0.05%, 0.1%, 0.5%, 1%, 2%, and 3%) for each pathogen, applied by spraying the aerial parts of the plants. Disease prevalence and severity assessed using a visual rating scale. Calculation of Area Under the Disease Progress Curve (AUDPC), Area Under the Incidence Progress Curve (AUIPC), and Area Under the Severity Progress Curve (AUSPC). All bioassays were conducted using a completely randomized design (CRD), with 4 and 5 replications for *in vitro* and *in vivo* treatments. Analysis of variance, regression analysis, and Tukey's test at 5% significance were performed using Sisvar software (FERREIRA 2007).

RESULTS AND DISCUSSION

The *in vitro* experiment results, assessing bacterial growth at various concentrations of tea tree essential oil, showed a reduction in bacterial multiplication and development, as illustrated in (Figure 1A). The reduction was proportional to the increase in oil concentration, achieving complete inhibition at 1% and 2% concentrations. The presence of compounds such as terpenoids, terpinen-4-ol, and cineole in tea tree essential oil has been linked to antimicrobial and anti-inflammatory properties, disrupting bacterial vital processes (HILLEN et al. 2012, RAMOS et al. 2016).

The antibiogram activity of *X. axonopodis pv. phaseoli* (Figure 1B) revealed inhibition of bacterial growth zones at concentrations of 0.5%, 1%, 2%, and 3%, suggesting that higher oil concentrations lead to larger inhibition zones. However, there's a threshold beyond which higher concentrations may not yield a proportional increase in inhibition. This data is crucial for farming methods, considering productivity, cost-effectiveness, and environmental considerations (CORREA et al. 2020, MARQUES et. al 2022).

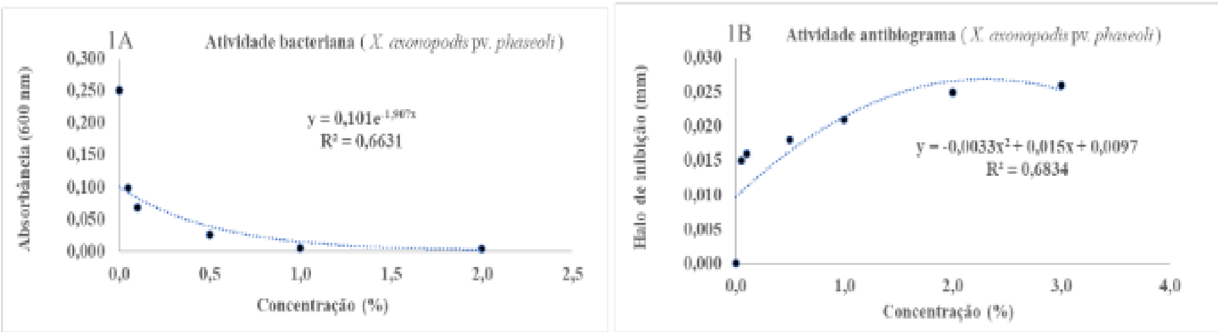

Figure 1. Bacterial activity (1A) and antibiogram activity of *X. axonopodis pv. phaseoli* (1B) under varying concentrations of *M. alternifolia* essential oil.

Figure 1. Bacterial growth (1A) and antibiotic susceptibility patterns of X. axonopodis pv. phaseoli (1B) when exposed to varying concentrations of M. alternifolia essential oil.

In growth tests of various pathogens, including *Macrophomina phaseolina, Alternaria radicina, A. dauci*, and *Pseudocercospora griseola*, melaleuca essential oil showed inhibitory effectiveness at different concentrations (MARTINS et al. 2010, NASCIMENTO et al. 2019). Thus, the oil disrupted metabolic processes, demonstrating its potential as a fungicidal agent, as previously reported in the literature (NEPOMOCENO & PIETROBON 2020, PORTELLA et al.). 2021).

The greenhouse *in vivo* experiment showed that tea tree essential oil concentrations of 0.5% and above effectively combated anthracnose and bacterial blight, demonstrating reduced disease incidence and severity (PUVAČA et al. 2019, QUINTÃO et. al 2021). These findings align with previous results obtained through scanning electron microscopy (PHONGPAICHIT et al. 2004). In this study, the authors ultimately revealed cellular collapse and denaturation, proposing altered cytoplasmic membrane permeability as the mechanism of action.

The angular leaf spot results revealed significant differences between treatments and the control group, demonstrating the positive impact of tea tree essential oil in reducing disease spread (PEIXINHO et al. 2017). Thus, the composition and concentration of essential oil components influenced their biological properties (BARBOSA et al. 2015). Melaleuca essential oil shows promise as an effective alternative for pest control in bean cultivation, potentially enhancing agricultural sustainability and productivity.

CONCLUSION

In vivo tests showed that the 0.5% concentration was most effective in inhibiting phytopathogenic fungi and bacteria, significantly reducing the incidence and severity of bean plant diseases.

The disease incidence progress curve area (DIPCA) and disease severity progress curve area (DSPCA) parameters were significantly influenced by the treatments, particularly at the 0.5% essential oil concentration. This highlights tea tree oil's potential as a tool for managing bean crop diseases, with implications for sustainable agriculture. Further research is recommended to validate these findings.

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