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RESEARCH ARTICLE

ANTIFUNGAL POTENTIAL OF SELECTED TROPICAL PLANT EXTRACTS AGAINST ANTHRACNOSE PATHOGENS RESPONSIBLE FOR EARLY AND LATE BLIGHT OF TOMATO

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ABSTRACT

Tomato early and late blight, caused by anthracnose, is a disease of economic importance that threatens tomato production wherever it is grown. This study evaluated the efficacy of two different plant extracts (eucalyptus and Zingiber officinale) against tomato blight-causing Anthracnose. The positive and negative controls, Ridomil Gold and sterile distilled water, were built up using a completely randomized design (CRD). Two vertical lines were drawn underneath each Petri dish to create four equal servings. A 5mm slice of a 7-day-old FOL culture was inoculated in the centre of each petri dish using a sterile 5mm cork borer. To collect data on the suppression of radial growth, the petri dishes were then grown for six days at 29 ± 2°C. The results showed that 80g/250ml ethanol had the lowest radial growth (12.66mm) and was statistically comparable to Ridomil Gold, which had a lower radial growth (11.51mm) at 6 DAI, when compared to other treatments and the negative control, which had the highest radial growth (58.59%). In comparison to the negative control, which had the highest radial growth (53.44%), the lantana methanol root extract at 80g/250ml concentration displayed a similar pattern, with lower radial growth (9.17%) that was statistically comparable to the mancozeb, which had the lowest radial growth (7.00%) at 6 DAI. The results highlight the significance of solvent selection and concentration for antifungal efficacy. These findings suggest that plant extracts from eucalyptus and Zingiber officinale could be utilized to treat tomato blight in an eco-friendly way. By using the right solvent and concentration combination, novel, sustainable antifungal agents can be produced.

KEYWORDS

Tomato, Eucalyptus, and Zingiber officinale, antifungal efficacy.

1. INTRODUCTION

The cultivated tomato (Solanum lycopersicum L.) is the most widely consumed vegetable worldwide, due to its use as a basic ingredient in a diverse range of raw, cooked, and processed foods (FAOSTAT, 2023). It belongs to the Solanaceae family, which also includes several other commercially significant species. Tomatoes are cultivated worldwide for both domestic use and as an export crop (FAOSTAT, 2023). This traditional vegetable crop, which is cultivated commercially on 4.02 million hectares globally, has a production of 152.9 million tons and a productivity of 37.8 tonnes/ha. According to FAOSTAT, around 4.5% of the 163,719,357 tons of fresh tomatoes produced globally in 2023 were traded (FAOSTAT, 2023). The commercially important tomato fruit comes in a variety of colors, sizes, and shapes (Vaughan and Geissler, 1997). The fruit is high in water, vitamins, and minerals, low in proteins and fats, and somewhat carbohydrate-based. It also contains carotenes like lycopene, which gives the fruit its mostly red color, and beta-carotene, which gives it its orange hue (OECD, 2008).

In contemporary tomato varietals, sugar can make up as much as 3% of the fresh fruit weight. There is also tomatine, an alkaloid that has fungicidal properties (OECD, 2008). Although Nigeria is known for its diverse range of fruits and vegetables, the tomato is a staple in Nigerian cooking. Tomatoes are a basic food that Nigerians have been growing for a very long time. They can be consumed both fresh and in paste (Taofiq, 2017). Every household uses it, and it is part of the national food security program. Nigeria is currently the continent's second-largest producer of environmental sustainability and biocompatibility (Al-Karagoly et al., fresh tomatoes, accounting for 10.8% of total production (Taofiq, 2017). Nigeria is the 14th largest tomato producer in the world, with an annual production of 2.3 million tons (FAOSTAT, 2023). Nigeria is the second-largest producer of tomatoes in Africa, but output is constrained by both biotic and abiotic factors.

Among Nigeria's primary production obstacles are insect pests and illnesses, rainfall, weeds, low-quality seeds, environmental factors, socioeconomic issues, etc. Anthracnose, also known as early and late tomato leaf blight, is a common disease that primarily affects older, lower leaves due to their increased vulnerability. It is among the illnesses that cause large losses in tomato fruits and have a major financial impact on tomato production. Lesions begin as small, irregularly shaped, black patches that grow into increasingly larger, concentric rings. As the disease worsens, it may cause reduced yields and leaf death. The illness can move to the upper leaves and infect the stems and fruits at any time, even though it often begins in the lower portion of the plant. A stem infection may result in Alternaria stem canker (Chohan et al., 2015).

Numerous attempts have been made to prevent tomato blight using biological, chemical, physical, and cultural methods (Haruna et al., 2024). Cultural control methods have been used and are currently the most commonly recognized method of disease management because one type of tomato early blight fungus has a broad range of hosts and is both environmentally benign and organically viable. However, cultural control methods may not be sufficient to stop the diseases; they need to be used in conjunction with other control methods that are as safe for customers and the environment.

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2. Literature Review

2.1 Pharmacological Properties of Zingiber Officinale

Ginger (Zingiber officinale Roscoe) is believed to have originated in Maritime Southeast Asia and was initially domesticated by Austronesian peoples. These early producers dispersed ginger over the Indo-Pacific region some 5,000 years ago during the Austronesian expansion (Ravindran, 2023). Ginger was widely employed in traditional Chinese cuisine and medicine after its cultivation spread throughout Asia, eventually reaching China and India. The spice eventually reached Europe through the spice trade, where it became well-liked by the ancient Greeks and Romans. Ginger is grown in many tropical and subtropical locations nowadays, and its top producers include India, China, Nigeria, and Indonesia (Nair and Nair, 2019). India accounted for 43% of the global ginger production in 2020, which totaled over 4.3 million tons (Akshitha et al., 2019). Given its vast distribution, ginger's economic importance as a global product and its ability to withstand a range of meteorological conditions are highlighted (Tripathi, 2024).

The plant is well-known for its pharmacological properties, particularly its anti-inflammatory and antioxidant properties; these medicinal effects are largely due to the main bioactive ingredients in ginger, such as paradols, shogaols, and gingerols; its ability to inhibit key inflammatory enzymes, such as lipoxygenase (LOX) and cyclooxygenase-2 (COX-2), is largely responsible for its anti-inflammatory properties; it reduces inflammation in conditions like rheumatoid arthritis and osteoarthritis by lowering the synthesis of pro-inflammatory mediators, such as prostaglandins and leukotrienes; additionally, its antioxidant properties are linked to the activation of the Nrf2 signaling pathway, which increases the expression of antioxidant enzymes and reduces oxidative stress (Zammel et al., 2021). Because of its anti-inflammatory and antioxidant properties, ginger is a promising natural treatment for chronic inflammatory diseases and a protective measure against oxidative damage (Ayustaningwarno et al., 2024). Ginger's anti-inflammatory qualities are further enhanced by studies showing that it can modify the immune system (Zammel et al., 2021; Ayustaningwarno et al., 2024). Overall, ginger's pharmacological properties show promise as a treatment for various diseases associated with inflammation and oxidative stress (Sonam Shashikala, 2024; Ayustaningwarno et al., 2024).

In addition to its anti-inflammatory and antioxidant qualities, ginger also possesses potent antiviral and antibacterial qualities. Ginger's essential oils and extracts have demonstrated broad-spectrum antibacterial properties against a variety of bacterial and fungal illnesses, claim (Harun and Mohamad, 2023). Compounds including zingiberene, zingerone, phellandrene, and camphene are primarily responsible for these antibacterial effects (Harun and Mohamad, 2023). Because of its antibacterial properties, which have been shown to be effective against common pathogens including Escherichia coli, Staphylococcus aureus, and Candida albicans, ginger is a helpful natural alternative for treating infections (Teles et al., 2019). In addition to its antibacterial properties, ginger has shown antiviral activity against several viruses, such as influenza and the herpes simplex virus (Harun and Mohamad, 2023; Sowley and Kankam, 2019). Ginger's antiviral qualities are believed to derive from its ability to inhibit viral replication and strengthen the immune system (Harun and Mohamad, 2023). Our findings suggest that ginger might be an effective natural remedy for viral infections, especially in light of the growing incidence of antibiotic resistance (Harun and Mohamad, 2023). Ginger's antiviral and antibacterial qualities underscore its potential as a multifunctional therapeutic agent in the fight against infectious disorders (Teles et al., 2019; Harun and Mohamad, 2023).

2.2 Pharmacological Properties of Eucalyptus

Because of its inherent antibacterial, antifungal, and antiviral qualities, eucalyptus plants have been used for many generations to cure a range of illnesses and infections (Aladejana et al., 2024). Utilizing chemicals derived from plants to fight cancer, infectious illnesses, and the growing problem of antimicrobial resistance (AMR) has garnered more attention recently. Multidrug-resistant infections have emerged as a result of the extensive use and abuse of antibiotics as well as bacteria's natural capacity to become resistant to manmade medications (Alara and Alara, 2024). This emphasizes how urgently alternative medications are needed, and plant-based chemicals are showing promise as substitutes.

Many medicinal plants, including eucalyptus, contain bioactive chemicals that could be the basis for safer and more efficient therapeutic production of vegetables and food crops devoid of synthetic pesticide residues. Nigerians have traditionally utilized plants that have antibacterial, anti-inflammatory, and wound-healing properties, such as Eucalyptus globulus, or blue gum (Sa'id and Abdullahi, 2022). These compounds' diverse pharmacological properties, which include antibacterial, anticancer, and antioxidant activity, are a component of their innate defense mechanisms and emphasize their significance in the hunt for novel treatment approaches (Anwar et al., 2025). Because they prevent or reverse the harmful effects of free radicals in the body, antioxidants are essential for preserving cellular homeostasis (Bajaj et al., 2024).

Numerous chronic diseases, such as cancer, cardiovascular disease, and neurological issues, have been linked to oxidative stress, which is caused by an imbalance between antioxidants and reactive oxygen species (ROS) (Muscolo et al., 2024). Eucalyptus globulus, known for being a strong antioxidant, has promise for use in nutritional and therapeutic supplements. Eucalyptus, like camphor, has a lovely pale-yellow hue and a pleasant, energizing fragrance. Its unique scent explains its many uses in the flavoring, fragrance, and cosmetics industries in addition to describing its olfactory character (Benabdesslem et al., 2020). The primary constituent of eucalyptus essential oil is 1,8-cineole, commonly referred to as eucalyptol. Because of its pleasant spicy taste and aroma, this monoterpene oxide is widely used in flavoring agents, perfumes, and cosmetic items. It is praised for its fragrant properties. Eucalyptol's therapeutic potential is further evidenced by the fact that it is a component of mouthwashes and cough suppressants, among other oral hygiene products. The physical characteristics of this essential oil are crucial in determining its quality.

3. Materials And Methods

3.1 Study area

This research was carried out at the Microbiology Department Laboratory, Faculty of Science, Ekiti State University, Ado-Ekiti, under an ambient temperature of 27.90 °C to 33.0 °C (room temperature) and relative humidity of 56% to 74%. Ado Ekiti is characterized by the coordinates, latitude 7.61240N and longitude 5.23710E, situated at 609.37 with 293 km in Area size, lies in the Western Rainforest ecological region of Nigeria.

3.2 Sources and materials

Eucalyptus and Ginger leaves and roots were collected as a sample plant extract. These plant roots and leaves were collected early in the morning and rinsed with sterile distilled water and packed in sterile polythene bags already lined with soft tissue paper and transported to the microbiology laboratory for further experimentation. Tomato plants exhibiting blight symptoms were collected randomly from the Teaching and Research farm and transferred to the study area's microbiology.

3.3 Isolation and Identification of Fungi

Isolation of the pathogen was performed using the direct inoculation method described by (Ghimire et al., 2019). Plant parts exhibiting wilt symptoms were first cleaned under sterile running water. These fragments were excised, surface-sterilized with a 0.5% sodium hypochlorite solution for one minute, and then rinsed three times with sterile distilled water. The fragments were dried on sterile filter paper to eliminate excess moisture and then cultivated on acidified potato dextrose agar in sterile petri dishes. The dishes were incubated at 28°C for 3–5 days. After incubation, the plates were observed for fungal growth. The isolated fungi were subcultured to achieve pure cultures, and their morphological characteristics were analyzed and compared to the standard descriptions provided (Li et al., 2023).

3.4 Plant Extracts Preparation

The leaves and roots of Zingiber officinale and Eucalyptus were rinsed three times with distilled water, then left to air-dry at room temperature (28°C) for 15 days. After drying, the materials were ground into a fine powder using a mechanical grinder and stored in airtight containers for future use. For extraction, 40g, 60g, and 80g portions of the ground powder from the leaves and roots were weighed and each mixed with 250ml of distilled water, ethanol, and methanol in separate conical flasks, respectively. The mixtures were soaked in an electric soaker for 2 days. The solvent suspensions were then filtered through Whatman No. 1 filter paper. The filtrates were evaporated using a vacuum evaporator with a water bath to obtain the crude extracts, which were stored in amber bottles for later use.

3.5 Media Preparation

Prepared 9.8 grams of PDA was weighed and poured into a clean sterile 250 millilitres conical flask, 250ml of distilled water was added, a cork was inserted into the conical flask and sealed with masking tape. The medium was then stirred vigorously and placed on a hot plate, heated to boiling to ensure the medium was completely homogenised. The culture medium was sterilized by autoclaving at 121°C for 20 minutes and then cooled at room temperature.

3.6 Laboratory Evaluation of Plant Extracts against Tomato Anthracnose (Colletotrichum lycopersici)

The experiment employed a completely randomized design with three replicates. Following the method of this study was conducted to assess the effect of plant extracts on the radial growth of Colletotrichum lycopersici (Worku et al., 2025). The experimental layout and methodology were designed to evaluate the effect of plant extracts on the fungal pathogen. At the bottom of each petri dish, two vertical lines were drawn, dividing the dish into four equal sections. Plant extracts at concentrations of 40g, 60g, and 80g per 250ml were dispensed into sterile petri dishes, gently swirled to ensure a homogeneous mixture, and allowed to solidify. Control petri dishes consist of PDA with no plant extracts but sterile distilled water (SDW), and synthetic fungicide was inoculated with the test fungus, both serve as negative and positive controls. A 5mm disk of 7-day-old Colletotrichum lycopersici culture was placed at the center of each petri dish (where the two lines intersected) using a 5mm corn borer.

The dishes were incubated at 28 ± 2°C for one week. The colony diameter was measured as the average growth along the two perpendicular lines on the back of the petri dishes, and the percentage inhibition of Colletotrichum lycopersici sp. Lycopersici was calculated following the method.

3.7 Data Collection

Data collected on the radial growth inhibition Days After Inoculation (DAI) of each inoculum was measured at 2 days intervals over six days using a meter rule (Ortiz and Hoyos-Carvajal, 2016; Akaeze et al., 2017).

3.8 Data Analysis

The data obtained were subjected to analysis of variances (ANOVA) using a GENSTAT (25th editions) statistical package and were separated by level of significance at 99% confidence level.

4. Results And Discussion

4.1 Effect of Various Solvents and Concentration of Zingiber officinale leave Extracts on Radial Growth of Colletotrichum lycopersici

The effects of various solvents and Zingiber leaf extract concentrations on the radial mycelial development of Colletotrichum lycopersici days after inoculation (DAI) are displayed in Table 1. Regardless of the solvent or its concentration, the data demonstrated a steady radial growth of Colletotrichum lycopersici at 1 DAI, which increased gradually with time. Zingiber at 80g/250ml was found to produce the smallest radial growth (31.67mm) at 6 DAI, after the positive control, which recorded 10.33. 32.33 mm was then seen at 6 DAI under zingiber ethanol leaf extracts at 80g/250ml. In general, it was found that zingiber leaf extracts were the most resistant or tolerant to fungal infection. This supports the findings of who found that the extracts' antifungal efficacy is more pronounced when they prevent sporulation than when they reduce the growth of fungal mycelia (Passão et al., 2023). The presence of tannin and flavonoids in methanol and hydroethanolic extracts may be the cause of their enhanced inhibitory impact. According to research, flavonoids can prevent plant pathogen spores from germinating, while tannins can interfere with the development of the germ tube (Das et al., 2024).

Table 1: Effect of Various Solvents and Concentration of Zingiber officinale leave Extracts on Radial Growth of Colletotrichum lycopersici

Zingiber officinale Leave Extracts (Treatments)		Radial Growth Days After Inoculation (%)					
Solvent	**Concentration g/ml**	**1**	**2**	**3**	**4**	**5**	**6**
Aqueous	40	0.00ᵃ	12.32ᶜ	23.67ᵈᵉ	26.00ᵇᶜ	32.00ᵇ	41.00ᵇ
	60	0.00ᵃ	12.32ᶜ	21.00ᶜᵈᵉ	25.67ᵇᶜ	30.33ᵇ	38.67ᵇ
	80	0.00ᵃ	11.23ᶜ	21.00ᶜᵈᵉ	25.57ᵇᶜ	29.33ᵇ	34.67ᵇ
Ethanol	40	0.00ᵃ	11.00ᵇᶜ	15.33ᵇᶜ	23.00ᵇᶜ	30.33ᵇ	32.33ᵇ
	60	0.00ᵃ	8.67ᵇᶜ	14.67ᵇᶜ	21.33ᵇᶜ	28.33ᵇ	33.33ᵇ
	80	0.00ᵃ	5.33ᵇ	11.33ᵇ	19.33ᵇ	26.33ᵇ	32.33ᵇ
Methanol	40	0.00ᵃ	8.00ᵇ	17.67ᵇᶜᵈ	28.77ᵇᶜ	34.00ᵇ	36.68ᵇ
	60	0.00ᵃ	8.33bᶜ	13.67ᵇᶜᵈ	25.65ᵇᶜ	30.00ᵇ	34.00ᵇ
	80	0.00ᵃ	5.00ᵇ	12.67ᵇᶜ	21.00ᶜᵈ	24.00ᵇ	31.67ᵇ
Ridomil Gold		0.00ᵃ	0.00ᵃ	0.00ᵃ	4.33ᵃ	6.33ᵃ	10.33ᵃ
Control		7.33ᵇ	15.00ᵈ	25.67ᵉ	35.00ᵈ	52.00ᶜ	51.33ᶜ
SL		**	**	**	**	**	**
SE (±)		0.274	2.250	3.500	3.803	4.512	5.821

SL: significance level, SE Standard error, DAI Days after inoculation. Mean followed by the same letter in the same columns are not significantly different ≤ 0.01

4.2 Effect of Various Solvents and Concentration of Zingiber Root Extracts on Radial Growth of Colletotrichum lycopersici

The impact of zingiber root extracts on the radial mycelial growth of Colletotrichum lycopersici is shown in Table 2. At 1 day after inoculation (DAI), a similar trend of constant radial growth of 0.00mm was observed across the solvents and their concentration, except for the negative control, which recorded 5.00mm on that day.

A significant difference ($p \leq 0.01$) was observed among the treatments as the extract concentration increased. At 6 DAI, the results showed a lower (11.81mm) radial mycelial growth under ethanol zingiber root extract, which was comparable to zingiber officinale's 3g/250ml concentration, recording 13.55mm at that time. At 58.82 mm, the control showed the greatest radial mycelial development. Through a variety of animal models, a group researchers investigated the potential of officinale for glycemia management, indicating its antidiabetic properties in vivo (Keyla et al., 2022). Researchers are looking into the pharmacological characteristics of zingiber because of its traditional use, which has attracted a lot of scientific attention.

Table 2: Effect of Various Solvents and Concentration of Zingiber Root Extracts on Radial Growth of Colletotrichum lycopersici

Treatments		Radial Growth Days After Inoculation (DAI)					
Solvent	**Concentration g/ml**	**1**	**2**	**3**	**4**	**5**	**6**
Aqueous	40	0.00^{a}	13.67^{g}	15.67^{bf}	21.33cf	27.33^{ce}	35.00^{e}
	60	0.00^{a}	11.57^{bfg}	14.33^{bef}	20.00^{cef}	26.00^{ce}	34.00^{ce}
	80	0.00^{a}	11.00^{bcefg}	13.00^{bdef}	17.00^{cdef}	21.33^{bcde}	27.00^{bcde}
Ethanol	40	0.00^{a}	4.67^{abcde}	8.00^{abcd}	12.00^{abcd}	17.^{abcd}	21.67^{abcd}
	60	0.00^{a}	4.00^{abcd}	7.33^{ab}	11.33^{abcd}	16.67^{abcde}	21.33^{abcd}
	80	0.00^{a}	2.00^{a}	5.33^{a}	8.67^{ab}	11.00^{a}	11.81^{a}
Methanol	40	0.00a	4.27^{abcde}	9.00^{abcdef}	13.^{abcde}	16.67^{abcd}	20.67^{abcd}
	60	0.00a	5.50^{abcdef}	8.67^{abcde}	13.^{abcdef}	15.50^{ab}	17.50^{ab}
	80	0.00a	4.50^{abc}	8.50^{abcde}	10.50^{abcd}	13.50^{ab}	17.00^{ab}
Ridomil Gold		0.00^{a}	0.00^{a}	5.50^{a}	8.00^{a}	10.67^{a}	13.55^{a}
Control		5.00^{b}	14.67^{g}	24.67^{g}	36.00^{g}	45.67^{f}	58.82^{f}
SL		**	**	**	**	**	**
SE (±)		0.447	3.946	3.083	2.069	3.985	4.442

SL: significant level, SE: Standard error, DAI: Days after inoculation. Mean followed by the same letter in the same columns are not significantly different, p ≤ 0.01

4.3 Effect of Various Solvents and Concentration of Eucalyptus Leaf Extract on Radial

4.3.1 Growth inhibition of Colletotrichum lycopersici

Table 3 displays the eucalyptus leaf extracts at 40g, 60g, and 80g/250ml days after inoculation (DAI) from distilled water, ethanol, and methanol. Under ethanol and at all concentrations under methanol, a consistent increase of 0.00mm was noted at 1DAI and 2 DAI at 60 and 80g/250ml.

The petri plates treated with 80g/250ml methanol extract showed the shortest radial growth at 6 DAI (7.44mm), followed by 60g/250ml (10.00mm), despite the fact that there was a significant difference ($p < 0.01$) between the treatments. At 6 DAI, the control group had the greatest mycelial development (56.55mm). Many researchers found that eucalyptus leaf extracts are effective in managing C. lycopersici, and this result is consistent with their findings (Nguyen et al., 2024; Mendoza-Buenrostro et al., 2025). According to a study, eucalyptus, however, has a wide range of antifungal properties, including the ability to suppress Colletotrichum lycopersici in citrus plants (Rajput et al., 2023). Bioactive and phytochemical substances such as flavonoids, phenols, alkaloids, essential oils, saponins, glycosides, naphthoquinones, and terpenoids are thought to be responsible for these antifungal qualities.

Table 3: Effect of Various Solvents and Concentration of Eucalyptus Leaf Extract on Radial Growth inhibition of Colletotrichum lycopersici

Treatments		Radial Growth Days After Inoculation (DAI)					
Solvent	**Concentration g/ml**	**1**	**2**	**3**	**4**	**5**	**6**
Aqueous	40	0.00^{a}	11.67^{b}	21.33^{c}	28.67^{d}	35.33^{d}	40.67^{e}
	60	0.00^{a}	8.23^{c}	19.67^{c}	28.00^{d}	19.00^{c}	38.87^{e}
	80	0.00^{a}	6.67^{b}	13.67^{b}	16.00^{c}	32.67^{d}	25.67^{d}
Ethanol	40	0.00^{a}	2.67^{a}	4.67^{a}	9.33^{b}	13.67^{bc}	20.33^{cd}
	60	0.00^{a}	0.00^{a}	4.443^{a}	6.67^{ab}	12.33^{abc}	16.67^{bcd}
	80	0.00^{a}	0.00^{a}	2.23^{a}	3.67^{ab}	7.67^{ab}	15.00^{abc}
Methanol	40	0.00^{a}	0.00^{a}	2.34^{a}	5.67^{ab}	6.00^{ab}	12.67^{abc}
	60	0.00^{a}	0.00^{a}	2.00^{a}	2.67^{ab}	7.00^{ab}	10.00^{ab}
	80	0.00^{a}	0.00^{a}	1.67^{a}	2.67^{ab}	6.00^{ab}	7.44^{ab}
Ridomil Gold		0.00^{a}	0.00^{a}	0.00^{a}	1.33^{a}	3.67^{a}	5.00^{a}
Control		5.00^{b}	14.67^{d}	28.33^{d}	31.00^{d}	56.00^{e}	56.55^{f}
SL		**	**	**	**	**	**
SE (±)		0.246	1.659	2.651	3.072	4.141	4.483

SL: significant level, SE: Standard error, DAI: Days after inoculation. Means followed by the same letter in the same columns are not significantly different, p ≤ 0.01

4.4 Effect of Various Solvents and Concentration of Eucalyptus Root Extract on Radial Growth inhibition of Colletotrichum lycopersici

The result of the effect of eucalyptus root extract on the radial growth of Colletotrichum lycopersici is presented in Table 4. It was observed except for 1 and 2 DAI, there were significant differences ($p \leq 0.01$) among the treatments. Additionally, it was noted that petri plates treated with methanol root extracts of eucalyptus exhibited reduced radial growth from days 4, 5, and 6 following inoculation, which was similar to the Ridomil Gold. The results were similar on days 4, 5, and 6 and showed 2.22 mm for plates treated with 80g/250ml of methanol root extract, 3.17 mm

for Ridomil Gold, 6.77 mm for methanol root extract, and 5.45 mm for Ridomil Gold on day 5 after inoculation, 8.67 mm for methanol-treated Petri plates, and 7.00 mm for Ridomil Gold on day 6. The control or untreated plates showed the greatest radial development (53.33m). A group researcher state that the bioactive polyphenols, either alone or in combination, disrupt fungal life processes through a variety of mechanisms, including protein binding, chelating agent action, structural component synthesis alteration, and disruption or destruction of cell membrane permeability, all of which change the physiological state of the cells (Ogwu et al., 2025). These findings align with previous research. Other researchers, however, have discovered that the flavonoid concentration in plant extracts is the main reason why they inhibit bacteria and fungi.

Table 4: Effect of Various Solvents and Concentration of Eucalyptus Root Extract on Radial Growth Inhibition of Colletotrichum lycopersici

Treatments		Radial Growth Days After Inoculation (DAI)					
Solvent	**Concentration g/ml**	**1**	**2**	**3**	**4**	**5**	**6**
Aqueous	40	0.00^{a}	5.48^{b}	10.67^{e}	14.00^{bc}	25.67^{b}	29.69^{c}
	60	0.00^{a}	1.67^{a}	7.63^{de}	16.67^{c}	21.33^{b}	24.00^{bc}
	80	0.00^{a}	0.00^{a}	5.00^{acd}	8.33^{ab}	14.00^{a}	16.33^{ab}
Ethanol	40	0.00^{a}	1.33a	5.00^{a}	8.00^{ab}	13.00^{a}	14.33^{ab}
	60	0.00^{a}	0.00a	4.67^{abcd}	6.00^{a}	9.00^{a}	10.00^{a}
	80	0.00^{a}	0.00^{a}	0.00^{a}	2.67^{a}	7.67^{a}	15.33^{ab}
Methanol	40	0.00^{a}	0.00^{a}	2.00^{abc}	3.67^{a}	9.00^{a}	12.00^{a}
	60	0.00^{a}	0.00^{a}	1.77^{abc}	5.00^{a}	7.67^{a}	11.00^{a}
	80	0.00^{a}	0.00^{a}	0.00^{a}	2.22^{a}	6.77^{a}	8.67^{a}
Ridomil Gold		0.00^{a}	0.00^{a}	0.00^{a}	3.17^{a}	5.45^{a}	7.00^{a}
Control		6.67^{b}	13.33^{c}	22.67^{f}	33.67^{d}	43.00^{c}	53.33^{d}
SL		**	**	**	**	**	**
SE (±)		0.389	2.082	2.665	3.738	4.116	4.724

SL: significance Level, SE Standard error, DAI Days after inoculation. Mean followed by the same letter in the same columns are not significantly different $p \leq 0.01$

5. Conclusion

Using aqueous, ethanol, and methanol solvents of zingiber and eucalyptus leaf and root at different concentrations (40g, 60g, and 80g) during six days, this study examined the radial growth inhibition of the Colletotrichum lycopersici pathogen. The findings shed important light on zingiber and eucalyptus's antifungal qualities. Superior radial growth inhibition was shown by the methanol solvent, especially at 80g concentration, suggesting that it may be a useful antifungal agent. The antifungal inhibition of ethanol solvent was modest, whereas the least effective solvent was aqueous. These results imply that radial growth inhibition is highly influenced by solvent concentration and choice. The findings of the study have significant ramifications for creating new antifungal drugs and refining solvent-based fungus control methods. The outcome further emphasizes how crucial it is to take solvent concentration and exposure time into account when developing antifungal treatments.

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