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Antifungal Activity of Noni (*Morinda citrifolia*) Leaf Extract against *Cercospora capsici* on Red Curly Chili Pepper (*Capsicum annuum*) In Vitro

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Abstract: This study aimed to evaluate the antifungal potential of noni leaf (*Morinda citrifolia*) extract at different concentrations in inhibiting the growth of *Cercospora capsici*, the causal agent of leaf spot disease in red curly chili pepper (*Capsicum annuum*). The study was conducted using a Completely Randomized Design (CRD) consisting of seven treatments, including noni leaf extract at concentrations of 20%, 40%, 60%, 80%, and 100%, a negative control (sterile distilled water), and a positive control (0.1% propineb). The research procedures included purification of the *Cercospora capsici* isolate, preparation of methanolic noni leaf extract, qualitative screening of secondary metabolites, and an in vitro growth inhibition assay using the poisoned food technique. The inhibition data were analyzed using one-way analysis of variance (ANOVA), followed by Duncan's Multiple Range Test (DMRT) at a 5% significance level. Qualitative phytochemical screening revealed that noni leaf extract contained alkaloids, phenols, flavonoids, saponins, tannins, and steroids. The inhibition assay showed that the antifungal activity increased with increasing extract concentration. The highest Percentage Inhibition of Radial Growth (PIRG) was observed in the 100% noni leaf extract treatment, with a value of 93.82 ± 0.56%, categorized as very strong inhibition. This value was higher than that of the positive control (0.1% propineb), which exhibited a PIRG value of 47.19 ± 2.52%. These findings indicate that noni leaf extract has strong antifungal activity against *Cercospora capsici* under in vitro conditions and has potential as a plant-derived antifungal agent. Further studies under in vivo and field conditions are required to confirm its effectiveness in controlling leaf spot disease of red curly chili pepper.
Keywords: Red curly chili pepper (*Capsicum annuum*); *Cercospora capsici*; noni (*Morinda citrifolia*); antifungal activity; plant-based fungicide

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INTRODUCTION

Red curly chili pepper (*Capsicum annuum* L.) is one of the economically important horticultural commodities in Indonesia due to its high market demand and nutritional value. Chili fruits contain essential nutrients, including carbohydrates, proteins, lipids, vitamins, and minerals, as well as capsaicin, an alkaloid-derived secondary metabolite responsible for their characteristic pungency (Musdalifah et al., 2023). This crop is widely cultivated in tropical regions, particularly in lowland to medium-altitude areas where environmental conditions support optimal growth. The demand for red curly chili pepper has continuously increased annually, reaching approximately 1.5 million tons in 2023 (A'yuni et al., 2024). However, despite its economic importance, chili pepper productivity in Indonesia remains unstable due to various biotic and abiotic constraints, including plant diseases caused by phytopathogenic microorganisms (Badan Pusat Statistik, 2025).

Among the major biotic constraints affecting chili production, phytopathogenic fungi represent one of the most destructive factors responsible for substantial yield losses worldwide. These pathogens can reduce crop productivity by interfering with plant physiological processes, damaging plant tissues, and disrupting nutrient acquisition (Sukapiring et al., 2023). *Cercospora capsici* is an important fungal pathogen associated with leaf spot disease in chili pepper plants (*Capsicum annuum*) (Reddy et al., 2023). The disease is characterized by the development of circular to irregular necrotic lesions with grayish-white centers on infected leaves, which subsequently reduce photosynthetic capacity and plant growth (Pamekas et al., 2023). Infection by *C. capsici* has been reported to negatively affect chili plant development and production (Apithanasakulngeon et al., 2023). In severe cases, this pathogen can cause yield losses ranging from 20.77% to 40% depending on environmental conditions and disease severity (Lestari et al., 2021; Berutu et al., 2023). These losses are particularly significant considering that the average productivity of red curly chili pepper in Indonesia remains relatively low, approximately 6.7 tons ha^{-1} $year^{-1}$ (Prastia & Hasnelly, 2021).

Currently, the management of fungal diseases in agricultural systems largely depends on synthetic fungicides, including azole compounds, carbendazim, metalaxyl, mefenoxam, and propineb (Wang et al., 2019; Tomah et al., 2020). Although synthetic fungicides provide effective disease suppression, their excessive and prolonged application may cause undesirable consequences, including the emergence of fungicide-resistant pathogen populations. The development of resistance enables phytopathogenic fungi to survive and reproduce under fungicide exposure, reducing the long-term effectiveness of chemical control strategies (Neves et al., 2021). In addition, intensive fungicide application may increase chemical residues in agricultural environments, potentially affecting non-target organisms, contaminating water resources, and degrading soil quality (Purwantisari et al., 2026). Therefore, sustainable and environmentally friendly alternatives are urgently required to reduce dependence on synthetic fungicides.

Plant-derived fungicides have gained considerable attention as promising alternatives for sustainable crop protection because they contain bioactive compounds with antimicrobial properties and generally exhibit better environmental compatibility than synthetic chemicals (Cenobio-Galindo et al., 2024). Botanical fungicides are commonly obtained from different plant organs, including leaves, roots, fruits, and seeds, which contain diverse secondary metabolites capable of suppressing phytopathogenic microorganisms (Santra & Banerjee, 2020). The antifungal mechanisms of plant-derived compounds are associated with multiple cellular targets, including disruption of fungal cell membranes, inhibition of enzyme activity, interference with nucleic acid synthesis, and suppression of fungal development (Gurjar et al., 2012). Compared with synthetic fungicides, plant-based products are generally biodegradable and have lower risks of generating persistent residues in agricultural ecosystems (Aji & Rosyidah, 2020).

Noni (*Morinda citrifolia* L.) is a widely distributed medicinal plant with considerable potential as a source of botanical fungicides. This plant can grow under various environmental conditions and contains diverse bioactive compounds, including organic acids, alkaloids, flavonoids, saponins, steroids, and terpenoids, which have been associated with antimicrobial activity (Hardani et al., 2020; Haruna et al., 2023). Several studies have demonstrated the antifungal potential of *M. citrifolia* extracts against different phytopathogenic fungi. Ethanol extracts of noni leaves have been reported to inhibit the growth of *Alternaria solani*, *Colletotrichum lagenarium*, and

Fusarium oxysporum, which are associated with plant diseases in agricultural crops (Osorio et al., 2021). Furthermore, Wongkar et al. (2022) demonstrated that methanol extract of noni leaves effectively suppressed the growth of *Colletotrichum capsici*, the causal agent of anthracnose disease in cayenne pepper (*Capsicum frutescens*), with an inhibition rate of 66.84%.

The antifungal activity of noni leaf extracts is considered to be associated with their secondary metabolites. Alkaloids may inhibit fungal growth by interfering with cellular metabolism and nucleic acid synthesis, whereas phenolic compounds can induce protein denaturation and disrupt enzymatic activity. Flavonoids and saponins have also been reported to exhibit antifungal effects through membrane destabilization and impairment of fungal cell integrity (Gurjar et al., 2012; Aji et al., 2020). These biological properties indicate that *M. citrifolia* has potential as a source of natural antifungal agents for plant disease management.

Although previous studies have investigated the antifungal activity of noni leaf extracts using different solvents, most studies have focused on pathogens other than *Cercospora capsici*. For instance, Aji and Rohmawati (2020) evaluated ethanol extract of noni leaves against *Fusarium oxysporum*, while Haruna et al. (2023) investigated methanol extract against fungal pathogens associated with crown rot disease. However, information regarding the inhibitory potential of methanol extract of noni leaves against *Cercospora capsici* remains limited. Therefore, this study aimed to evaluate the antifungal activity of methanol extract of noni leaves at different concentrations against *Cercospora capsici* under in vitro conditions. The findings of this study are expected to provide scientific evidence supporting the development of *M. citrifolia*-based botanical fungicides as sustainable alternatives for managing fungal diseases in chili pepper cultivation.

METHOD

Research Location and Period

This study was conducted at the Biotechnology Laboratory, Department of Biology, Faculty of Science and Mathematics, Universitas Diponegoro, Indonesia, from March to June 2025. The research procedures included media preparation, purification of *Cercospora capsici* isolates, preparation of noni (*Morinda citrifolia*) leaf extract, qualitative screening of secondary metabolites, and an in vitro growth inhibition assay against *C. capsici*. The *C. capsici* isolate was obtained by the authors from red curly chili (*Capsicum annuum*) agricultural fields located in Dempet District, Demak Regency, Central Java Province, Indonesia, and was maintained as a stock culture of the phytopathogenic fungus.

In Vitro Experimental Design

The inhibitory activity of noni leaf extract against *Cercospora capsici* was evaluated using a Completely Randomized Design (CRD) consisting of seven treatments. Each treatment was performed with three biological replicates as follows:

- **KN:** Negative control treatment using 1 mL of sterile distilled water.
- **P:** Positive control treatment using 1 mL of 0.1% propineb.
- **EDM1:** Treatment with 1 mL of 20% noni leaf extract solution.
- **EDM2:** Treatment with 1 mL of 40% noni leaf extract solution.
- **EDM3:** Treatment with 1 mL of 60% noni leaf extract solution.
- **EDM4:** Treatment with 1 mL of 80% noni leaf extract solution.
- **EDM5:** Treatment with 1 mL of 100% noni leaf extract solution.

Media Preparation and Purification of *Cercospora capsici* Isolate

Potato Dextrose Agar (PDA) (HiMedia, India) was used as the growth medium for purification of the *Cercospora capsici* isolate. PDA powder (39 g) was dissolved in 1 L of sterile distilled water. The medium was subsequently sterilized using an autoclave at 121°C and 1 atm pressure for 15 min. The *C. capsici* isolate was purified on sterile PDA medium and incubated at 27°C for 1 week.

Morphological Characterization of *Cercospora capsici* Isolate

The morphological characteristics of the *Cercospora capsici* isolate were characterized based on macroscopic and microscopic observations. Macroscopic characteristics included colony color, colony texture, growth zone, radial growth pattern, and exudate production. Microscopic characteristics included hyphae, conidiophores, asexual or sexual spores, and other morphological structures associated with *C. capsici*. Morphological identification was performed based on the reference of Barnett and Hunter (1998). Microscopic observations were conducted using Lactophenol Cotton Blue (LCB) staining and examined under a light microscope at magnifications of 10×, 40×, and 400×.

Preparation of Noni Leaf Extract

Noni leaves were collected using a purposive sampling method from Mranggen District, Demak Regency, Central Java Province, Indonesia. Fresh and undamaged leaves were collected, washed under running water to remove dust and impurities, and rinsed three times with sterile distilled water. The leaves were cut into 5–10 cm pieces and dried in an oven at 45°C for 3 days. The dried leaves were subsequently ground into simplicia powder, and 100 g of powder was extracted using 1 L of methanol (CH_3OH) with a ratio of 1:1 (w/v). The extraction process was conducted using the maceration method for 24 h in a closed container.

The extract solution was filtered using Whatman No. 1 filter paper (Cytiva, United Kingdom), and the obtained filtrate was concentrated using a rotary evaporator at 45°C until a concentrated crude extract was obtained. The extraction yield was calculated based on the mass of obtained noni leaf extract relative to the initial mass of noni leaf simplicia powder (Wijaya et al., 2018), using the following equation:

$$\text{Extraction yield (\%)} = \frac{\text{Mass of extract (g)}}{\text{Mass of simplicia powder (g)}} \times 100\%$$

The obtained noni leaf extract was used as the stock extract solution. The stock solution was diluted to prepare 20%, 40%, 60%, and 80% concentrations for the *C. capsici* growth inhibition assay. Dilution was performed using sterile distilled water to obtain 10 mL of extract solution at each desired concentration (Mirasti et al., 2024). The dilution formula used was:

$$C_1 \times V_1 = C_2 \times V_2$$

Note:

- $\mathbf{C_1}$ = concentration of stock noni leaf extract (%)
- $\mathbf{V_1}$ = volume of stock noni leaf extract (mL)
- $\mathbf{C_2}$ = desired concentration of noni leaf extract (%)
- $\mathbf{V_2}$ = final volume of noni leaf extract solution used in each treatment (mL)

Qualitative Screening of Secondary Metabolites

Qualitative screening of secondary metabolites in noni leaf extract was performed to detect alkaloids, phenols, flavonoids, saponins, and steroids following the methods described by Pratama et al. (2024) and Simarmata et al. (2024).

1. **Alkaloid Test**
   Two drops of Dragendorff's reagent were added to the noni leaf extract solution and incubated for 30 min. A positive reaction was indicated by the formation of an orange precipitate.
2. **Phenolic Test**
   Three to five drops of ferric chloride solution ($FeCl_3$) were added to the noni leaf extract solution. A positive reaction was indicated by the formation of a bluish-black, greenish-black, or brownish-black precipitate.
3. **Flavonoid Test**
   The noni leaf extract solution was supplemented with three drops of concentrated hydrochloric acid (HCl) and 2 mg of magnesium powder (Mg), followed by homogenization. A positive reaction was indicated by the formation of a red, yellow, or orange precipitate.
4. **Saponin Test**
   The noni leaf extract solution was mixed with sterile distilled water and heated using a spirit lamp. A positive reaction was indicated by the formation of stable foam that persisted for 30 min and remained after the addition of concentrated HCl.
5. **Steroid Test**
   Liebermann–Burchard reagent was added to the noni leaf extract solution. A positive reaction was indicated by the formation of a bluish-green precipitate.

In Vitro Growth Inhibition Assay of *Cercospora capsici*

The inhibitory activity of noni leaf extract against *Cercospora capsici* was evaluated at concentrations of 20%, 40%, 60%, 80%, and 100%, with negative and positive controls included for comparison. The assay was conducted using the poisoned food technique described by Aji et al. (2020).

A 1 mL aliquot of each treatment solution was added to 5 mL of PDA medium. The treated media were poured into sterile Petri dishes and allowed to solidify. A 5 mm diameter plug of *C. capsici* mycelium was obtained using a cork borer, placed at the center of the PDA medium, and incubated at 25°C for 14 days.

The parameter measured in the inhibition assay was colony diameter growth of *C. capsici* after 14 days of incubation. The percentage inhibition of radial growth (PIRG) was calculated according to Haruna (2023) using the following equation:

$$\text{PIRG} = \frac{(R_1 - R_2)}{R_1} \times 100\%$$

Note:
- **PIRG** = Percentage Inhibition of Radial Growth (%)
- **R_1** = Colony diameter of *Cercospora capsici* in the negative control on day 14 (mm)
- **R_2** = Colony diameter of *Cercospora capsici* in the positive control or treatment group on day 14 (mm)

Table 1. Categories of Percentage Inhibition of Radial Growth (PIRG) on day 14

PIRG (%)	PIRG Category
0	No Inhibition
1–25	Weak
26–50	Moderate
51–75	Strong
75–100	Very Strong

(Suganda et al., 2024)

Data Analysis

The PIRG data obtained from the *Cercospora capsici* growth inhibition assay were analyzed using the Shapiro–Wilk normality test and Levene's homogeneity test. Subsequently, one-way analysis of variance (ANOVA) was performed to determine whether significant differences existed among the seven treatment groups. When significant differences were detected, Duncan's Multiple Range Test (DMRT) was conducted at a significance level of 5% ($p < 0.05$). Statistical analyses were performed using Statistical Package for the Social Sciences (SPSS) version 23.

RESULTS AND DISCUSSION

Morphological Characteristics of *Cercospora capsici* Isolate

Based on macroscopic and microscopic observations, the *Cercospora capsici* isolate grown on Potato Dextrose Agar (PDA) exhibited white coloration on the upper colony surface, while the reverse colony appeared whitish-yellow. The isolate showed a cotton-like texture; however, no distinct growth zones, radial growth patterns, or exudate droplets were observed. Microscopically, the isolate possessed septate hyphae, clustered conidiophores, and elongated rod-shaped conidia accompanied by additional structures, including stroma and three-celled phragmospores. According to Barnett and Hunter (1998), these observed characteristics correspond to *Cercospora capsici*, particularly based on the morphological features of its conidia. In general, *Cercospora capsici* colonies exhibit bright coloration ranging from white to yellowish, unclear growth zones, and irregular growth patterns on PDA medium. The characteristic structures include unbranched but clustered conidiophores accompanied by conidia consisting of phragmospores and stroma.

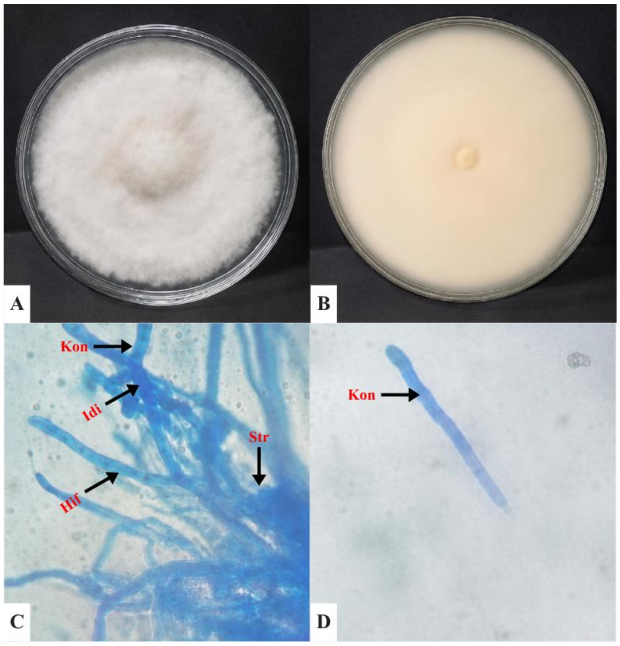

Figure 1. Morphology of the *Cercospora capsici* isolate used in this study: A-B, macroscopic characteristics; C-D, microscopic characteristics. Hif: Hyphae, Idi: Conidiophore, Kon: Conidium, and Str: Stroma

Cercospora capsici is a phytopathogenic fungus responsible for leaf spot disease in red curly chili pepper. Infection by this pathogen begins with the formation of pseudostromata, which function as structures for conidia production. Optimal environmental conditions, such as temperature and humidity, can promote the growth

and development of *C. capsici* in cultivated fields (Devianto et al., 2023). These conditions accelerate conidial release, allowing the pathogen to colonize chili leaves through hyphal growth containing hydrolytic enzymes, such as cellulase and pectinase, which degrade plant cell walls (Spanner et al., 2022). Consequently, infected leaves develop circular lesions with concentric patterns, indicating the transition from chlorosis to necrosis and resulting in visible leaf damage (Kristi et al., 2024). Furthermore, the dispersal of *C. capsici* conidia is influenced by environmental factors, including wind, rainfall, light intensity, and biological vectors such as arthropods (Bublitz et al., 2021).

Qualitative Screening of Secondary Metabolite Compounds in Noni Leaf Extract

The yield of noni leaf extraction obtained in this study was 9.8%, using 100 g of dried noni leaf powder extracted with 1 L of methanol. Methanol was selected as the extraction solvent because it can effectively isolate polar organic compounds. Therefore, methanol is capable of extracting polar and semi-polar secondary metabolites from noni leaves, including alkaloids, anthocyanins, flavonoids, saponins, steroids, and tannins (Ibrahim et al., 2021).

Figure 2. Methanolic extraction solution of noni leaves

Qualitative screening of secondary metabolites in the noni leaf extract showed positive results for all tested metabolite groups. Haruna (2023) reported that methanolic extracts of noni leaves contain secondary metabolites, including flavonoids, phenolic compounds, and steroids. This finding is also supported by Hardani (2024), who reported that methanolic noni leaf extracts contain alkaloids and saponins. The presence of these secondary metabolites indicates that noni leaf extract has potential as a botanical fungicide.

Table 2. Qualitative screening of secondary metabolite groups in methanolic noni leaf extract

Secondary Metabolite Group	Screening Result
Alkaloids	Positive, indicated by the formation of orange precipitate at the bottom of the test tube
Phenols	Positive, indicated by the formation of greenish-black precipitate at the bottom of the test tube
Flavonoids	Positive, indicated by the formation of reddish-yellow precipitate at the bottom of the test tube

Secondary Metabolite Group	Screening Result
Saponins	Positive, indicated by the presence of bubbles after the addition of concentrated HCl
Steroids	Positive, indicated by the formation of bluish-green precipitate at the bottom of the test tube

Inhibition Activity of Noni Leaf Extract against *Cercospora capsici*

Macroscopic observation revealed differences in colony diameter of *Cercospora capsici* among the tested treatments.

Table 3. Percentage Inhibition of Radial Growth (PIRG) values of *Cercospora capsici* treated with noni leaf extract after 14 days

Treatment	Colony Diameter (mm)	PIRG Value ± SD (%)	PIRG Category
KN	89.0 ± 0.00	0.00 ± 0.00f	None
P	47.0 ± 0.00	47.19 ± 2.52d	Moderate
EDM1	79.1 ± 0.44	11.05 ± 5.03e	Weak
EDM2	31.1 ± 0.22	64.98 ± 2.54c	Strong
EDM3	15.1 ± 0.53	82.96 ± 6.06b	Very strong
EDM4	7.3 ± 0.10	91.76 ± 1.17a	Very strong
EDM5	5.5 ± 0.05	93.82 ± 0.56a	Very strong

ANOVA F-value: 436
ANOVA p-value: <0.0001

Note: The same letters within the same column indicate no significant difference among treatments based on Duncan's Multiple Range Test (DMRT) at a 5% significance level. KN: negative control; P: 0.1% propineb; EDM1: 20% noni leaf extract; EDM2: 40% noni leaf extract; EDM3: 60% noni leaf extract; EDM4: 80% noni leaf extract; EDM5: 100% noni leaf extract.

The negative control treatment containing sterile distilled water resulted in a *Cercospora capsici* colony diameter of 89.0 ± 0.00 mm. In contrast, the positive control treatment containing 0.1% propineb resulted in a colony diameter of 47.0 ± 0.00 mm. Treatment with noni leaf extract at concentrations of 20%, 40%, 60%, 80%, and 100% produced colony diameters of 79.1 ± 0.44 mm, 31.1 ± 0.22 mm, 15.1 ± 0.53 mm, 7.3 ± 0.10 mm, and 5.5 ± 0.05 mm, respectively. These results indicate that noni leaf extract exhibited different inhibitory effects against *C. capsici* depending on the applied concentration.

The inhibition assay demonstrated different PIRG values among treatments. The positive control, 0.1% propineb, exhibited moderate inhibition with a PIRG value of 47.19 ± 2.52%. Noni leaf extract at 20% concentration showed weak inhibition (11.05 ± 5.03%) against *C. capsici*, whereas the 40% concentration demonstrated strong inhibition (64.98 ± 2.54%). Meanwhile, extracts at concentrations of 60%, 80%, and 100% exhibited very strong inhibition, with PIRG values of 82.96 ± 6.06%, 91.76 ± 1.17%, and 93.82 ± 0.56%, respectively. The inhibitory activity increased with increasing extract concentration, indicating that extract concentration influenced the growth rate of *C. capsici*.

One-way ANOVA followed by DMRT analysis demonstrated significant differences among the negative control, positive control, and noni leaf extract treatments at concentrations of 20% (EDM1), 40% (EDM2), and 60% (EDM3) ($p < 0.05$). However, the 80% (EDM4) and 100% (EDM5) noni leaf extract treatments showed no significant difference ($p > 0.05$). Therefore, the 80% concentration represents the most efficient treatment among the tested concentrations because it provided inhibitory activity comparable to the 100% extract concentration.

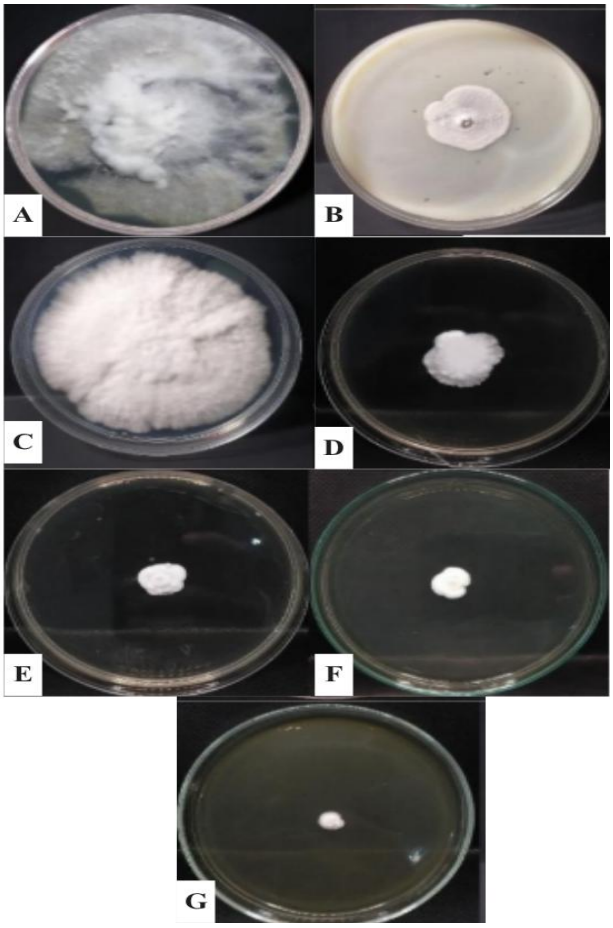

Figure 3. Colony diameter of *Cercospora capsici* after 14 days of inhibition assay: A. Negative control, B. Positive control, C. EDM1, D. EDM2, E. EDM3, F. EDM4, and G. EDM5

The antifungal activity of noni leaf extract against *Cercospora capsici* observed in this study can be compared with previous studies. Siswandi et al. (2020) reported that *C. capsici* growth was inhibited by jengkol (*Archidendron pauciflorum*) peel extract at a concentration of 90%, with a PIRG value of 84.88%. Furthermore, Salam et al. (2022) demonstrated that garlic (*Allium sativum*) extract at a concentration of 10% inhibited *C. capsici* growth by up to 100%. These findings indicate that noni leaf extract exhibited a comparable inhibitory category to garlic extract in suppressing *C. capsici* growth. Differences in PIRG values among plant extracts may be influenced by plant species and variations in the secondary metabolite composition.

The results of secondary metabolite screening and inhibition assays suggest the presence of antifungal compounds in noni leaf extract. Alkaloids exhibit antifungal activity by disrupting fungal cell walls and inhibiting enzymes associated with Deoxyribonucleic Acid (DNA) and Ribonucleic Acid (RNA) biosynthesis, thereby suppressing phytopathogenic fungal growth (Gholib, 2009; Siswandi et al., 2020; Ilmi et al., 2024). Purwantisari et al. (2023) reported that phenolic compounds exhibit antifungal activity through protein denaturation, inhibition of cellular metabolism, and suppression of fungal enzymes. Flavonoids possess antifungal properties by reducing fungal plasma membrane permeability. The hydroxyl groups (OH) in flavonoids can interfere with nutrient transport, inhibit cellular respiration through mitochondrial electron transport disruption, and generate toxic organic compounds against phytopathogenic fungi (Komala et al., 2023).

Saponins are secondary metabolites with antifungal properties because their monosaccharide groups function similarly to detergents, allowing them to disrupt fungal cell membranes by reducing membrane stability (Aji et al., 2020). Collectively, noni leaf extract contains various secondary metabolite groups that may suppress *Cercospora capsici*, the causal agent of leaf spot disease in red curly chili pepper. The antifungal activity of noni leaf extract likely involves complex interactions among these compounds, which may collectively inhibit fungal growth through disruption of hyphal formation and interference with DNA biosynthesis (Utami et al., 2020).

The present study demonstrated that noni leaf extract strongly inhibited *Cercospora capsici* growth at concentrations of 80% and 100%. The potential application of noni leaf extract as a botanical pesticide candidate is supported by the presence of secondary metabolites, including alkaloids, phenols, flavonoids, saponins, and steroids. However, further studies are required to evaluate the effectiveness of noni leaf extract under field conditions, determine the optimal application concentration, and assess its ability to reduce leaf spot disease incidence in agricultural systems.

CONCLUSION

This study demonstrated that methanolic extract of noni (*Morinda citrifolia*) leaves exhibited strong antifungal activity against *Cercospora capsici* under in vitro conditions. The inhibitory effect increased with increasing extract concentration, with the highest Percentage Inhibition of Radial Growth (PIRG) observed at 100% concentration (93.82 ± 0.56%). However, the 80% and 100% concentrations showed no significant difference based on DMRT, indicating that 80% may represent an efficient concentration for inhibiting *C. capsici* growth. The antifungal activity may be associated with the presence of secondary metabolites, including alkaloids, phenols, flavonoids, saponins, and steroids. These findings suggest that noni leaf extract has potential as a candidate botanical fungicide for managing *C. capsici*-induced leaf spot disease in red curly chili pepper (*Capsicum annuum*). Further in vivo and field-scale evaluations are required to confirm its effectiveness and application potential.

RECOMMENDATION

Further studies are required to evaluate the effectiveness of noni leaf extract through in vivo and in planta assays under agricultural field conditions where red curly chili pepper plants are affected by leaf spot disease caused by *Cercospora capsici*. In addition, further identification and characterization of secondary metabolites are necessary to determine the specific antifungal compounds responsible for the inhibitory activity through metabolomic approaches, such as Gas Chromatography–Mass Spectrometry (GC–MS) analysis or other relevant analytical methods.

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