

Efficacy of Ellagic Acid in controlling *Alternaria solani*-induced Early Blight of Tomato

**PRADEEP DATTATRAY TEKALE¹, JYOTHI CHANDRAKANT¹, YOGESH KASHIRAM BELKAR²,
DIPAKRAVSAHEB NAVSUPE² AND SAMRUDDHI ANIL JUNNARKAR³**

¹Department of Post Graduate Studies in Botany, Sharnbasva University,
Kalaburagi-585 106, Karnataka

²Department of Plant Pathology, Dr.Panjabrao Deshmukh Krishi Vidyapeeth,
P.O. Krishi Nagar, Akola – 444104, Maharashtra

³Department of Post Graduate Studies in Zoology, The Maharaja Sayajirao
University of Baroda, Pratapgunj, Vadodara-390 002, Gujarat

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Ellagic acid, a biologically active phenolic compound, is known for its antimicrobial and antioxidant properties. This study evaluates its antifungal efficacy against *Alternaria solani*, the causative agent of early blight in tomato (*Solanum lycopersicum*). The experiment was conducted in Pune, Maharashtra, during the Rabi season of 2024. Different concentrations of ellagic acid (1.56–25 PPM) were prepared using dimethyl sulfoxide (DMSO) and applied through foliar sprays at three intervals. Disease severity was assessed using a 0–5 scale, and Percent Disease Intensity (PDI) was calculated. Results showed a significant reduction in disease intensity at higher concentrations. The lowest PDI (15.3%) and highest disease control (69%) were observed at 25 PPM, followed by 12.5 PPM (PDI 20.7%, 59% disease control). The lowest efficacy was recorded at 1.56 PPM (PDI 37.3%, 25% disease control). These findings suggest that ellagic acid exhibits moderate antifungal activity, with increased effectiveness at higher concentrations. This study highlights ellagic acid's potential as a bio-based alternative for managing early blight in tomato crops.

Keywords : *Alternaria solani*, antifungal activity, early blight, Ellagic acid, PDI, tomato

INTRODUCTION

Ellagic acid, a biologically active phenolic compound, was first identified by the French chemist and pharmacist Henri Braconnot in 1831. He named it “AcideEllagique,” derived from reversing the word “galle.” This compound is naturally abundant in various fruits, including strawberries, red raspberries, pomegranates, and rose hips. Ellagic acid has been widely recognized for its broad-spectrum bioactive properties, such as anti-inflammatory, anti-mutagenic, anticancer, antitumor, antibacterial, antioxidant, and antiproliferative effects (Ghudhaib *et al.* 2010; Evtugin *et al.* 2020; Rossatto *et al.* 2021).

Due to its antifungal potential, ellagic acid is gaining attention as a promising component in the development of natural fungicides.

Tomato (*Solanum lycopersicum*) is one of the most widely cultivated crops globally and ranks as the second most important vegetable after potatoes (Pritesh and Subramanian, 2011; Hadianet *et al.* 2011; Pannoet *et al.* 2021). It is a rich source of essential nutrients, including vitamins A, C, and E, as well as antioxidants, calcium, and niacin, all of which play crucial roles in metabolic processes and human health (Sgherri *et al.* 2008; Collins *et al.* 2022). However, fungal pathogens pose a major threat to tomato production, leading to substantial yield losses. One of the most destructive fungal diseases affecting tomatoes is early blight, caused by *Alternaria solani* (Niu *et al.* 2022). This pathogen can lead to yield reductions of up to 80% if not properly managed (Pamir *et al.* 2024).

Alternaria solani employs various enzymatic mechanisms, such as cellulases that degrade plant cell walls and pectin methyl galacturonase, which aids in host colonization (Shahbazi *et al.*

*Correspondence : tekalepradeep@gmail.com

2011; Xue *et al.* 2018). The disease manifests as characteristic bull's-eye lesions on leaves, surrounded by chlorotic halos. As the infection progresses, leaves dry up, turn yellow, and eventually drop. The pathogen also affects stems, petioles, twigs, and fruits, leading to defoliation, premature fruit drop, and overall yield decline (Gleason and Edmonds, 2006; Patil and Borse, 2024). The disease is particularly severe under conditions of high humidity, prolonged leaf wetness, and elevated temperatures, with plants being most susceptible during the fruiting stage (Momel and Pemezny, 2006; Safi *et al.* 2020).

Considering the significant damage caused by *Alternaria solani* to tomato crops, implementing effective disease management strategies is crucial. This study investigates the antifungal efficacy of ellagic acid as a potential biofungicide for managing early blight in tomato cultivation.

MATERIALS AND METHODS

Ellagic acid preparation

Ellagic acid was initially dissolved in dimethyl sulfoxide (DMSO) to obtain stock solutions at different concentrations of 0.16, 0.31, 0.63, 1.25, and 2.5 mg/mL (Ali *et al.* 2024) (Table1). These stock solutions were then further diluted with distilled water to achieve the desired final concentrations in parts per million (PPM) for foliar application. The use of dimethyl sulfoxide (DMSO) as a solvent ensured proper dissolution and stability of ellagic acid before its application (Aamer *et al.* 2024). The final concentrations were carefully prepared to maintain consistency across treatments, ensuring accurate assessment of their efficacy against *Alternaria solani*, the causative agent of early blight in tomatoes. The prepared solutions were then used for spraying at designated intervals to evaluate their antifungal activity in field conditions.

Culture Source

The fungal culture used in this study was collected from the Pune region, Maharashtra, India. The isolates of *Alternaria solani*, the causative agent of early blight in tomato (*Solanum lycopersicum*) (Fig. 1), were obtained from infected tomato plants

at a specific location (GPS: 18°42'52.7"N, 73°57'28.2"E). The infected plant samples were carefully collected and transported to the laboratory for further processing.

The fungal pathogen was isolated following standard microbiological procedures. Infected leaf tissues exhibiting characteristic early blight symptoms, such as concentric rings and necrotic lesions, were surface-sterilized with 0.1% sodium hypochlorite solution and rinsed with sterile distilled water to eliminate surface contaminants. The samples were then plated on Potato Dextrose Agar (PDA) medium and incubated at 25 ± 2°C under a 12-hour photoperiod for 5–7 days. Pure cultures were obtained by sub culturing hyphal tips onto fresh PDA plates.

The morphological characteristics of *A. solani* were examined under a compound microscope, and identification was performed based on conidial morphology, pigmentation, and cultural traits as described by Ellis and Martin (1882) and Jones and Grout (1897). Additionally, molecular identification was carried out using Internal Transcribed Spacer (ITS)-based sequencing following the protocols outlined by Jain *et al.* (2019).

Trial of Ellagic acid on tomato early blight

The experiment was conducted at an agricultural farm located within the jurisdiction of Vadgaon Ghenand, Taluka Khed, Pune, Maharashtra (GPS: 18° 42' 52.6" N 73° 57' 28.2" E) during the Rabi season of 2024. The field trials commenced in mid-December, with each experimental group consisting of three replicates (Sharma *et al.* 2018). Thirty-five-day-old tomato (*Solanum lycopersicum*) seedlings, raised in the farm nursery, were transplanted at the beginning of November with a spacing of 90 cm × 30 cm to ensure optimal growth and development.

Ellagic acid treatments were applied as foliar sprays at predefined concentrations. Three consecutive sprays were administered at intervals of 1, 7, and 15 days following the onset of early blight symptoms (*Alternaria solani*) (Fig. 2). The percent disease intensity (PDI) was recorded after each spray at 7- and 15-day intervals to

assess disease progression and treatment efficacy. Disease severity was evaluated based on a standardized 0–5 scale, as detailed in Table 2, by recording observations from multiple plants within each experimental plot.

Formula :

$$\text{PDI} = \frac{\text{Sum of all disease ratings}}{\text{Total no. of observations (sample)} \times \text{Maximal disease rating grade}} \times 100$$

Based on these observations, the Percent Disease Intensity (PDI) of early blight in tomato was recorded to assess the severity of the disease. PDI was calculated using the standard formula as described by Chester (1959) and Wheeler (1969). This method provides a quantitative measure of disease incidence and severity, allowing for an accurate evaluation of the effectiveness of ellagic acid treatments in controlling *Alternaria solani* infections.

RESULTS AND DISCUSSION

Effect of fungicides on the disease intensity and Efficacy of early blight of tomato

The fungicidal activity of ellagic acid was evaluated on tomato plants using the Percent Disease Intensity (PDI) method. Disease severity was recorded on day 7 after the first application (A) and subsequently on days 7 and 14 after the second application (B). The results, as summarized in Table 3, indicate that all tested concentrations of ellagic acid significantly reduced disease intensity compared to the untreated control. A significant variation in PDI was observed among the different treatment groups. The lowest PDI (15.3%) was recorded in plants treated with 25 PPM (T1), demonstrating the highest disease control efficacy (69%). As the concentration of ellagic acid decreased, PDI increased correspondingly. The highest PDI (37.3%) was observed at the lowest concentration (1.56 PPM, T5) at 14 days after the second application (Fig. 3).

These findings are in agreement with recent studies on the antifungal efficacy of phenolic compounds, including ellagic acid, against plant pathogens. For instance, (Rossatto *et al.* (2021)

reported that ellagic acid exhibited strong antifungal activity against *Candida auris*, a drug-resistant fungal pathogen, highlighting its broad-spectrum potential in plant disease management. Similarly, Evtyugin *et al.* (2020) discussed the antimicrobial applications of ellagic acid and its derivatives, demonstrating their effectiveness in controlling fungal pathogens. The reduction in PDI observed in this study aligns with the findings of Sharma *et al.* (2018), who evaluated the impact of different fungicides on *Alternaria solani*, the causal agent of early blight in tomatoes, and reported significant disease suppression at optimal concentrations. Furthermore, the study by Amer *et al.* (2024) on the antimicrobial activity of *Bienertia sinuspersici* extract, rich in polyphenolic compounds, including ellagic acid, reinforces the effectiveness of such natural compounds in plant disease control.

These results suggest that ellagic acid can serve as a potential biocontrol agent against fungal pathogens affecting tomato plants, reducing disease severity in a dose-dependent manner. Future studies should explore its mechanism of action and evaluate its long-term efficacy under field conditions.

A pot trial conducted under greenhouse conditions further assessed the efficacy of different concentrations of ellagic acid. The highest antifungal activity was recorded at 25 PPM, with a PDI of 15.3% and 69% disease control, followed by 12.5 PPM, which resulted in a PDI of 20.7% and 59% disease control. The lowest efficacy was observed at 1.56 PPM, with a PDI of 37.3% and only 25% disease control (Kadhem *et al.* 2010; Fernanda *et al.*, 2021).

These findings are consistent with previous studies demonstrating the antifungal properties of ellagic acid. Kadhem *et al.* (2010) reported that ellagic acid exhibited significant antibacterial activity against pathogenic bacteria, suggesting its broad-spectrum antimicrobial potential. Similarly, Fernanda *et al.* (2021) highlighted its strong antifungal activity against *Candida auris*, supporting its effectiveness in plant disease management. The dose-dependent efficacy observed in this study is in line with the results of Sharma *et al.* (2018), who demonstrated that

Table 1: Formulations of Ellagic Acid

Groups	Dose in ppm)	Ellagic Acid (in mg)	DMSO (1%) (in mL)	Distilled Water (in mL)	Final Volume (in mL)
UTC	0.0	NA	5	495	500
T1	25	12.5	5	495	500
T2	12.5	6.25	5	495	500
T3	6.25	3.13	5	495	500
T4	3.13	1.56	5	495	500
T5	1.56	0.78	5	495	500

Keys: PPM = Parts Per Millions, UTC = Untreated Control, T1-T5 = Treatment Concentrations, NA = Not Applicable

Table. 2: Disease rating scale used to calculate disease severity of early blight of tomato (Mayee and Datar, 1986).

Scale	Scale description
0	Healthy, No visibility of symptom on leaf
1	0-5 % leaf area infected but not present on petiole and branches.
2	6-20% leaf area infected and covered by spot, some spots on petiole.
3	21-40% leaf area infected and covered by spot, spots also seen on petiole, branches.
4	41-70% leaf area infected and covered by spot, spots also seen on petiole branches stem.
5	Healthy, No visibility of symptom on leaf

Table 3 : Efficacy of Ellagic acid against tomato early blight

Groups	Dose (in ppm)	Application Code	Disease (%)			Efficacy (% Control)		
			A07	B07	B14	A07	B07	B14
UTC	0.0	AB	29.9	41.7	50	0	0	0
T1	25	AB	7	10.6	15.3	77 a	74 a	69 a
T2	12.5	AB	9.9	16.3	20.7	67 b	61 b	59 b
T3	6.25	AB	13	20	26.7	57 c	52 c	47 c
T4	3.13	AB	17	24.7	32	43 d	41 d	36 d
T5	1.56	AB	21.3	30	37.3	29 e	28 e	25 e

Keys: UTC = Untreated Control, T1 - T5 = Treatment Concentrations, AB = Two applications, A = First application, B = Second application, a to e = higher to lower values, ppm = parts per million.

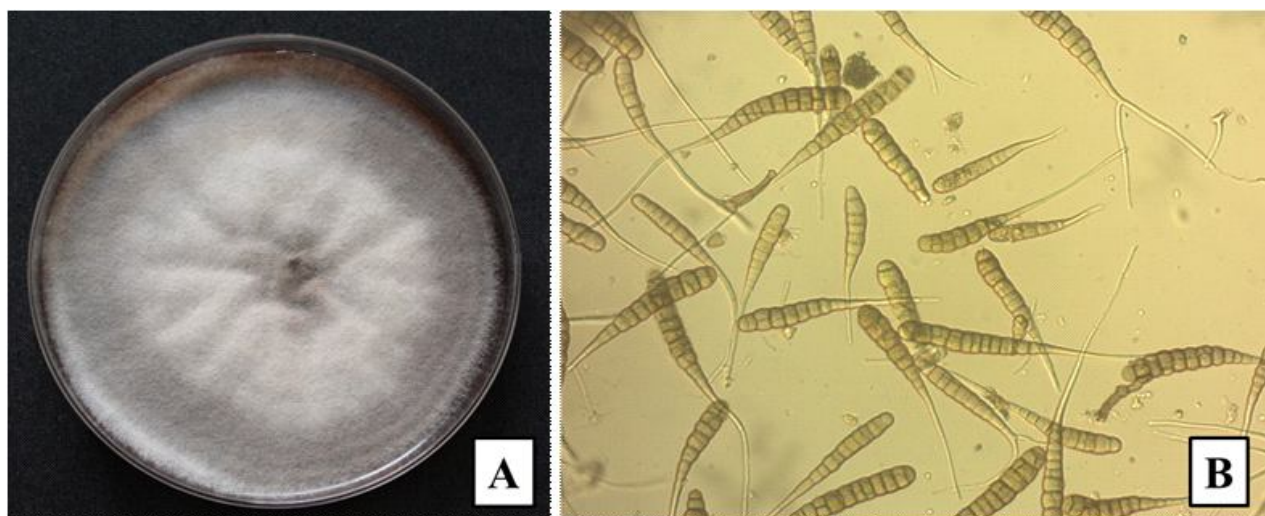


Fig. 1: A. Growth on PDA Media, B. Microscopic view of *Alternaria solani*



Fig. 2: Ellagic acid sprayed three times at 1, 7, and 15 days post-disease initiation.

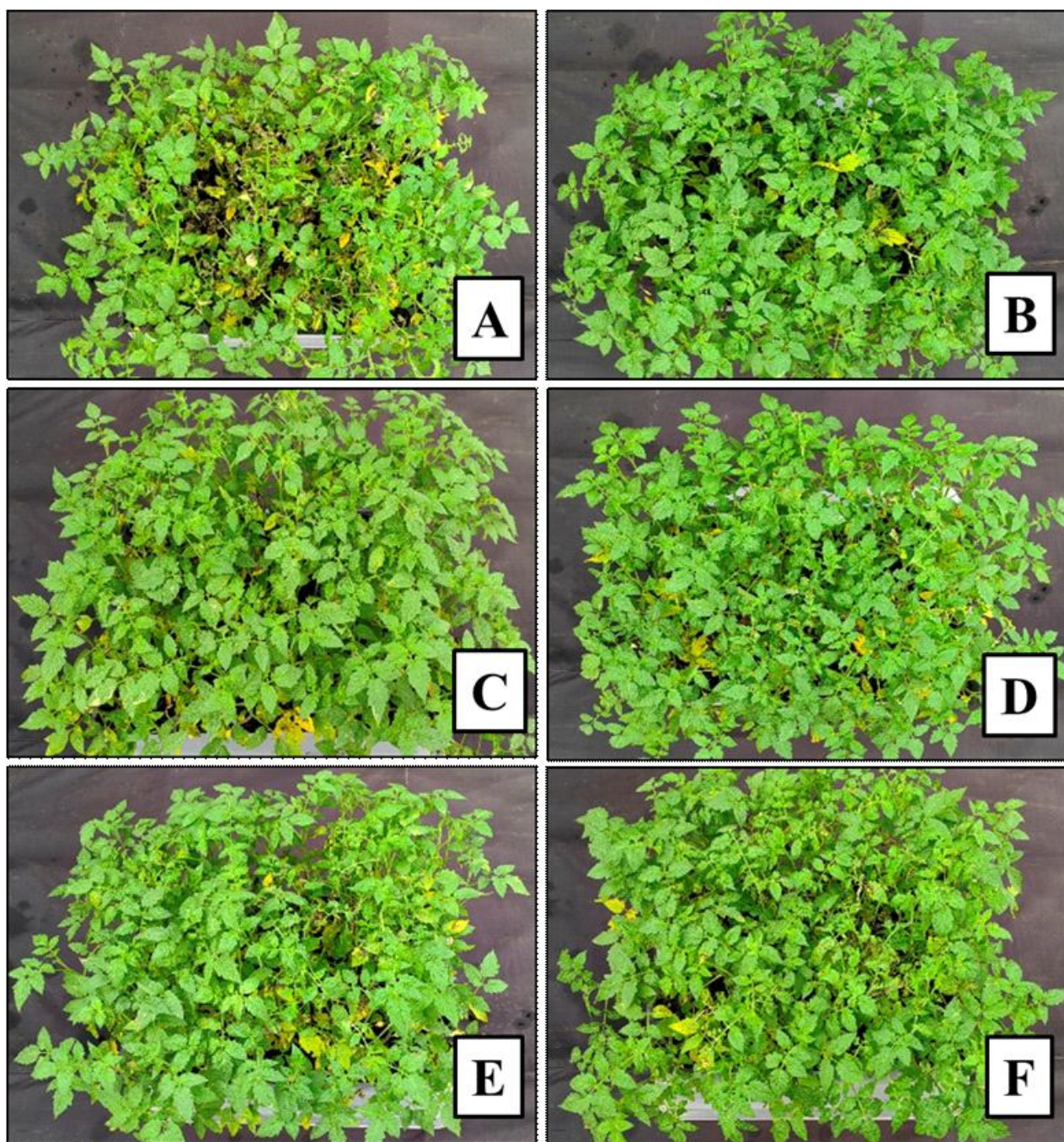


Fig. 3: Tomato Early Blight by *Alternaria solani*; A. Untreated Control, B. T1 (25 ppm), C. T2 (12.5 ppm), D. T3 (6.25 ppm), E. T4 (3.13 ppm), F. T5 (1.56 ppm). T1 - T5 = Treatment Concentrations

higher concentrations of fungicides led to greater suppression of *Alternaria solani*, the causal agent of early blight in tomatoes.

Recent studies further emphasize the role of natural phenolic compounds in plant disease control. Evtyugin *et al.* (2020) discussed the potential of ellagic acid derivatives in agricultural applications, highlighting their antimicrobial

properties. Aamer *et al.* (2024) reported that polyphenolic compounds, including ellagic acid, exhibited strong antifungal activity against plant pathogens, reinforcing the potential of natural compounds as eco-friendly alternatives to synthetic fungicides. The results of the pot trial confirm the effectiveness of ellagic acid in controlling fungal infections in tomato plants, particularly at higher concentrations. However,

further studies are needed to understand its long-term efficacy under field conditions and explore its mode of action against fungal pathogens.

The results suggest that ellagic acid exhibits dose-dependent antifungal activity against *Alternaria solani*, with higher concentrations providing better disease suppression. However, its efficacy remains moderate to low when compared to conventional fungicides. The findings highlight the potential of ellagic acid as a bio-based alternative for managing early blight in tomatoes, though further optimization of application methods and concentrations may be necessary to enhance its effectiveness.

CONCLUSION

Alternaria solani, the causative agent of early blight in tomatoes. The results indicate that ellagic acid exhibits dose-dependent efficacy, with higher concentrations significantly reducing disease severity and achieving the highest disease control. However, its effectiveness declined at lower concentrations, suggesting that an optimal dose is necessary for practical application. While ellagic acid presents a promising biofungicidal alternative, its moderate efficacy compared to conventional fungicides highlights the need for further research on formulation enhancements, application strategies, and synergistic combinations with other biocontrol agents. These findings contribute to the growing interest in natural plant-derived compounds for sustainable plant disease management and encourage future investigations into their commercial viability in integrated disease management programs.

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DECLARATION

Conflict of Interest. Authors declare no conflicts of interest related to the publication of this article.

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