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EFFECT OF *PSEUDOMONAS FLUORESCENS* AND ESSENTIAL OILS ON EARLY BLIGHT OF TOMATO (*SOLANUM LYCOPERSICUM L.)* CAUSED BY *ALTERNARIA SOLANI* (ELLIS) MARTIN

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ABSTRACT

Tomato (*Solanum lycopersicum* L.) is the principal vegetable crop grown for its nutritional and economic value. Major limiting factor in tomato production is early blight caused by Alternaria solani, which causes severe yield loss. This study was carried out in the Rabi season of 2023–2024 at SHUATS, Prayagraj to evaluate the efficacy of Pseudomonas fluorescens in combination with essential oils for the biological management of early blight. The field experiment followed a Randomized Block Design (RBD) where seven treatments were compared against three replications. Seed treatment and foliar sprays consisting of 2–10 ml of P. fluorescens and 3% concentration of essential oils (neem, castor, clove, eucalyptus, and mustard) were included in treatments. For comparison, a chemical control was also included. Percent Disease Intensity (PDI) were observed at 60-, 75-, and 90-days post transplanting, growth attributes, yield and cost benefit ratio. Among the combinations the combination of P. fluorescens (2 ml) + neem oil (3%) was the most effective, having the lowest PDI (16.23% at 90 DAT), improved plant height and branching, and the highest yield (25.63 t ha−1). In addition, this treatment provided the highest economic return. These results suggest that the integration of biological control agents and essential oils may provide sustainable, ecofriendly alternative to control early blight in tomatoes. Using this approach decreases chemical pesticide use and promotes better sustainable agricultural practices.
***Keywords*:** *Alternaria solani,* Bio agent, Early blight, Essential oil, Neem oil, *Pseudomonas fluorescens*, Tomato.

Introduction

Tomato (*Solanum lycopersicum* L.) is one of the most important and widely cultivated vegetable worldwide due to its high nutritive value and culinary uses. Second among the vegetables, the cultivated area is about 4.8 million hectares and the production is 163.9 million tonnes (FAOSTAT, 2019). Tomatoes are nutritionally rich in vitamins A, B, C, lycopene, β carotene, potassium, flavonoids making them very important for human health (Gopalan *et al.,* 1995). Tomato has other than dietary importance, it is used for medicinal purposes such as aiding in digestion and is a blood purifier (Waiganjo *et al.,* 2006).

Tomato production globally is limited by many diseases, the most destructive of which is early blight (caused by *Alternaria solani*). Tomato crops in temperate, tropical and subtropical climates are affected by this foliar disease, and yield losses up to 80% can occur, depending on the environmental conditions (Datar and Mayee, 1981; Bessadat *et al.,* 2022). The pathogen causes characteristic concentric lesions on leaves, stems, and fruits, the latter with an accelerating defoliation, and severely damages crop quality and productivity (Peralta *et al.,* 2005; Rahmatzai *et al.,* 2017).

Chemical fungicides are widely used to control early blight till now (Ramakrishnan *et al.,* 1971; Chand and Singh, 2004). Nevertheless, repeated fungicide application has brought about pathogen resistant strains, environmental contamination, and accumulation on produce. This has made there is a rising demand for eco-friendly and sustainable alternatives.

Pseudomonas fluorescens, which has been demonstrated to contain antagonistic activity against both soil borne and foliar pathogens as well as its plant growth promoting effects (Dobariya *et al.,* 2023; Pandey and Gupta, 2020) is one promising strategy. Moreover, oils from plants such as neem (*Azadirachta indica*), castor (Ricinus communis), clove (*Syzygium aromaticum*), and eucalyptus (Eucalyptus globulus) are natural antifungal, antibiotics, and insecticides (Javaid *et al.,* 2015; Chaieb *et al.,* 2007; Walter *et al.,* 1997). These oils may be integrated with biocontrol agents to further disease suppression and healthier crop development.

In this regard, this study was conducted to explore the potential of P. fluorescens in combination with single or a mixture of essential oils for the control of early blight of tomato. Not only were the disease suppression effects integrated, but the integrated treatment effects were also evaluated on key growth and yield parameters. In addition, the study was designed to find an economically viable and environmentally sustainable alternative to chemical fungicides for tomato growers.

Materials and Methods

Study Area

The Study took place at the Central Research Field in the Plant Pathology Department at SHUATS in Prayagraj, Uttar Pradesh, India, during the Rabi season of 2023-2024. The site is about 98 meters above sea level, located at a latitude of 25.57°N and a longitude of 81.85°E. With temperatures ranging from 20°C to 30°C and humidity often around 70%, this area has a subtropical climate that's ideal for the early growth of tomato blight caused by *Alternaria solani.* (Peralta *et al*., 2005; Nowicki *et al*., 2012).

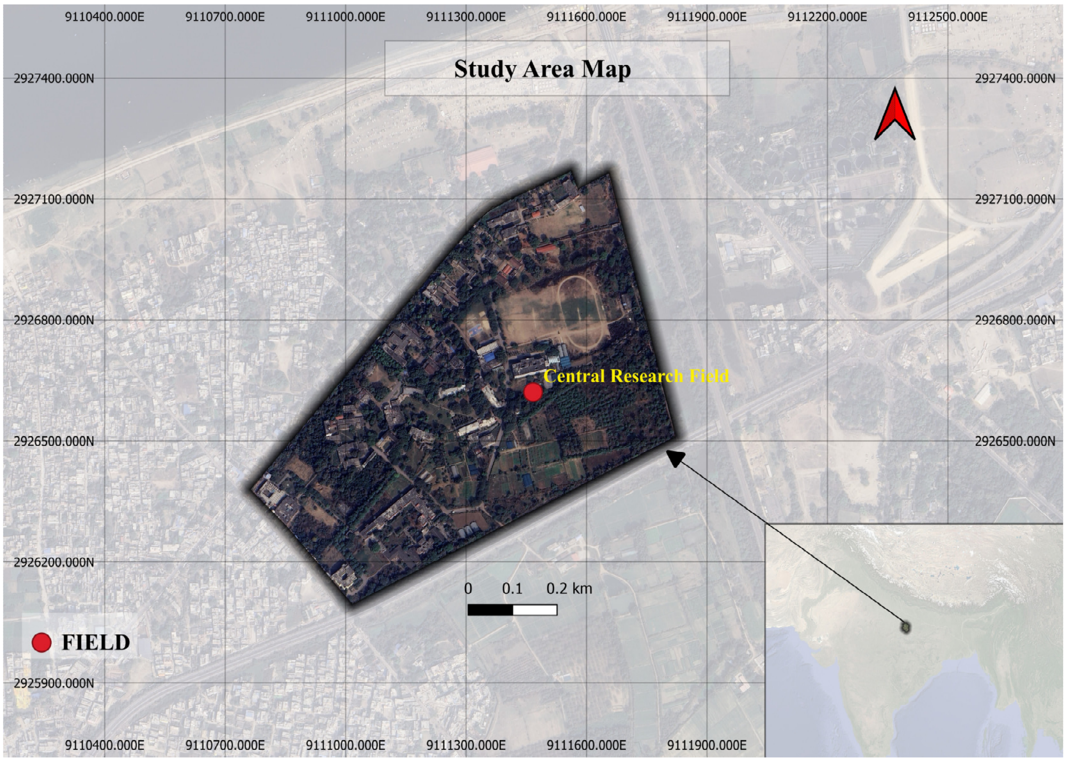

Fig. 1: Study site location at SHUATS, Prayagraj, India.

Experimental Design and Treatments

According to Gomez and Gomez (1984) for reducing experimental error and increasing reliability, the trial was laid out in Randomized Block Design (RBD) with seven treatments replicated three times. The foliar disease susceptible tomato variety 'Kala Sona' was used. Plots of 2 × 1 m spacing with 45 cm × 30 cm spacing between rows and plants were sown with seeds. Apart from disease control, standard agronomic practices were followed except that the treatments were only applied as per the treatment schedule.

Treatment Details

The treatments consisted of a combination of *Pseudomonas fluorescens* at different concentrations for seed treatment (S.T.) and essential oils at a 3% constant concentration for foliar spray (F.S.) and a chemical control (mancozeb) and untreated check.

T1 - *P. fluorescens* @ 2 ml (S.T.) + Neem oil @ 3% (F.S.)
T2- *P. fluorescens* @ 4 ml (S.T.) + Castor oil @ 3% (F.S.)
T3- *P. fluorescens* @ 6 ml (S.T.) + Clove oil @ 3% (F.S.)
T4- *P. fluorescens* @ 8 ml (S.T.) + Eucalyptus oil @ 3% (F.S.)
T5- *P. fluorescens* @ 10 ml (S.T.) + Mustard oil @ 3% (F.S.)
T6- Mancozeb 25 EC @ 0.25% (F.S.) – chemical standard
T0-Untreated control

Data Collection and Parameters Measured

1. Percent Disease Intensity (PDI): Visual scoring of disease severity was carried out at 60, 75 and 90 DAT using a 0–5 scale and PDI was calculated as described by (Mayee and Datar 1986.)
2. Growth Parameters: Plant height (cm), number of leaves per plant and number of branches per plant were recorded in five randomly selected plants per plot at 90 DAT.
3. Yield: Each plot was harvested to yield marketable fruits, weighed and extrapolated to yield per hectare (t/ha).
4. Economic Analysis: Current market prices of inputs and tomato yield returns were used to compute a benefit cost (B:C) ratio for each treatment (Reddi and Reddi, 2004).

Results and Discussion

Percent Disease Intensity (PDI)

The treatments significantly influenced disease severity measured as Percent Disease Intensity (PDI) for all growth stages. Based on the treatment consisting of Pseudomonas fluorescens @2 ml (S.T.) + Neem oil @3% (F.S.) (T1), the disease intensity was the least during the crop period and was 16.23% at 90 DAT. However, the maximum PDI of 53.88% in the untreated control (T0) represents natural disease progression without intervention. (Table 1) and (Fig. 2) present the complete PDI data at 60, 75 and 90 DAT across all treatments and shows clearly the superiority of T1 and the poor performance of the control. They are consistent with previous findings that neem oil has antifungal potential and that P. fluorescens can suppress foliar pathogens.

Table 1: Percent disease intensity (%) at 60, 75 and 90 DAT as affected by treatments

Sr. No.	Treatment	60DAT	75DAT	90DAT
T0	Control (untreated check)	33.86	42.34	53.88
T1	*Pseudomonas fluorescens* + Neem oil	20.98^{b}	26.42	32.1^{b}
T2	*Pseudomonas fluorescens* + Castor oil	26.64^{a}	37.09	42.01
T3	*Pseudomonas fluorescens* + Clove oil	24.85	31.05^{a}	37.33^{ab}
T4	*Pseudomonas fluorescens*+ Eucalyptus oil	22.51^{b}	29.23	35.56
T5	*Pseudomonas fluorescens*+ Mustard oil	29.06	39.94	45.23
T6	Mancozeb (treated check)	25.67^{a}	32.14^{a}	39.14^{a}
	S. Ed (±)	1.06	0.69	0.87
	CD (5%)	2.32	1.50	1.91

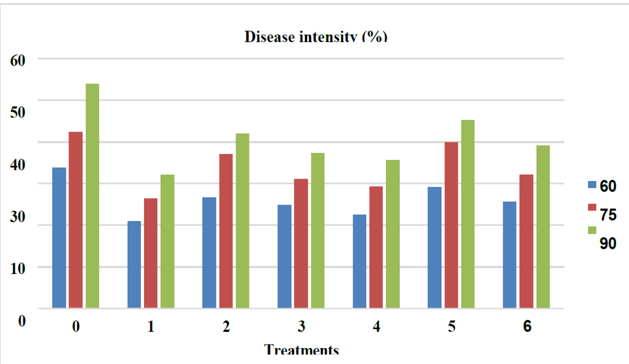

Fig. 2: Per cent disease intensity (%) at 60, 75 and 90 DAT as affected by treatments

Growth Parameters

Tomato plants differed considerably in their growth characteristics under different treatments. The major parameters assessed were plant height, total number of leaves produced per plant, and total number of branches produced per plant, observed at 30, 60, and 90 days after transplanting (DAT).

Plant height: Treatment T1 (Pseudomonas fluorescens + neem oil) produced the best mean height at all intervals, measuring 80.32 cm with a 90 DAT reading. This was followed by treatments T4 (eucalyptus oil combination) and T3 (clove oil combination), indicating a synergistic effect of P. fluorescens and essential oils in promoting vegetative growth. Control plot (T0) was by far the least in height development, consistently. The detailed height measurements can be found in (Fig. 3).

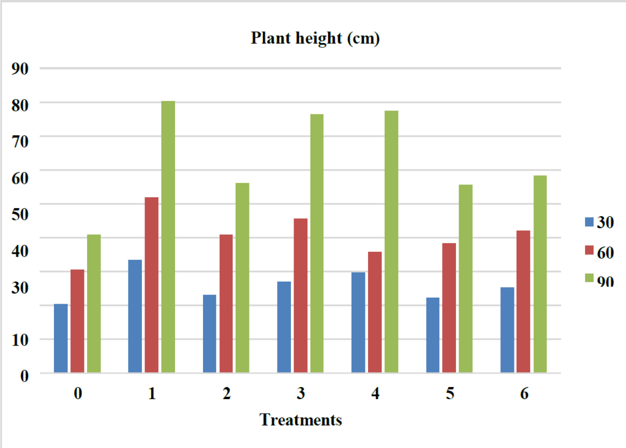

Fig. 3: Effect of selected treatment on plant height (cm)

Number of leaves per plant: The treatments significantly influenced foliage development. T1 continued beyond the other treatments with 273.06 leaves per plant at 90 DAT, while T4 and T6 also brought forward high leaves. The untreated control T0 recorded just lower with 106.46 leaves per plant. The specific results are depicted in (Fig. 4) which shows similar trends over the recounted time intervals.

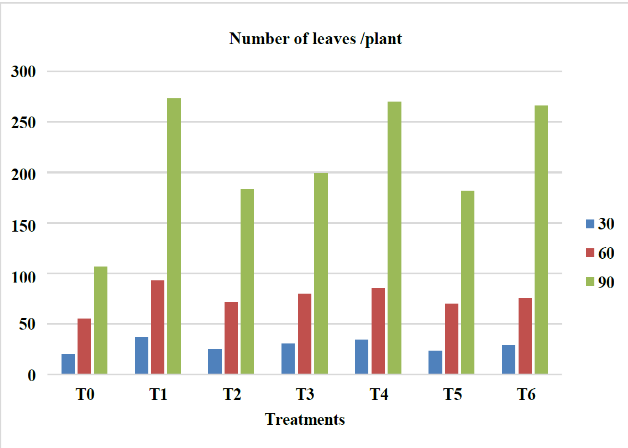

Fig. 4: Number of leaves per plant at 30, 60 and 90 DAT as affected by treatments

Number of branches per plant: Branching noticed great change due to the treatments. T1 leads with the highest number of branches at 90 DAT (24.93 plant out of T4 and T3), unlike the control value T0 where only 18 branches were recorded. Further assessments indicate the treatments differed significantly at (CD = 0.60 at 5%). The detailed values are illustrated in (Fig. 5).

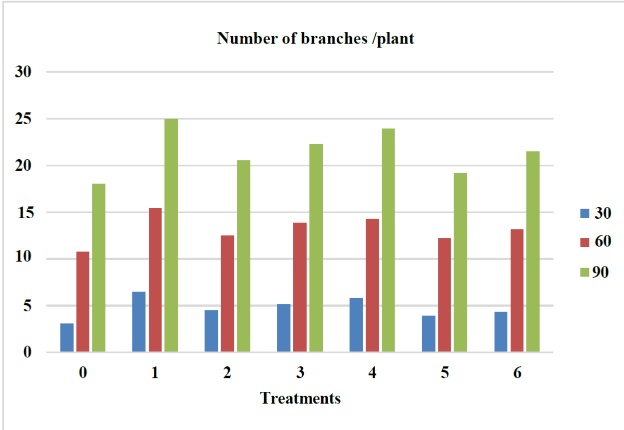

Fig. 5: Number of branches per plant at 30, 60 and 90 DAT as affected by treatments

The combined application of P. fluorescens and essential oils reduced disease incidence, and greatly improved vegetative growth in tomatoes, suggesting that essential oils do impart protective and growth-promoting benefits.

Yield Performance

The treatments had a significant influence on tomato yield. T1 gave the highest yield (25.63 t/ha) followed by T4 (19.80 t/ha) and T3 (17.36 t/ha). The control (T0) showed the lowest yield, indicating that disease pressure was an adverse factor to productivity. (Table 2) presents yield results. These findings support previous studies from others on the beneficial effect of neem biocontrol strategies on tomato production.

Table 2 : Tomato yield (tonnes/ha) as affected by treatments

Sr. No.	Treatment	Yield (t/ha)
T0	Control (untreated check)	6.13^{c}
T1	*Pseudomonas fluorescens* + Neem oil	5.2
T2	*Pseudomonas fluorescens* + Castor oil	8.53^{ab}
T3	*Pseudomonas fluorescens* + Clove oil	7.2^{bc}
T4	*Pseudomonas fluorescens*+ Eucalyptus oil	11.73
T5	*Pseudomonas fluorescens*+ Mustard oil	6.4^{c}
T6	Mancozeb (treated check)	9.6^{a}
	S. Ed (±)	0.96
	CD (5%)	2.09

Economic Viability

Economic analysis showed that T1 yielded the highest, while having the best benefit cost (B:C) ratio making it a viable option for the farmers. Chemical treatment was more expensive than treatments with essential oils and P. fluorescens, and the latter treatments had a higher return on investment. A graphical representation of the economic performance is depicted in (Fig. 6), clearly highlighting the superior profitability of T1 compared to other treatments.

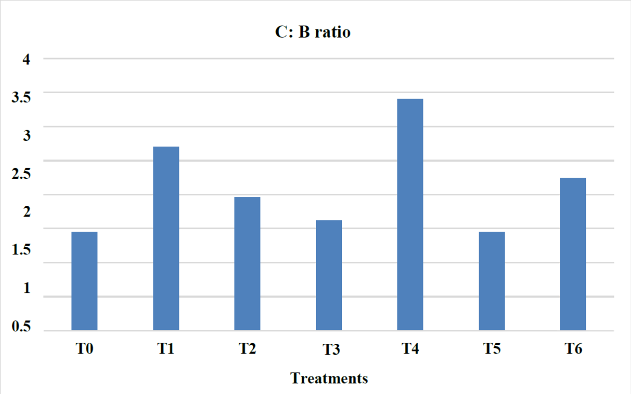

Fig. 6 : Effect of treatments on cost benefit ratio (C: B) of tomato

Conclusion

The present study clearly established that the ability of Pseudomonas fluorescens to be integrated with essential oils, especially with neem oil, serves an effective environment-friendly method of early blight management in tomato. Of all the treatments, P. fluorescens @ 2 ml (for seed treatment) followed by neem oil at @ 3% (foliar spray) was by far the best, registering the lowest percent disease intensity, the highest plant height (80.32 cm), the maximum number of leaves (273.06), and the most branching (24.93) at 90 DAT. This treatment also recorded the highest yield (25.63 t/ha) and economic return, thus underlining its dual benefits in disease suppression and plant growth promotion. This use of biocontrol agents as well as botanical extracts has not only reduced reliance on synthetic chemicals but also contributed to sustainable and profitable tomato production. This will help in scaling up integrated biological and botanical strategies for field management practices, while future investigations may test their applicability on other crops and agro-climatic zones.

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Competing Interests

The author declares that there are no competing interests regarding the publication of this manuscript.

Authors Contributions

Aditi Thakur- Conducted the research work, collected and analysed the data, interpreted the findings, and drafted the manuscript.

Dr. Shashi Tiwari- Supervised the study, provided critical guidance throughout the research, and reviewed and refined the final manuscript.

Both authors read and approved the final version of the manuscript.

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