



## Efficacy of *Pseudomonas fluorescens* in Suppressing Pea Wilt

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### ABSTRACT

Pea is an important legume crop widely cultivated for its nutritional and economic value. Its production is often limited by wilt disease caused by *Fusarium oxysporum* f. sp. *pisi*, a soil-borne fungal pathogen that can lead to severe yield losses. In the present study, the field demonstrations were conducted during Rabi seasons 2024-25 in village Kot Mohammad Khan of Tarn Taran district. The goal was to study the influence of seed treatments and sowing time on wilt disease incidence, plant growth and yield performances in peas under field conditions. The experiment included five seed treatment methods: T1 (*Pseudomonas fluorescens*), T2 (Captan), T3 (*P. fluorescens* + Captan), T4 (Untreated Control) and T5 (Farmers' Practice). Among the treatments, T3 (combined application of *P. fluorescens* and Captan) was most effective in reducing wilt incidence (6.33%) and severity (1.2%) under natural field conditions. It also resulted in significant improvements in plant height (70.5 cm), pod number (9.2), seeds per pod (9.5), pod weight (8.2 g), and maximum yield (13.43 q/ha). Control plots had the highest disease incidence (12.98%) and the lowest yield (11.57 q/ha). Sowing from mid-October to mid-November resulted in lower disease levels and higher yields across all treatments, with T3 achieving the highest yield (12.78 q/ha) and the lowest disease incidence (7.2%). This study concluded that using an integrated seed treatment with *P. fluorescens* and Captan, along with optimized sowing times, is an effective strategy for managing wilt disease and improving yield in pea cultivation under Punjab's agro-climatic conditions.

**Keywords:** Pea, wilt, *Pseudomonas fluorescens*, disease incidence, disease severity and yield.

### INTRODUCTION

Pea (*Pisum sativum* L.) is an important legume crop grown for its nutritional and economic value. It is consumed by both humans as vegetables and animals as feed around the world. It can be cultivated in winter season in India, where it thrives in cool and humid climates (Sharma, 2011). Pea seeds are high in protein (27.8%), carbohydrates (42.65%), vitamins, minerals, and dietary fibres (Urbano *et al*, 2003). After soybeans, chickpeas, and groundnuts, peas ranked among the most important leguminous crops globally (Foyer *et al*, 2016). However, pea production faces significant challenges from wilt disease caused by *Fusarium oxysporum* f. sp. *pisi*, a soil-borne fungus that can lead to substantial yield losses in pea farming worldwide (Sharma *et al*, 2018). This pathogen invades plant roots, blocks vascular tissues, and causes premature wilting and death of the plants. Its ability to survive in the soil for long periods, even without a host, makes it hard to manage (Agrios, 2005).

Conventional control methods, such as crop rotation and chemical fungicides, offer only limited and short-term protection (Gurumurthy *et al*, 2019;

Kavitha and Latha, 2019). The excessive and unregulated use of chemical pesticides has led to environmental degradation, increased pathogen resistance and residual toxins in the soil and food products (Aktar *et al*, 2009; Sudha *et al*, 2019; Sunil and Thara, 2022). Therefore, there is an urgent need to find sustainable and eco-friendly options for managing diseases in pea cultivation. Biological control using beneficial microorganisms has become a promising method in integrated pest and disease management. Disease control through biocontrol agents results from interactions among the plant, the pathogen, the biocontrol agent, the microbial community around the plant and the physical environment. Among various beneficial microorganisms, plant growth-promoting rhizobacteria (PGPR), specifically *Pseudomonas fluorescens*, has gained attention for its ability to fight against several soil-borne pathogens, including *Fusarium* spp. (Weller, 2007). This bacterium exerts biocontrol effects through multiple mechanisms, such as producing antibiotics, siderophores, hydrogen cyanide and lytic enzymes (Haas and Défago, 2005). Additionally, *P. fluorescens* improves plant health by boosting systemic resistance and enhancing nutrient uptake (Kloepper *et al*, 2004).

Considering its biocontrol potential, field demonstrations were conducted to assess the effectiveness of *P. fluorescens* in managing pea wilt under field conditions. The main objectives were to validate the performance of *P. fluorescens* in controlling wilt disease and to promote awareness among farmers about using biological control agents in sustainable agriculture. This study contributes to ongoing efforts to reduce dependency on chemicals in pea farming and promotes eco-friendly practices for long-term agricultural sustainability. Thus, the study aimed to evaluate the effectiveness of *P. fluorescens* in combination with other commonly available fungicides in managing pea wilt under field conditions and encourages farmers to adopt eco-friendly methods for sustainable agriculture.

## MATERIALS AND METHODS

### Study area

Tarn Taran district of Punjab located in north-west republic of India which further extends from 31° 05' and 31° 30' 05" north latitude and 74° 30' (India-Pakistan boundary) and 75° 15' 05" east longitudes. The district encompasses alluvial plains, covering an area of 2,583 sq. km. It is bordered by Amritsar district to the north, Kapurthala district to the east, Pakistan to the west, and Firozpur district to the south. The research was conducted at village Kot Mohammad Khan, block Naushehra Pannuan. Agriculture is the primary occupation with most arable land actively cultivated.

### Climate

Tarn Taran, an important district in Punjab, India, features a tropical steppe climate that is generally dry, except for a brief period during the south-west monsoon season. The district experiences four distinct seasons i.e. cold, hot, south-west monsoon, and post-monsoon (September to early November). During the cold season, a series of western disturbances influence the weather. The hot season is characterized by extreme heat, dryness and discomfort, while the period from July to September is marked by humidity and cloudiness. The average annual rainfall of 545 mm is unevenly distributed in the district.

### Experimental site

The present study was conducted by the Farm Advisory Service Centre, Tarn Taran during the *Rabi* seasons from 2023-24 to 2024-25 to evaluate the effectiveness of different seed treatment approaches in pea cultivation against pea wilt. The field

demonstrations were conducted on farmers field at village Kot Mohammad Khan, block Naushehra Pannuan of Tarn Taran district. A total of 20 front line demonstrations (FLDs) were sown over an area of 20 acres in both the years. The pea variety AP3 widely cultivated in the region for its high yield potential was sown in the experiments. The experiment was laid out in randomized block design with three replications.

### Procurement of biological control agent and other fungicides

The formulation of *Pseudomonas fluorescens* used in the study was provided by the Department of Plant Pathology, Punjab Agricultural University, Ludhiana. The formulation was prepared under controlled laboratory conditions to ensure high viability and effectiveness. It was used in the study as a biological control agent against pea wilt. The other fungicides required for the study were procured from authorized agrochemical dealers from the local market. All fungicides were selected based on their recommended dose and were applied as per standard agronomic practices.

### Seed treatments with biological control agent and other fungicides

To determine the effectiveness of different seed treatments, seeds were treated using the following methods.

**Table 1: Treatment details**

| Treatment | Treatment description                 |
|-----------|---------------------------------------|
| T1        | <i>Pseudomonas fluorescens</i>        |
| T2        | Captan                                |
| T3        | <i>P. fluorescens</i> + Captan        |
| T4        | Control (Untreated)                   |
| T5        | Farmers practice (Carbendazim+Thiram) |

A talc-based formulation of 15 g *P. fluorescens* per kilogram was used as a biological treatment, and Captan at 1 g/kg seed was applied as a chemical fungicide. In one treatment, both *Pseudomonas fluorescens* and Captan were combined. Additionally, untreated seeds served as a control to assess the natural disease occurrence and crop performance. A treatment based on local farming practices was included, which involved treating seeds with a mixture of Carbendazim and Thiram (2 g/kg seed), commonly fungicides in the region. The seeds were placed in a clean, dry drum and the formulation was added followed by thorough mixing to ensure all seeds were evenly coated.

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### Sowing and crop management

Seeds were sown in rows 30 cm apart with a plant-to-plant spacing of 7.5 cm. Standard package of practices were followed for irrigation, weeding and pest management except for protecting against wilt.

### Disease assessment

Data on disease incidence and severity were recorded at 10, 20, 30, and 45 days after sowing. The following formula was used to calculate disease incidence:

$$\text{Disease incidence (\%)} = \frac{\text{Number of wilted plants}}{\text{Total number of plants}} \times 100$$

Disease severity was assessed on a scale of 0 to 5, as per Charchar and Kraft (1989), using this formula:

0 = No disease

1 = pale yellow green, downward curling of leaf margin and stipules

2 = yellowing of leaves from stem base to apex

3 = stunting and wilting

4 = drying of lower leaves, yellow to orange brown discoloration of the vascular system in the upper tap root extending up the stem

5 = completely wilted or plant death.

$$\text{Disease severity (\%)} = \frac{\text{Sum of all ratings}}{\text{Total number of ratings} \times \text{Maximum rating}} \times 100$$

### Growth and yield parameters

At harvesting various growth and yield parameters were recorded, including plant height (cm), number of pods per plant, number of seeds per pod, pod weight (g), and grain yield (q/ha).

### Statistical analysis

The results were analyzed using one-way analysis of variance (ANOVA), followed by Tukey's HSD post-hoc test to determine significant differences between group means, with significance set at  $p < 0.001$ .

## RESULTS AND DISCUSSION

### Efficacy of seed treatments on Pea wilt incidence and severity

The results showed significant differences in wilt incidence and severity among the tested treatments (Table 3). The integrated seed treatment in T3 (*Pseudomonas fluorescens* + Captan) significantly reduced disease incidence (6.33%) and severity (1.2%) compared to the untreated control T4 (12.98% incidence and 6.2% severity). The results suggested a positive interaction between the biocontrol and chemical fungicide components. The effectiveness of *P. fluorescens* as a bacterium that colonizes the rhizosphere comes from its ability to produce antibiotics, siderophores and enzymes that suppress pathogenic fungi (Weller, 2007; Kumar *et al*, 2023; Lakshmikanthan *et al*, 2025), while Captan acts quickly to suppress fungal propagules through contact.

Seed treatment with *P. fluorescens* led to moderate disease control (8.77% incidence, 2.4% severity), confirming its biocontrol potential. However, its effectiveness was lower than the integrated application likely due to the time-dependent dynamics of colonization and the population levels needed for effective biocontrol (Kumar *et al*, 2023). The chemical treatment alone with Captan produced better results than the control but was less effective than the integrated approach, indicated that relying only on single-mode chemical treatments may not be enough under high pathogen pressure. The farmers practice with Carbendazim and Thiram also controlled the disease (11.54% incidence; 5.2% severity), although it was less effective than the integrated treatment. This limited effectiveness may be related to the development of pathogen resistance or suboptimal application practices, as seen in previous reports on managing soil-borne diseases (Gurjar *et al*, 2012).

### Influence on growth and yield parameters

The results in Table 4 showed a significant improvement in growth and yield parameters. Plants treated with *P. fluorescens* and Captan had the highest plant height (70.5 cm), number of pods per plant (9.2), seeds per pod (19.5), pod weight (8.2 g) and grain yield (13.43q/ha). The performance likely resulted from reduced pathogen levels, better root health, and nutrient uptake due to *P. fluorescens*, which is known for its plant growth promoting qualities such as phytohormone production and phosphate solubilization (PGPR) (Sahu *et al*, 2018; Sahu *et al*,

**Table 2: Technology used in the study.**

|                       |                                                                                                               |
|-----------------------|---------------------------------------------------------------------------------------------------------------|
| Variety               | AP-3, Pencil                                                                                                  |
| Seed treatment        | <i>Pseudomonas fluorescens</i> , Captan, Carbendazim, Thiram                                                  |
| Sowing Method         | Through seed drill                                                                                            |
| Seed rate and spacing | 112 kg/ha                                                                                                     |
| Spacing               | 30' 10 cm                                                                                                     |
| Time of sowing        | Early sowing (Mid-September to Mid-October)<br>Timely sowing (Mid-September to Mid-October)                   |
| Number of irrigations | 3-4 depending upon the soil type and weather conditions                                                       |
| Fertilizers           | 50kg of N (45 kg Urea) and 62.5 kg P <sub>2</sub> O <sub>5</sub> (387 kg Superphosphate) per ha before sowing |
| Weed control          | Pre-emergence application of Stomp 30 EC (Pendimethalin) @2.5 l/ha within 2 days of sowing.                   |

**Table 3: Effect of seed treatments on wilt disease incidence and severity in peas**

| Treatment                            | Disease Incidence (%) | Disease Severity (%) |
|--------------------------------------|-----------------------|----------------------|
| T1 ( <i>P. fluorescens</i> )         | 8.77 <sup>b</sup>     | 2.4 <sup>b</sup>     |
| T2 (Captan)                          | 10.55 <sup>c</sup>    | 4.0 <sup>c</sup>     |
| T3 ( <i>P. fluorescens</i> + Captan) | 6.33 <sup>a</sup>     | 1.2 <sup>a</sup>     |
| T4 (Control)                         | 12.98 <sup>d</sup>    | 6.2 <sup>f</sup>     |
| T5 (Farmers Practice)                | 11.54 <sup>cd</sup>   | 5.2 <sup>d</sup>     |
| F-value                              | 47.87                 | 425.329              |
| p-value                              | <0.001*               | <0.001*              |

Means with different letters in the superscript differ significantly (p<0.001)

**Table 4: Effect of seed treatment on plant growth and yield parameters in peas**

| Treatment                            | Plant height (cm) | Number of pods/plant | Number of seeds/pod | Pod weight (g)   | Yield (q/ha)       |
|--------------------------------------|-------------------|----------------------|---------------------|------------------|--------------------|
| T1 ( <i>P. fluorescens</i> )         | 63.2 <sup>c</sup> | 8.2 <sup>bc</sup>    | 9.0 <sup>b</sup>    | 7.7 <sup>c</sup> | 13.15 <sup>c</sup> |
| T2 (Captan)                          | 64.0 <sup>c</sup> | 8.5 <sup>c</sup>     | 8.4 <sup>ab</sup>   | 7.0 <sup>b</sup> | 12.54 <sup>b</sup> |
| T3 ( <i>P. fluorescens</i> + Captan) | 70.5 <sup>d</sup> | 9.2 <sup>c</sup>     | 9.5 <sup>b</sup>    | 8.2 <sup>d</sup> | 13.43 <sup>c</sup> |
| T4 (Control)                         | 52.4 <sup>a</sup> | 7.5 <sup>a</sup>     | 7.2 <sup>a</sup>    | 6.1 <sup>a</sup> | 11.57 <sup>a</sup> |
| T5 (Farmers practice)                | 58.5 <sup>b</sup> | 8.0 <sup>ab</sup>    | 8.3 <sup>ab</sup>   | 6.8 <sup>b</sup> | 12.74 <sup>b</sup> |
| F-value                              | 638.98            | 12.375               | 6.5                 | 99.556           | 96.732             |
| p-value                              | <0.001*           | <0.001*              | 0.001               | <0.001*          | <0.001*            |

Means with different letters in the superscript differ significantly (p<0.001)

2022; Kumar *et al*, 2023). The treatments T1 (*P. fluorescens*) and T2 (Captan) also produced better yields than the control, producing 13.15 q/ha and 12.54 q/ha, respectively. However, T1 had a higher seed count per pod, which may indicate that *P. fluorescens* helped in improving reproductive efficiency. Control plots (T4) consistently showed poorer performance, with the lowest plant height of 52.4 cm, pod weight of

6.1 g and yield of 11.57 q/ha, which directly related to higher disease presence. The farmers practice (T5) yielded 12.74 q/ha showed some level of disease suppression but was less effective than the integrated method. This highlighted the potential of combining biocontrol and chemical treatments to enhance plant health and productivity beyond just suppressing pathogens.

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**Table 5: Influence of sowing date on development of disease incidence and yield in peas**

| Sowing Date                  | Treatment                            | Wilt Incidence (%) | Yield (q/ha)        |
|------------------------------|--------------------------------------|--------------------|---------------------|
| Mid-September to Mid-October | T1 ( <i>P. fluorescens</i> )         | 11.66 <sup>b</sup> | 10.44 <sup>c</sup>  |
|                              | T2 (Captan)                          | 12.25 <sup>b</sup> | 10.11 <sup>b</sup>  |
|                              | T3 ( <i>P. fluorescens</i> + Captan) | 8.0 <sup>a</sup>   | 10.96 <sup>d</sup>  |
|                              | T4 (Control)                         | 15.1 <sup>c</sup>  | 9.79 <sup>a</sup>   |
|                              | T5 (Farmers' Practice)               | 14.3 <sup>c</sup>  | 10.32 <sup>bc</sup> |
|                              | F-value                              | 63.311             | 39.124              |
|                              | p-value                              | <0.001*            | <0.001*             |
| Mid-October to Mid-November  | T1 ( <i>P. fluorescens</i> )         | 9.1 <sup>b</sup>   | 11.70 <sup>c</sup>  |
|                              | T2 (Captan)                          | 9.8 <sup>b</sup>   | 11.04 <sup>ab</sup> |
|                              | T3 ( <i>P. fluorescens</i> + Captan) | 7.2 <sup>a</sup>   | 12.78 <sup>d</sup>  |
|                              | T4 (Control)                         | 10.2 <sup>b</sup>  | 10.80 <sup>a</sup>  |
|                              | T5 (Farmers' Practice)               | 9.3 <sup>b</sup>   | 11.37 <sup>c</sup>  |
|                              | F-value                              | 11.188             | 100.687             |
|                              | p-value                              | <0.001*            | <0.001*             |

Means with different letters in the superscript differ significantly (p<0.001)

**Table 6: Monthly weather parameters during September to November during 2023 and 2024 for Tarn Taran district**

| Month     | Max. Temp (°C) | Min. Temp (°C) | Avg. RH (%) | Rainfall (mm) | Rainy Days | Sunshine (hrs/day) | Wind Speed (km/h) | Pressure (mbar) |
|-----------|----------------|----------------|-------------|---------------|------------|--------------------|-------------------|-----------------|
| September | 37.0           | 27.0           | 77.0        | 91.18         | 3.0        | 297.5              | 5.80              | 1003.0          |
| October   | 36.5           | 24.0           | 65.0        | 24.90         | 1.0        | 223.0              | 5.25              | 1009.5          |
| November  | 30.0           | 17.0           | 65.0        | 9.005         | 1.5        | 332.0              | 5.30              | 1014.0          |

### Impact of sowing date on disease progression and yield

The sowing time greatly affected disease development and yield, as shown in Table 5. Pea crop sown from mid-October to mid-November had lower wilt incidence and higher yields across all treatments compared to those sown earlier (mid-September to mid-October). This pattern matched weather data indicated that early sowing coincided with high soil moisture and humidity (81% RH, 116.9 mm of rain in September), conditions that favored *Fusarium* sp. growth (Naseri and Faregh, 2024). The lowest wilt incidence of 7.2% and the highest yield of 12.78 q/ha under late sowing were observed in T3, demonstrating its stability and adaptability. The treatments T1 (*P. fluorescens*) and T2 (Captan) also had lower disease occurrence with late sowing, but yields were slightly lower, possibly due to shorter growth phases caused by cooler November temperatures (min 17°C). These results emphasized the importance of adjusting planting dates as a practice to reduce pathogen exposure during peak periods. Additionally, combining biocontrol seed treatment with optimal sowing times offers a sustainable, low-input way to manage disease (Naseri and Faregh, 2024).

### Influence of climatic conditions on disease development

Weather data for the Tarn Taran district in Table 6 (September-November 2024) showed a gradual temperature decline (Max: 37°C to 31°C; Min: 25°C to 17°C), along with relative humidity (81% to 71%) and rainfall (116.9 mm to 12.1 mm). The high humidity and soil moisture in September, along with elevated temperatures, likely created conditions suitable for *Fusarium* growth and early infection. This aligned with the higher disease incidence found in early sowing treatments (Table 5). As conditions became drier and cooler in October and November 2024, disease pressure reduced, as seen with lower wilt incidence in late-sown treatments. Additionally, longer sunshine hours (from 119 hr/d in October to 352 hr/d in November) and stable atmospheric pressure likely aided crop health and limited pathogen survival. Wind speed showed a slight decrease (from 7 to 5 km/h), suggesting little effect on pathogen spread, since *F. oxysporum* mainly affects soil and roots. Studies showed that *F. oxysporum* thrives best in warm (25-30°C) and humid (80-100%) conditions (Liu *et al*, 2023; Sahu and Dubey, 2025).

## CONCLUSION

This study demonstrated that an integrated seed treatment combining the biocontrol agent *Pseudomonas fluorescens* with the fungicide Captan was the most effective strategy for managing pea wilt. This specific combination significantly reduced disease incidence and severity while maximizing plant growth and overall grain yield. Furthermore, shifting the sowing date to mid-October or mid-November when cooler, drier weather naturally suppresses fungal growth further minimized wilt occurrence. Ultimately, integrating biological control agents with judicious chemical use and optimal planting schedules provides farmers with a highly productive, sustainable, and eco-friendly approach to long-term pea cultivation.

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