# *Pseudomonas fluorescens* as biocontrol agent

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## Abstract

This review paper provides an overview of the potential of *Pseudomonas fluorescens* as a biocontrol agent for plant pathogens. *P. fluorescens* has broad-spectrum antifungal, antibacterial, and antiviral activities due to the production of various secondary metabolites, including antibiotics, siderophores, enzymes, and volatile organic compounds (VOCs). These secondary metabolites can inhibit the growth of plant pathogens, stimulate plant growth, and enhance plant defence mechanisms, thereby improving plant health and productivity. *P. fluorescens'* biocontrol mechanisms can be classified into two categories: direct and indirect mechanisms. Direct mechanisms involve the direct inhibition of plant pathogens by *P. fluorescens*, while indirect mechanisms involve the stimulation of plant growth and enhancement of plant defence mechanisms. *P. fluorescens* has been successfully applied as a biocontrol agent in various crops against a range of plant pathogens.

**Key words** *Pseudomonas fluorescens*, Biocontrol, Antibiotics, Secondary metabolites, Siderophore

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## Introduction

The gram-negative bacteria *Pseudomonas fluorescens* is a member of the *Pseudomonas* genus. This ubiquitous microbe, which has been found in both soil and water, is well known for its capacity to create a range of secondary metabolites with bio controllable properties. Due to its capacity to inhibit the growth of many plant diseases through a variety of methods, *P. fluorescens* has received substantial research as a possible biocontrol agent. This review paper seeks to give a general overview of *P. fluorescens*' potential for biocontrol and the processes behind its biocontrol functions.

## Biocontrol potential of *P. fluorescens*

*P. fluorescens* has been shown to have broad-spectrum antifungal, antibacterial and antiviral activities, making it a promising biocontrol agent for various plant pathogens. The biocontrol potential of *P. fluorescens* is attributed to the production of various secondary metabolites, including antibiotics, siderophores, enzymes, and volatile organic compounds (VOCs) that can inhibit the growth of plant pathogens (Mishra *et al,* 2018). These secondary metabolites can also stimulate plant growth and enhance plant defence mechanisms, thereby improving plant health and productivity.

*P. fluorescens* produces a wide range of antibiotics that can inhibit the growth of various plant pathogens. For example, *P. fluorescens* strain CHAO produces 2,4-diacetylphloroglucinol (DAPG), which has broad-spectrum antifungal activity against a range of plant pathogens (Suresh *et al*, 2022). DAPG inhibits fungal growth by disrupting fungal cell membranes, altering fungal gene expression, and inducing reactive oxygen species (ROS) production in fungi (Lima *et al*, 2021). In addition, *P. fluorescens* strains also produce pyrrolnitrin, phenazine, and pyoluteorin, which have been shown to have antifungal activity against various plant pathogens (Castaldi *et al,* 2021). *P. fluorescens* also produces siderophores, which are small organic molecules that can chelate and sequester iron from the environment. Since iron is an essential nutrient for the growth of many plant pathogens, the production of siderophores by *P. fluorescens* can inhibit the growth of these pathogens by limiting their access to iron (Ahmed and Holmström, 2014). Siderophore production by *P. fluorescens* has been shown to be effective in controlling plant pathogens such as *Fusarium oxysporum* and *Rhizoctonia solani* (Fadhal *et al*, 2019). *P. fluorescens* produces a range of enzymes that can degrade the cell walls and extracellular matrices of plant pathogens, thereby inhibiting their growth and virulence. For example, *P. fluorescens* strain Pf-5 produces chitinases and proteases that can degrade the cell walls of fungal pathogens such as *Botrytis cinerea* and *Sclerotinia sclerotiorum* (Flury *et al*, 2016). *P. fluorescens* also produces exopolysaccharides (EPS) that can inhibit the growth and virulence of plant pathogens.

***Table 1 Pseudomonas fluorescens Characteristics***

| **Characteristic** | **Description** |
|---|---|
| Kingdom | Bacteria |
| Phylum | Proteobacteria |
| Class | Gammaproteobacteria |
| Order | Pseudomonadales |
| Family | Pseudomonadaceae |
| Genus | Pseudomonas |
| Species | Pseudomonas fluorescens |
| Gram Stain | Negative |
| Shape | Rod-shaped |
| Motility | Motile |
| Oxygen Requirement | Aerobic |
| Temperature Range | 4°C to 30°C |
| Optimal Growth pH | 6.0 to 7.0 |
| Flagella | Present |
| Biofilm Formation | Capable of forming biofilms |
| Production of Pyoverdine | Yes |
| Production of Pyocyanin | Yes |
| Nitrate Reduction | Positive |
| Citrate Utilization | Positive |
| Role in Agriculture | Plant growth promotion, biocontrol |
| Pathogenicity | Generally non-pathogenic |
| Environmental Impact | Important in bioremediation processes |

*P. fluorescens* produces a range of volatile organic compounds (VOCs) that can inhibit the growth and virulence of plant pathogens. These VOCs can also induce systemic resistance in plants, thereby enhancing their defence mechanisms against pathogens (Raza *et al*, 2016). For example, *P. fluorescens* strain CHAO produces 2,3-butanediol, which can induce systemic resistance in plants against various pathogens (Meena *et al*, 2020). In addition, *P. fluorescens* produces VOCs such as hydrogen cyanide, which has been shown to have antifungal activity against various plant pathogens.

The biocontrol mechanisms of *P. fluorescens* can be classified into two categories: direct and indirect mechanisms. Direct mechanisms involve the direct inhibition of plant pathogens by *P. fluorescens*. These mechanisms include the production of antibiotics, siderophores, enzymes, and VOCs discussed earlier. The production of these secondary metabolites can inhibit the growth and virulence of various plant pathogens. Indirect mechanisms involve the stimulation of plant growth and enhancement of plant defence mechanisms by *P. fluorescens*. These mechanisms include the production of growth-promoting hormones, such as indole-3-acetic acid (IAA), and the induction of systemic resistance in plants. The production of IAA by *P. fluorescens* can promote plant growth and enhance plant stress tolerance (Chen *et al*, 2017). In addition, *P. fluorescens* can induce systemic resistance in plants by activating various defence-related genes and inducing the production of defence-related compounds such as phytohormones and phenolic compounds (Vleesschauwer *et al,* 2008).

## Advantages and limitations of *P. fluorescens* as a biocontrol agent

The use of *P. fluorescens* as a biocontrol agent has several advantages over chemical pesticides. First, *P. fluorescens* is environmentally friendly and does not have any negative impact on non-target organisms. Second, the use of *P. fluorescens* can reduce the use of chemical pesticides, thereby reducing the risk of pesticide residue accumulation in crops and the environment. Third, *P. fluorescens* can enhance plant growth and productivity, leading to increased crop yields. However, the use of *P. fluorescens* as a biocontrol agent also has some limitations. One of the major limitations is the variability in biocontrol efficacy under different environmental conditions. The biocontrol efficacy of *P. fluorescens* can be affected by factors such as temperature, pH, and moisture content (Ownley *et al*, 2003). In addition, the efficacy of *P. fluorescens* can also be influenced by the presence of other microorganisms in the soil, which can affect its colonization and biocontrol activity (Dandurand and Knudsen, 2002). Another limitation is the cost and availability of commercial formulations of *P. fluorescens*.

## Conclusion

*P. fluorescens* is a promising biocontrol agent that has the potential to control various plant pathogens through a range of mechanisms, including the production of antibiotics, siderophores, enzymes, and VOCs. In addition, *P. fluorescens* can also stimulate plant growth and enhance plant defence mechanisms, leading to improved plant health and productivity. The application of *P. fluorescens* as a biocontrol agent has several advantages over chemical pesticides, including its environmental friendliness, reduction in pesticide residues, and enhancement of crop yields. However, the efficacy of *P. fluorescens* can be influenced by various environmental factors, and its use as a biocontrol agent may require careful consideration of the specific conditions and pathogens present in a given crop.

Further research is needed to better understand the mechanisms underlying the biocontrol activity of *P. fluorescens* and to develop more effective formulations for its application in different crops and environments. In addition, the potential interactions between *P. fluorescens* and other microorganisms in the soil need to be further investigated to better understand the impact of *P. fluorescens* on soil microbial communities and ecosystem functions. Overall, *P. fluorescens* is a promising biocontrol agent that can offer sustainable and effective solutions to plant disease management. Its potential to enhance plant growth and productivity also makes it a valuable tool for sustainable agriculture. With further research and development, *P. fluorescens* has the potential to play an increasingly important role in the transition towards more sustainable and environmentally friendly agricultural practices.

## Conflict of interest

The authors declare that there are no conflicting issues related to this research article.

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