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Multidimensional role of *Pseudomonas*: from biofertilizers to bioremediation and soil ecology to sustainable agriculture

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ABSTRACT

Pseudomonas species are a versatile group of gram-negative bacteria that thrive in diverse ecological niches including soil, water, and plant environments. Their remarkable metabolic flexibility arises from their ability to utilize a plethora of compounds as carbon or energy sources, a feature that has attracted extensive scientific research. These microbial powerhouses are equipped to degrade various pollutants and toxins, thereby positioning them as valuable allies for bioremediation. This detoxification process is not only claim for ecological fame. *Pseudomonas* also exhibits potent biocontrol capabilities, and acts as a guard against plant pathogens. Their control strategies includes a suite of antimicrobial substances, along with an innate ability to outcompete other microbes for nutrients and stimulate plant defense. By harnessing these natural defenders, a range of *Pseudomonas*-based biocontrol agents have been formulated for agriculture. This approach is of growing interest for leveraging *Pseudomonas* strains as biofertilizers to support sustainable farming practices. These bacterial promoters enhance plant growth by boosting nutrient assimilation and by promoting robust root systems. New-generation biofertilizers can support crop yields and fortify soil vitality, thereby offering resilience to abiotic stress. This offers dual benefit of improving agricultural productivity while attenuating the harmful environmental problems caused by chemical fertilizers. Overall, the versatility of *Pseudomonas* species makes them a promising resource, spanning from agricultural enhancement to environmental remediation. As research accelerates, the ambition is to unlock and refine the myriad applications of these extraordinary bacteria.

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