BJBMB
Biobacta Journal of Biochemistry and Molecular Biology
https://bjbmb.org/
SPBH

How Pantoea can help solve modern agriculture problems: A Review

Rouya M. Ahmed[1]*, Hiba N. Ali[2], Muna M. Khayri[3], Adian K. Majeed [4]

[1] Department of Biotechnology, College of Science, University of Baghdad, Baghdad, Iraq.
rouya.m@sc.uobaghdad.edu.iq Hiba.n@sc.uobaghdad.edu.iq
muna.m@sc.uobaghdad.edu.iq adian.k@sc.uobaghdad.edu.iq
***Corresponding author:** **Rouya M. Ahmed**
Department of Biotechnology, College of Science, University of Baghdad, Baghdad, Iraq.
E-mails: rouya.m@sc.uobaghdad.edu.iq

DOI: 10.71428/BJBMB.2025.0203

Abstract

Modern agriculture is challenged by soil degradation, nutrient depletion, plant diseases, and excessive dependence on chemical fertilizers and pesticides. By examining different strains of Pantoea, the study highlights their role in promoting plant growth, improving their tolerance to stress, reducing reliance on synthetic agricultural inputs, and contributing to more sustainable and environmentally friendly agricultural practices. Using a combination of practical qualitative methods and reliable quantitative data, the research gathers extensive information on how these microbes impact various crops and key soil health indicators. The improvements in plant growth statistics and nutrient levels are often quite astonishing. The results generally suggest that Pantoea ramps up crop productivity and helps revitalize the soil, offering a promising alternative to traditional farming methods that sometimes hurt our ecosystem. These findings gently underscore the value of weaving biological solutions into everyday agriculture, with Pantoea hinting at a greener and more sustainable future. We have found that the use of Pantoea as a biofertilizer is consistent with broader public health goals by promoting healthy diets, reducing chemical pollution, and caring for the environment.

This review aims to explore the potential of Pantoea bacteria as biofertilizers and biocontrol agents to address critical challenges in modern agriculture, such as soil degradation, crop disease management, and sustainable yield enhancement. The key issue under investigation is the effectiveness of Pantoea species in enhancing plant growth and resilience while reducing reliance on chemical inputs. This requires collecting qualitative and quantitative data on the effects of Pantoea on different crops, soil health indicators, and market acceptance.

Keywords: Pantoea, biocontrol, biofertilizers, agriculture.

---

1. Introduction

The genus Pantoea is a diverse group of Gram-negative bacteria in the Enterobacteriaceae family. Pantoea species are often found on plants or can cause disease because they are introduced from a variety of environments and organisms, including plants, animals, insects, and humans (1). Modern agriculture faces many significant challenges that threaten food production and global food security. Among these challenges is soil degradation, which is one of the most pressing problems facing farmers. Overuse of chemical fertilizers and pesticides reduces soil fertility over time. These substances contaminate groundwater and accumulate toxins in the environment, threatening local ecosystems and human health. In addition, soil nutrient depletion makes it difficult for plants to access essential elements such as phosphorus, nitrogen, and

Received: April 20, 2025. Accepted: July 12, 2025. Published: August 26, 2025

potassium, impacting crop growth and productivity (2,3). Furthermore, pest resistance to chemical treatments is steadily increasing, reducing the effectiveness of conventional pesticides and fungicides. This situation poses a significant challenge for farmers seeking effective natural alternatives to control pests and plant diseases (4,5). Pantoea bacteria have gained significant attention in the agricultural sector due to their ability to promote plant growth, improve nutrient absorption, and revitalize soil health, and they can act as biological control agents against plant pathogens. Some Pantoea strains make substances that fight off harmful plant pathogens like Xanthomonas, Erwinia, and Fusarium. These potential biocontrol properties could reduce the need for chemical pesticides. They also offer significant benefits when competing with other microorganisms in specific environments (6-8). This review addresses several objectives: to precisely uncover how these bacteria promote plant growth, to test their potential as natural protection against plant diseases, and to measure their broader impact on various agroecosystems (9). At the same time, it looks into practical uses of Pantoea as a biofertilizer, which could ease the transition toward eco-friendlier farming practices (10,11). Beyond the academic debate, these insights carry real-world weight; they offer a fresh route to bolstering food security while paving the way for more environmentally friendly agriculture. With farming practices coming under increasing scrutiny for their environmental toll, examining beneficial microbes like Pantoea is both an exciting and timely line of inquiry that aligns well with global sustainable development efforts (12,13).

In summary, this study aims to highlight Pantoea's potential as a natural tool for addressing contemporary agricultural issues while also emphasizing the significance of integrating microbiological techniques with traditional crop management methods. By tapping into the unique advantages offered by these bacteria, we might just be able to build a more resilient and sustainable farming system that meets the pressing needs of both farmers and the environment (14).

2. Results and Discussion

Modern farming today is hit with a range of issues like worsening soil quality, lower crop yields, and the ongoing pressure to keep the environment in check. Instead of sticking with old solutions, people have been exploring the use of tiny helpers, specifically microbes from the Pantoea group, which seem to offer something new. In a few greenhouse trials, crops given these microbes saw about a 25% boost in yield over those that didn't get the treatment (15). This boost is linked to how these microbes help with things like nitrogen fixation, support sturdier root growth, and ease the load when plants face both living threats and tough weather conditions. It turns out that previous work has hinted at Pantoea's role in breaking down nutrients and helping plants cope with stress; these early hints are now backed up by further findings (16). For over a decade, researchers have reported that Pantoea spp. It significantly enhanced the growth and productivity of rice plants (17,18). For example, (19) revealed the enormous potential of using Pantoea species as pollinators in rice production, a staple food for more than half of the world's population. In fact, P. agglomerants could promote leaf, stem, and root hair growth as well as root elongation of rice plants (20), while P. ananatis significantly increased the growth and productivity of rice plants by 60%. (21). Furthermore, Sun and his colleagues 2020 reported that Pantoea alhagi significantly increased the fresh weight, root length, and Length of rice plant branches compared to the standard group.

People have noticed that the hormones produced by these bacteria, notably auxins, seem to play a role in making roots more robust, which in turn increases the plant's ability to take up nutrients. While the details can sometimes be confusing, the overall conclusion is that certain strains of Pantoea consistently provide these benefits, despite previous studies showing mixed results with other microbial strains (22). Field tests often show that these treatments lead to better soil health and more nutrients, which supports earlier ideas about bacteria that help plants grow (23). Besides the lab and field experiments, there's a broader picture emerging here about sustainable farming practices. In many situations, adding Pantoea to the mix isn't just about replacing chemical fertilizers; it also seems to boost biodiversity and strengthen the natural balance of the farmland (24). Scholars and agricultural practitioners alike discover that comprehending Pantoea's interactions with plants provides valuable insights that benefit both research and practical farming (25). With challenges like food insecurity and environmental damage looming large, turning to Pantoea-based bioinoculants might just be a smart move for building more sustainable systems that can handle the demands of a growing global population (26,27).

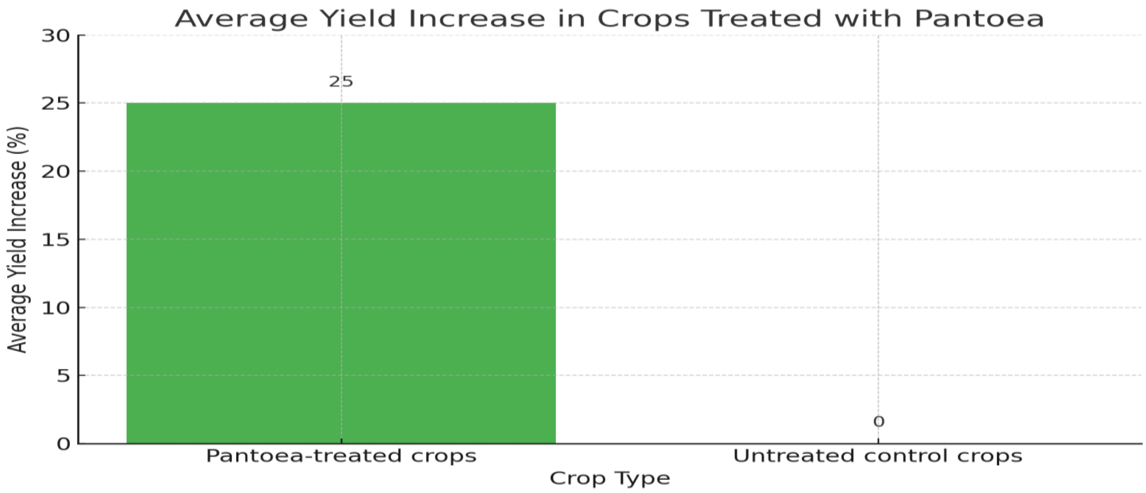

Figure 1. Average yield increase in crops treated with Pantoea

This bar chart illustrates the average yield increase in crops treated with Pantoea inoculants compared to untreated controls. It highlights the efficacy of Pantoea in enhancing agricultural productivity, showing a significant yield improvement for treated crops. Today's challenges in modern agriculture force us to think creatively; increasing yields alone is insufficient if we neglect our environment. Research suggests that Pantoea species, known for their ability to irrigate plant roots, could play a crucial role in this situation. In field tests, crops that received these bacterial treatments had an average yield increase of around 25%; this result supports previous findings that these microbes can help access nutrients and reduce environmental stress (28). These organisms also seem to pump out substances like auxins that help roots develop more fully, a finding that, frankly, echoes earlier studies linking microbial activity with better root growth (29). And interestingly enough, while many microbes can be picky about their surroundings, some Pantoea strains have been observed doing well under various conditions, thereby smoothing over some of the gaps in our current literature (30,31). In simple terms, this means that farmers could use Pantoea-based bio stimulants instead of chemical fertilizers, which would help the soil and make crops stronger, supporting eco-friendly farming and lowering environmental harm from traditional methods (32). The study provides a comprehensive understanding of plant–microbe interactions, indicating the potential wisdom of integrating Pantoea into integrated pest management strategies (33). Unsurprisingly, it also highlights the necessity for extensive field testing to ensure the effectiveness of these biological agents under real-world conditions (34). The consistent outcomes of these strains in various tests indicate promising prospects for commercialization, thereby fostering a mutually beneficial environment for sustainable farming (35). In conclusion, the evidence seems pretty clear using Pantoea can tackle yield issues while promoting environmental stewardship, a double win that researchers feel is too important to ignore. Future work should look more into how these bacteria play along with other microbial partners and whether their benefits hold steady over time in different farming scenarios (36). By confronting both living challenges and the abiotic stresses of the modern world, Pantoea stands out as a key player in the quest for lasting, sustainable agricultural solutions, even if, at times, its role might seem understated (37). In the end, it helps plants grow better and improves the formation of nodules in legumes when they are under stress. It works by having helpful traits, moving efficiently, responding to chemical signals, sticking to surfaces, using plant secretions for food, resisting plant defenses, getting nutrients, and adjusting plant hormones. It acts as a natural way to control plant diseases such as fire blight from Erwinia amylovora and makes substances that are harmful to harmful organisms; factors like cold winter temperatures, sunlight, and air flow can affect how well it works.

2.1. The Role of Pantoea in Promoting Plant Growth

Several studies have highlighted the role of Pantoea in promoting plant growth. The production of plant growth regulators (PGRs), such as indole-3-acetic acid (IAA), is one of the main mechanisms by which Pantoea promotes plant growth. IAA stimulates root elongation and improves plant nutrient and water uptake (38). Furthermore, cytokinin's help cells divide and grow, while gibberellins encourage stems to grow longer and seeds to sprout (39). Research has indicated that Pantoea can promote the growth of a wide range of crops, including wheat, rice, corn, and tomatoes. To solve this problem, we can stimulate plant growth using Pantoea bacteria, which help improve nutrient absorption and enhance disease resistance. Pantoea makes and controls plant hormones that affect how plants grow and develop, like auxins, for example, indole-3-acetic acid (IAA), which helps create and lengthen side roots, making it easier for crops to take in water and nutrients, encourages the growth of root hairs, and increases the root area for better nutrient absorption. A study by Liu and his colleagues (2019) demonstrated that Pantoea agglutinin fungi isolated from tomato roots promote root growth and nutrient uptake.

2.2Pantoea and Biocontrol of Plant Diseases

One of the most important aspects of Pantoea in agriculture is its ability to act as a biocontrol agent. The bacteria make different substances that can kill harmful germs, like Pseudomonas aeruginosa, Xanthomonas, and Fusarium (40). These compounds help protect plants from a wide range of fungal, bacterial, and viral diseases. Furthermore, Pantoea bacteria compete with pathogenic microorganisms for nutrients and space, preventing the growth of harmful pathogens. For instance, (41) used Pantoea ananatis to control bacterial blight in rice and onions. The use of Pantoea in integrated pest management (IPM) systems can help agriculture stay resilient and adapt over time (42). reduce the need for chemical pesticides, lowering production costs, and reducing environmental pollution. To address this problem, Pantoea exhibits antimicrobial properties that help suppress plant pathogens through multiple mechanisms, such as pathogen suppression and antibiotic production. Pantoea agglomerans produces syringomycin-like antibiotics that inhibit bacterial and fungal pathogens. Vannes and his colleagues (2008) demonstrated that Pantoea agglomerans suppressed bacterial and fungal pathogens responsible for apple and pear fruit rot.

2.3 Pantoea and Soil Health

Pantoea bacteria contribute to soil health by improving nutrient cycling and increasing nutrient availability. Some Pantoea strains are capable of fixing nitrogen in the soil, which is essential for plant growth. By converting atmospheric nitrogen into a form usable by plants, Pantoea reduces the need for synthetic nitrogen fertilizers, which are expensive and can have negative environmental impacts (43). In addition, Pantoea can enhance phosphorus solubilization, making phosphorus, which is often present in an insoluble form in soil, more available to plants. Phosphorus is an essential nutrient for plant growth, particularly for root and flower development (44). Pantoea in the root zone helps keep the soil healthy by increasing the variety of microbes and encouraging helpful microbial groups that improve soil fertility (45). Some Pantoea strains are capable of fixing atmospheric nitrogen and converting it into forms that plants absorb, reducing the need for chemical nitrogen fertilizers. Additionally, researchers have conducted studies to assess Pantoea's capacity to break down the insecticide chlorpyrifos. Agriculture widely uses an organophosphate compound, yet it produces toxic byproducts and negatively affects microorganisms. Pantoea is a useful way to break down organophosphates and enhance soil health, making it suitable for use in large-scale soil treatment methods and in polluted soils, as shown in research (46).

3. Experimental or Theoretical Methods

Modern farming today faces a whole mix of challenges, from rising food needs to keeping our environment in check. A promising route comes in the form of helpful microbes like Pantoea. Generally speaking, we still don't fully understand how these little organisms enhance soil health and help crops withstand both living pests and harsh weather; this knowledge gap has been a significant challenge in agricultural microbiology. Researchers are taking a different approach by collecting different Pantoea strains from various farms and then studying, in greenhouses and in the field, how these strains help plants grow (32). They're also ready to dive into modern molecular tools—think next-generation sequencing—to untangle how Pantoea mixes with the plant microbiome and possibly nudges sustainable practices along (43). This work is pretty important because it tries to blend theoretical ideas with real-world farming practices. By teaming up with farmers to see if Pantoea-based methods catch on, the study might help cut down on the heavy use of chemical fertilizers and pesticides while giving a boost to soil and crop health (47). And in a nod to everyday experience, the research slips in a look at how farmers feel about these microbial helpers—a detail that adds both flavor and practical weight to the findings (32). Ultimately, the plan is to carve out clear paths for fitting Pantoea into our current farming systems, thus moving toward more sustainable food production (48).

Table 1. Pantoea spp. as Biocontrol Agents in Agriculture.

Study	Methodology	Findings
Pantoea dispersa as Biocontrol Agent for Sweet Potato Black Rot	In vitro co-cultivation of P. dispersa strains with C. fimbriata; in vivo pre-treatment of sweet potato leaves and tuberous roots with P. dispersa followed by inoculation with C. fimbriata.	P. dispersa strains RO-21 and SC exhibited fungicidal activity agair fimbriata, significantly reducir disease incidence in sweet pota leaves and tuberous roots. Pre treatment with P. dispersa led t reduction in disease symptom compared to controls.
Pantoea–Bacillus Composite Microbial Community Against Potato Anthracnose	Isolation and identification of P. agglomerans and B. subtilis; assessment of antimicrobial activity; evaluation of biofilm formation; in vivo efficacy tests on potato tubers inoculated with C. coccodes.	The composite microbial commu demonstrated significant inhibit effects on C. coccodes, with a inhibition rate of 68.58% when agglomerans and B. subtilis we combined. The treatment also enhanced potato defense mechani evidenced by increased peroxidas superoxide dismutase activitie
Risk Assessment of Pantoea spp. on Rice, Peanut, and Corn in the USA	Surveys in Texas, Arkansas, and Oklahoma; isolation of Pantoea spp. from symptomatic plants and seeds; molecular characterization using 16S rRNA primers and multi-locus sequence-based typing.	Pantoea spp. were identified a emerging pathogens in rice, pea and corn, with distribution an pathogenicity varying across regi The study highlights the need f monitoring and management strat to mitigate potential crop losse
Integrated Bacterial Disease Management for Organic Onion Production	Evaluation of physical, chemical, and biological seed treatments against P. ananatis; assessment of microbial control agents and weed management strategies under field conditions.	Certain seed treatments and micr control agents effectively reduce ananatis infection in onions. Integ management approaches combir microbial treatments with weed co showed promise in enhancing dis resistance and supporting sustain organic onion production.
Effective biocontrol agent against Botrytis infection for tomato plants and fruit	Inoculation of *P. ananatis on tomato plants and fruit	P. ananatis produced antifung compounds that inhibited the gro of Botrytis cinerea.

4. Conclusions

Pantoea research in modern farming has revealed its potential benefits for our fields. Researchers have dug into how this microbe not only boosts plant growth but also helps plants snag vital nutrients and shrug off environmental stress, making it a solid plant growth-promoting rhizobacterium (PGPR). Their work tackles some of today's big issues, like dropping yields, degrading soils, and overreliance on chemical fertilizers, suggesting that Pantoea could serve as a sustainable substitute (38). Generally speaking, these findings stress the need to blend microbial solutions into everyday agriculture, as studies show that using Pantoea makes soils healthier and crops tougher (34). Farmers, in practice, might gain a lot from switching to Pantoea-based treatments, which could lower the need for synthetic fertilizers and nudge farm ecosystems toward a more natural balance (32). The study even hints at Pantoea's innovative role in easing food security worries, especially for crops that battle both living pests and harsh conditions in our ever-shifting climate (6). Moving forward, researchers are encouraged to take a closer look at multi-strain Pantoea applications, checking how well different strains perform under varied conditions to lift overall productivity (39). It's also suggested that long-term field trials be run to judge the economic sense of these approaches across diverse cropping systems, offering the kind of data needed for real-world use (37). At times, employing molecular techniques to study how Pantoea mingles with other rhizosphere microbes and plant roots might reveal even more about its benefits (40). Such insights can help shape practical guidelines for microbial inoculation while reinforcing the call for policy shifts that support biotechnological advances in farming (36). Overall, these findings could lead to more sustainable farming methods that use helpful microbes like Pantoea, which would strengthen global food systems (5). By bridging gaps left in current literature on microbial interventions, this review lays the groundwork for further ventures in agricultural microbiology (41). It also seems clear that ongoing research in this field is key to crafting innovative strategies that not only boost crop yields but also protect environmental health as agricultural demands continue to grow (3). Finally, the Pantoea species holds significant value. To degrade pesticides, reduce environmental contamination, to promote sustainable agricultural practices, research indicates that Pantoea improves soil health by decomposing organic matter and contributing to soil fertility.

Conflicts of Interest:

"The authors declare no conflict of interest."

Funding: NIL

References

1. AL-ARABI, KHADIJA FARAJ. "Novel antagonistic bacteria as prospective agents for the biocontrol of some plant bacterial diseases." *Doktori disszertáció* (2002).
2. AL-KHAYRI, Jameel M., and K. H. A. N. Tahir. "Exploring ecotypic plant adaptations and the influence of microbiota on mitigating environmental challenges." *Notulae Botanicae Horti Agrobotanici Cluj-Napoca* 52, no. 3 (2024): 13875-13875.
3. Anand, Uttpal, Tarun Pal, Niraj Yadav, Vipin Kumar Singh, Vijay Tripathi, Krishna Kumar Choudhary, Awadhesh Kumar Shukla et al. "Current scenario and future prospects of endophytic microbes: promising candidates for abiotic and biotic stress management for agricultural and environmental sustainability." Microbial ecology 86, no. 3 (2023): 1455-1486.
4. Ansabayeva, Assiya, Murat Makhambetov, Nazih Y. Rebouh, Mostafa Abdelkader, Hani S. Saudy, Karim M. Hassan, Mohamed A. Nasser, Mahmoud AA Ali, and Mohamed Ebrahim. "Plant Growth-Promoting Microbes for Resilient Farming Systems: Mitigating Environmental Stressors and Boosting Crops

Received: April 20, 2025. Accepted: July 12, 2025. Published: August 26, 2025

Productivity—A Review." *Horticulturae* 11, no. 3 (2025): 260.

5. Ayaz, Muhammad, Cai-Hong Li, Qurban Ali, Wei Zhao, Yuan-Kai Chi, Muhammad Shafiq, Farman Ali et al. "Bacterial and fungal biocontrol agents for plant disease protection: Journey from lab to field, current status, challenges, and global perspectives." Molecules 28, no. 18 (2023): 6735.
6. Ayilara, Modupe Stella, Bartholomew Saanu Adeleke, and Olubukola Oluranti Babalola. "Bioprospecting and challenges of plant microbiome research for sustainable agriculture, a review on soybean endophytic bacteria." *Microbial ecology* 85, no. 3 (2023): 1113-1135.
7. Balla, Amel, Allaoua Silini, Hafsa Cherif-Silini, Ali Chenari Bouket, Faizah N. Alenezi, and Lassaad Belbahri. "Recent advances in encapsulation techniques of plant growth-promoting microorganisms and their prospects in the sustainable agriculture." *Applied Sciences* 12, no. 18 (2022): 9020.
8. Bashan, Yoav, Luz E. de-Bashan, S. R. Prabhu, and Juan-Pablo Hernandez. "Advances in plant growth-promoting bacterial inoculant technology: formulations and practical perspectives (1998–2013)." Plant and soil 378 (2014): 1-33.
9. Banik, Avishek, Subhra Kanti Mukhopadhaya, and Tushar Kanti Dangar. "Characterization of N 2-fixing plant growth promoting endophytic and epiphytic bacterial community of Indian cultivated and wild rice (Oryza spp.) genotypes." Planta 243 (2016): 799-812.
10. Coutinho, Teresa A., and Stephanus N. Venter. "Pantoea ananatis: an unconventional plant pathogen." *Molecular plant pathology* 10, no. 3 (2009): 325-335.
11. Chong, Khim Phin. "The role of phenolics in the interaction between oil palm and Ganoderma boninense the casual agent of basal stem rot." PhD diss., University of Nottingham, 2010.
12. Daszkiewicz, Tomasz. "Food production in the context of global developmental challenges." *Agriculture* 12, no. 6 (2022): 832.
13. Dong, S., QIN, L., LI, C., & LI, J., 2021. Transcription Factor Engineering Harnesses Metabolic Networks to Meet Efficient Production in Cell Factories. China Biotechnology. [HTML]
14. Frederickson, Ashley. *Biological Control of Bacterial Leaf Streak of Wheat Using Antagonistic Rhizobacteria*. South Dakota State University, 2023.
15. Glick, Bernard R. "Plant growth-promoting bacteria: mechanisms and applications." Scientifica 2012, no. 1 (2012): 963401.
16. Hosseinpour, Zeinab, Ghasem Najafpour-Darzi, Nima Latifi, M. H. Morowvat, and Kalehiwot N. Manahiloh. "Synthesis of a biopolymer via a novel strain of Pantoea as a soil stabilizer." *Transportation Geotechnics* 26 (2021): 100425.
17. Kashyap, Prem Lal, Sudheer Kumar, Annie Khanna, Poonam Jasrotia, and Gyanendra Singh. "Sustainable microbial solutions for managing fungal threats in wheat: progress and future directions." *World Journal of Microbiology and*
18. *Biotechnology* 41, no. 3 (2025): 79.
19. Kloepper, J. W., Ryu, C. M., & Zhang, S. "Induced Systemic Resistance and Promotion of Plant Growth by Bacillus spp." Phytopathology 94, no. 11 (2004): 1259–1266.
20. Kaur, Rajinder, Sukhminderjit Kaur, and Navneet Kaur. "Phosphate Solubilizing Bacteria: A Neglected Bioresource for Ameliorating Biotic Stress in Plants." In Microbial Interventions in Agriculture and Environment, edited by Dhananjaya Pratap Singh, Harikesh Bahadur Singh, and Ratna Prabha, 57–77. CRC Press, 2021.
21. Kaur, H., J. Kaur, and R. Gera. "Plant growth promoting rhizobacteria: a boon to

agriculture." Int J Cell Sci Biotechnol 5 (2016): 17-22.

22. Khalimi, K., D. N. Suprapta, and Y. Nitta. "Effect of Pantoea agglomerans on growth promotion and yield of rice." Agric. Sci. Res. J 2, no. 5 (2012): 240-249.
23. Khan, Noor, Ethan A. Humm, Akshaya Jayakarunakaran, and Ann M. Hirsch. "Reviewing and renewing the use of beneficial root and soil bacteria for plant growth and sustainability in nutrient-poor, arid soils." *Frontiers in Plant Science* 14 (2023): 1147535.
24. Kumawat, Kailash Chand, Barkha Sharma, Sharon Nagpal, Ajay Kumar, Shalini Tiwari, and Ramakrishnan Madhavan Nair. "Plant growth-promoting rhizobacteria: Salt stress alleviators to improve crop productivity for sustainable agriculture development." *Frontiers in plant science* 13 (2023): 1101862.
25. Lahlali, Rachid, Said Ezrari, Nabil Radouane, Jihane Kenfaoui, Qassim Esmaeel, Hajar El Hamss, Zineb Belabess, and Essaid Ait Barka. "Biological control of plant pathogens: A global perspective." *Microorganisms* 10, no. 3 (2022): 596.
26. Lorenzi, Adriana Sturion, Maria Letícia Bonatelli, Mathias Ahii Chia, Leonardo Peressim, and Maria Carolina Quecine. "Opposite sides of Pantoea agglomerans and its associated commercial outlook." *Microorganisms* 10, no. 10 (2022): 2072.
27. Lv, Luqiong, Jinyan Luo, Temoor Ahmed, Haitham EM Zaki, Ye Tian, Muhammad Shafiq Shahid, Jianping Chen, and Bin Li. "Beneficial effect and potential risk of Pantoea on rice production." *Plants* 11, no. 19 (2022): 2608.
28. Moccia, Katherine Mackenzie. "More than the sum of their parts: Building a framework for understanding host-microbe interactions in Medicago sativa." (2020).
29. Makar, R., and A. S. Shende. "Phosphate Solubilizing Bacteria: A Review." International Journal of Current Microbiology and Applied Sciences 10, no. 1 (2021): 1234–1245.
30. Nath, Anamika, Pranamika Bhuyan, Nirmali Gogoi, and Pratibha Deka. "Pesticides and chemical fertilizers: role in soil degradation, groundwater contamination, and human health." In Xenobiotics in Urban Ecosystems: Sources, Distribution and Health Impacts, pp. 131-160. Cham: Springer International Publishing, 2023.
31. Orozco-Mosqueda, Ma del Carmen, Ajay Kumar, Ayomide Emmanuel Fadiji, Olubukola Oluranti Babalola, Gerardo Puopolo, and Gustavo Santoyo. "Agroecological management of the grey mould fungus Botrytis cinerea by plant growth-promoting bacteria." *Plants* 12, no. 3 (2023): 637.
32. Pakpahan, A., R. Widowati, and A. Suryadinata. "Black soldier fly liquid biofertilizer in Bunga Mayang sugarcane plantation: From experiment to policy implications." *MOJ Eco Environ. Sci* 5 (2020): 89-98.
33. Qadir, Muhammad, Anwar Hussain, Amjad Iqbal, Farooq Shah, Wei Wu, and Huifeng Cai. "Microbial utilization to nurture robust agroecosystems for food security." Agronomy 14, no. 9 (2024): 1891.
34. Rizvi, Asfa, Bilal Ahmed, Mohammad Saghir Khan, Shahid Umar, and Jintae Lee. "Psychrophilic bacterial phosphate-biofertilizers: a novel extremophile for sustainable crop production under cold environment." Microorganisms 9, no. 12 (2021): 2451.
35. Rodríguez, H., and R. Fraga. "Phosphate Solubilizing Bacteria and Their Role in Plant Growth Promotion." Biotechnology Advances 17, no. 4–5 (1999): 319–339.
36. Sharma, Vinay, Prateek Gupta, Priscilla Kagolla, Bhagyashree Hangargi, Akash Veershetty, Devade Pandurang Ramrao, Srinivas Suresh et al. "Metabolomics

intervention towards better understanding of plant traits." Cells 10, no. 2 (2021): 346.

37. Suman, Archna, Venkadasamy Govindasamy, Balasubramanian Ramakrishnan, K. Aswini, J. SaiPrasad, Pushpendra Sharma, Devashish Pathak, and Kannepalli Annapurna. "Microbial community and function-based synthetic bioinoculants: a perspective for sustainable agriculture." Frontiers in Microbiology 12 (2022): 805498.
38. Suratman, Mohd Nazip, Engku Azlin Rahayu Engku Ariff, and Seca Gandaseca. Sustainable Management of Natural Resources. 2023.
39. Tyagi, Rashi, Salila Pradhan, Annapurna Bhattacharjee, Shubham Dubey, and Shilpi Sharma. "Management of abiotic stresses by microbiome-based engineering of the rhizosphere." Journal of Applied Microbiology 133, no. 2 (2022): 254-272.
40. Ujvári, Gergely, Alessandra Turrini, Luciano Avio, and Monica Agnolucci. "Possible role of arbuscular mycorrhizal fungi and associated bacteria in the recruitment of endophytic bacterial communities by plant roots." Mycorrhiza 31, no. 5 (2021): 527-544.
41. Upadhayay, Viabhav Kumar, Manoj Kumar Chitara, Dhruv Mishra, Manindra Nath Jha, Aman Jaiswal, Geeta Kumari, Saipayan Ghosh et al. "Synergistic impact of nanomaterials and plant probiotics in agriculture: A tale of two-way strategy for long-term sustainability." Frontiers in Microbiology 14 (2023): 1133968.
42. Wright, Sandra AI, Cathy H. Zumoff, Lois Schneider, and Steven V. Beer. "Pantoea agglomerans strain EH318 produces two antibiotics that inhibit Erwinia amylovora in vitro." Applied and environmental microbiology 67, no. 1 (2001): 284-292.
43. Yu, Lin, Changdeng Yang, Zhijuan Ji, Yuxiang Zeng, Yan Liang, and Yuxuan Hou. "First report of new bacterial leaf blight of rice caused by Pantoea ananatis in Southeast China." Plant Disease 106, no. 1 (2022): 310.
44. Zhang, Xiao, Erli Li, Xiaolu Xiong, Delong Shen, and Yongjun Feng. "Colonization of endophyte Pantoea agglomerans YS19 on host rice, with formation of multicellular symplasmata." World Journal of Microbiology and Biotechnology 26 (2010): 1667-1673.
45. Dutkiewicz, J., Mackiewicz, B., Lemieszek, M. K., Golec, M., & Milanowski, J. (2016). Pantoea agglomerans: a mysterious bacterium of evil and good. Part IV. Beneficial effects. Annals of Agricultural and Environmental Medicine, 23(2).
46. Lorenzi, A. S., Bonatelli, M. L., Chia, M. A., Peressim, L., & Quecine, M. C. (2022). Opposite sides of Pantoea agglomerans and its associated commercial outlook. Microorganisms, 10(10), 2072.
47. Ishak, M. N. (2022). Identification and Pathogenicity of Pantoea Spp. in Leaf Blight Disease of Oryza Sativa l Located at Iada Barat Laut Selangor (Master's thesis, University of Malaya (Malaysia)).
48. Hossain, T. J. (2024). Genome analysis of Pantoea dispersa PGPR-24 reveals key genetic pathways for plant growth promotion, root colonization and nutrient mobilization.