Annual Methodological Archive Research Review
http://amresearchreview.com/index.php/Journal/about
Volume 3, Issue 11 (2025)

Online ISSN 3007-3197
Print ISSN 3007-3189

http://amresearchreview.com/index.php/Journal/about

Multifaceted Ecological and Functional Roles of Bacterial Endophytes in Plant–Soil–Microbe Systems

Fahad Said Khan

Department of Eastern Medicine, University of Poonch Rawalakot, Azad Kasimr, Pakistan

Imtiaz Mahmood Tahir

College of Allied Health Professionals, Government College University Faisalabad Pakistan

Muhammad Mudassar

College of Allied Health Professionals, Government College University Faisalabad, Pakistan

Mudassar Khan

Health Services Academy, Islamabad Pakistan

Hira Abbasi

Department of Agronomy, University of Poonch Rawalakot Azad Kashmir, Pakistan

Saima Siddique

Department of Eastern Medicine, Government College University Faisalabad Pakistan

Ghazala Shaheen

University College of Conventional Medicine, The Islamia University of Bahawalpur, Pakistan

Shamaila Kausar

Department of Microbiology, University of Lahore, Pakistan

Rimsha Zainab

Department of Botany, Shaheed Benazir Bhutto Women University, Peshawar, Pakistan

Akif Saeed Ch

Director Medical Services and Research Hope Family Clinic & Rehab Faisalabad Pakistan

Rabia Anum

Institute of Business Management, Karachi Pakistan

Annual Methodological Archive Research Review
http://amresearchreview.com/index.php/Journal/about
Volume 3, Issue 11 (2025)

Online ISSN 3007-3197
Print ISSN 3007-3189

http://amresearchreview.com/index.php/Journal/about

Nimra Shahid

Department of Eastern Medicine, Government College University Faisalabad Pakistan

Mustansar Abbas

Department of Eastern Medicine, Government College University Faisalabad Pakistan

Taufiq Ahmad

Department of Eastern Medicine, University of Balochistan, Quetta, Pakistan

Fatima Ilyas

Department of Eastern Medicine, Government College University, Faislabad.

Hamad Ahmed

Department of Eastern Medicine, Government College University, Faisalabad, Pakistan

Muhammad Amir

Medical Research Institute, Southwest University, Beibei, Chongqing 400715, China

Muhammad Irshad

Department of Chemistry, University of Kotli, Azad Jammu and Kashmir, Pakistan

Tabish Ali Virk

Department of Botany , Faculty of Life Sciences, Government College University, Faislabad

Tahir Hafeez

CEO/Founder Tahir Holistic Healing and Research Institute, Mandi Bahauddin, Pakistan

Arsalan Abid

Department of Nursing and Community Health, Faculty of Public Health, Glasgow Caledonian University, Glasgow

Syed Adnan Rahmat

School of Public Health, Hebei Medical University, Shijiazhuang, China

Jawad Zaheer

Department of Pharmacy, University of Poonch Rawalakot Azad Kashmir, Pakistan

Annual Methodological Archive Research Review
http://amresearchreview.com/index.php/Journal/about
Volume 3, Issue 11 (2025)

Online ISSN 3007-3197
Print ISSN 3007-3189

http://amresearchreview.com/index.php/Journal/about

Tahani R. K. Bsharat

An-Najah National University, Faculty of Humanities – Department of Teaching English as a Foreign-language(TEFL).

Muhammad Akram*

Department of Eastern Eastern Medicine, Government College University, Faislabad. Corresponding Author Email: muhammadakram@gcuf.edu.pk

ABSTRACT

Bacterial endophytes are an additional category of microorganisms that play significant roles in plant-soil-microbe interactions by colonizing plant tissues without causing disease. Among their many ecological activities are growth promotion through direct and indirect mechanisms, disease resistance, stress tolerance, and nutrient absorption. Endophytic colonization requires intricate processes, including tissue-specific dispersion, root surface adhesion, and endocytosis-like infiltration. Quorum sensing, chemical signaling, and genetic communication between the microbe and its host coordinate these processes. These interactions enhance plant growth through stimulating the synthesis of bioactive metabolites, phosphate solubilization, nitrogen fixation, and hormone control. Additionally, endophytes support biocontrol by preventing phytopathogens through the production of antimicrobial substances, niche competition, and induced systemic resistance. Mutations and genetic adaptations within endophytic populations additionally improve host specificity, environmental compatibility, and evolutionary co-dependence with plants. Endophytes have immediate effects on microbial diversity, rhizosphere chemistry, and nutrient cycling in soil ecosystems, all of which support sustained agricultural productivity. Acquiring information about the distribution, functional genes, and ecological behavior of bacterial endophytes presents potentially intriguing opportunities for biofertilizers, biopesticides, and climate-resilient crops. This abstract illustrates the integrated activities of endophytic bacteria as crucial regulators of plant health and environmental balance.

Keywords: Bacterial Endophytes, Plant–Microbe Interactions, Biocontrol Mechanisms, Sustainable Agriculture, Rhizosphere Ecology.

Annual Methodological Archive Research Review
http://amresearchreview.com/index.php/Journal/about
Volume 3, Issue 11 (2025)

Online ISSN 3007-3197
Print ISSN 3007-3189

http://amresearchreview.com/index.php/Journal/about

Introduction

Endophytes in three distinct sections of the plant survival system spread. Endophytes do not have to generate vegetative seeds and can proliferate through seeds rather than atmospheric roots. Endophytes are active and free-living in the soil, but they use disease management to regulate crops when space is provided. After one month, it is common to have more than one potato rootstock. (Shahzad, R., 2018) It is observed that greater endophyte concentrations in the carrot crown relative to the metaxylem were attributable to increased photosynthesis in the crown region, which provided more resources for bigger and ecto-toe Communities. Although clinical investigations have identified plants and made the endophytes distribution system apparent, the regular sequence of the endophytes distribution system remains unknown, which is a potential field of creative study. Endogenous transcription in the host plant has remained a mystery, and studies like these can help uncover potential internal plant alterations(Verma, S.K., Kharwar, et al., 2019).

The significance of germs in plant development, for example, is well known, as it is impossible to reproduce species without bacteria. Rhizobia is also an example of a broader topic of phytobacteria. Microbes benefit from weeds because they provide more nutrients, whereas plants benefit from microbes because they stimulate growth and reduce stress (Kumar et al., 2018). This idea has been developed in the field of agricultural engineering to eliminate all traces from the roots without harming the plant material (Umesha et al., 2018). Vegetarians rely solely on grass plants for development and survival, and they can transmit their genes to other plants or from a vector if necessary. Indoor trees with a long lifespan have a level of habitat outside the tree. Bacterial infections can be classified as endophytes in extreme situations since they are typically the type of virus that is seeded. Consider bringing more plants to the river and beyond to generate additional nutrients, such as Ks. Indoor testing for fastidiosa is still possible. Taking into account the kind of plants in the house, and the fact that dangerous bacteria will not be employed. Another basis for this research is the finding of inner life, which focuses on the inner cells that make up human relationships (Siegel et al., 2020). Endophytes have a two-fold life cycle that affects both the plant and its surroundings. Many microbes that flourish in plants can survive in this environment. However, there are alternative

Annual Methodological Archive Research Review
http://amresearchreview.com/index.php/Journal/about
Volume 3, Issue 11 (2025)

Online ISSN 3007-3197
Print ISSN 3007-3189
http://amresearchreview.com/index.php/Journal/about

avenues for the virus to enter the plant (Pierroz et al., 2021).

Equipment

The reversal of chemical processes from root exudates, for example, is one element that leads to root control competition. Because these responses vary widely across plant species, many alternative strategies are likely to have evolved during plant-microbe interactions. The nutritional value of bacteria may be evident in these interactions, and in each situation, chemical interactions for a given organism may influence the reaction (Weiland-Bräuer et al., 2021). The movement's origins may be traced back to colonization. Moving active regions and root areas to a suitable indoor environment can boost their metabolism and create healthier conditions, allowing for improved nutrition, competition, and development. A sensor in the environment responds to symptoms, enabling the genetic expression necessary for dominance (Kurosaki et al., 2019).

Furthermore, phenotypic variations in standard retention and essential root control characteristics, such as pyoverdin, cyanide, and exoprotease synthesis, can be partially explained by differences in two-stage control systems. Qualified endophytes will add to the solid root around the roots to reach the root canal, which is the site of root growth, root advice, and/or pests caused by disease or prognosis. It was later found in *Azoarcus* sp. Repeated movements of BH72 are complex, leading to regulatory deficiencies. PilT Locus is involved in the migration of bacteria associated with plants. The capacity of these items to control *Azoarcus* sp. is demonstrated by the degradation of PilA and PilT, which are necessary for hair cutting and thinning and, individually, reduce bacterial motility (Shyi et al., 2019).

Genetic Communication with the Host

Plants and birds have interacted over millions of years, allowing bacteria to produce a range of chemicals that aid in their control of the plants (Shi et al., 2018). Endophytic gene alterations in bacteria have been seen in large-scale investigations. Genetic examination of the fungus *Verrucomicrobia virus*, for example, revealed a reduced genetic complexity compared to other bacteria. This genome reduction in endosymbiotic mandor bacteria provides a mechanism for host receptors to perform various tasks, which may be explained by the significant development of the identification system in internal plant cells. The internal trees of their house are

Annual Methodological Archive Research Review
http://amresearchreview.com/index.php/Journal/about
Volume 3, Issue 11 (2025)

Online ISSN 3007-3197
Print ISSN 3007-3189
http://amresearchreview.com/index.php/Journal/about

accessed via two distinct systems: cross-linking and active (Mnich et al., 2020). The most common entry point into subterranean areas is at the location of external roots or pests caused by harmful bacteria, where penetration is achieved by injecting endophytic bacteria into plant cells via their flagella and by producing specific chemicals that aid digestion. Exopolysaccharides, cell wall-destroying enzymes, and various other quorum-sensing compounds are among these metabolites. The presence of flagella in endophytic cells may boost their efficacy, allowing bacteria to move by chemotaxis and follow-up in plants when flagella-deficient mutants were suppressed and controlled. The natural bacteria possessing a full flagellum iron could effectively limit wheat root function (Dudeja et al., 2021).

Cellulase, xylanase, cell hydrolase, endoglucanase, and metagenomics of numerous houseplant bacteria have all been found as genetic factors that can substitute wall enzymes. Endoglucanases, for example, are critical for Azoarcus sp. and the control of rice roots, in which Bradyrhizobium sp. secretes pectin, which is required for their entrance and transformation into intracellular cavities on the same plant species (Fernandez-Llamosas et al., 2021). Pathogenic spores may take advantage of several interactions, including epiphysis and feeding. It is interesting to note that it is present in several crop varieties, including rice, wheat, tomatoes, maize, strawberries, beans, and numerous wild plants. Bacterial interaction-associated metabolites internal flora of alien endophyte colonization of endophytic bacteria is influenced by a variety of circumstances, beginning with the nuclei of various signalling cells between endophytes and their hosts. These cells may modulate the cell cycle and the expression of microbes, thereby affecting bacterial relationships. Flavonoids are one of the most well-known chemical attractants, particularly on legume roots and rhizomes. Non-stem endophytic cells, such as root and rice domination by the endophytic bacteria *Serratia* sp., benefit from these chemicals as well (Kisiriko et al., 2021).

Plant Diseases and Endophyte Mutations: A Better Understanding

Plant processes are well understood when it comes to plant-pathogen interactions, but resistance to viral symptoms has not been explored (Paudel et al., 2018). Bacterial houseplants must first protect the plant to control the fabric's surface and/or entry. Unlike plant pathogens, bacterial endophytes can produce

Annual Methodological Archive Research Review
http://amresearchreview.com/index.php/Journal/about
Volume 3, Issue 11 (2025)

Online ISSN 3007-3197
Print ISSN 3007-3189
http://amresearchreview.com/index.php/Journal/about

mitochondrial membranes to suppress plant defense responses. When houseplants converse with one another, however, these signals may differ. The protected MAMP standards can differ across plants of two distinct species, one pathogenic and the other non-pathogenic. *Bacillus subtilis*, a beneficial bacterium, produces subtilomycin, a peptide antibiotic that binds to a self-made target, avoiding strong plant interactions that could be due to a lack of knowledge about the virus (Teixeira et al., 2019).

Stimulates the Secondary Plant Metabolism

As a result of the contact, secondary fruit and micro-symbiosis may change. Several methods can be used to bring about these modifications. The cell may affect the host's metabolism by encouraging a protective pathway, or the plant could regulate the cell's metabolism to control its input and growth. Furthermore, various sections of the same organism can exist in plants and bacteria, or the host can break down bacterial secretions. However, secondary metabolism often mediates interactions between the caregiver and the endosymbiont (Chenicheri et al., 2020). Other secondary metabolites found in the Arabidopsis plant related to Pseudomonas fluorescens SS101 were phytoalexin chamalexin and glucosinolate. The levels of benzooxanin in corn-related plants changed dramatically. Pseudomonas putida KT2440 inoculated at the root alters the benzoxanenone system three days after inoculation and triggers the first response in maize via the JA and ABA pathways, according to research (Wang et al., 2020).

Biocontrol

Plant development is aided by biocontrol, which helps protect against plant diseases. There may be a variety of interventions, such as releasing carriers or administering antibiotics. By competing with pathogens for nutrients, iron acids like buculin and salicylic acid, as well as iron chelate, can help prevent illness. When fruit and vegetable extracts from *Ralstonia solanacearum* were obtained from DAPG, for example, wild eggplant of Ralstonia solanacearum showed a decrease of up to 70%. Given the relevance of the PGPBE family plan in improving health outcomes, a slew of research has examined its use as a vaccine, notably in plants (Datta et al., 2021).

Annual Methodological Archive Research Review
http://amresearchreview.com/index.php/Journal/about
Volume 3, Issue 11 (2025)

Online ISSN 3007-3197
Print ISSN 3007-3189
http://amresearchreview.com/index.php/Journal/about

Soil

Due to variations in ideal racial environmental circumstances, two big and local indoor agricultural production systems can determine endophytic systems. When managing weeds and improving plant health, these variables must be considered. By detecting microorganisms residing on land, the high temperatures and environment provide external control over the endophyte community. These variables might spread histological studies, potentially changing the plant-plant connection. Endophytes in weeds can be formed when latitude, altitude, temperature, and precipitation interact. *Agrobacterium tumefaciens* and *Sinorhizobium meliloti* endophytes, for example, are common in regions with high rainfall and annual conditions in sweet rhizomes. However, Paenibacillus is more frequent in locations with moderate rainfall and low rainfall (Verhelst et al., 2021).

In terms of precipitation, soil type, and soil content, the inner cells of the red and rootless bladder may be well divided within the research region and across various locations. Local adaptation conditions may influence the deployment of endophyte indoor systems (Hamzazai et al., 2020). Frankia spp. is a genus of Frankia spp. When comparing cities developed in aquatic environments to those in lowlands, it was found that the largest cities of trees grew in the lowlands. Endophytic regions change depending on the original place, according to studies evaluating numerous genetic markers cultivated elsewhere. Although plants play an essential role in microbial soil mixing, their roots have a significant impact on this community, according to the scientists; the plants may be ascribed to speculation that already exists on land. Plant species and soil types can interact. The community of microbial endophytes is influenced by the Fi Eli in which the plant develops. These findings were also investigated in a recent study examining dense endophytes linked to the *Bacillus thuringiensis* gene, which are partially soil-derived but not genetic material and have been found to alter the composition of native endophytes (Mashiane et al., 2018).

In addition, land issues related to traditional agriculture may affect the resilience of inland communities. Harvesting apple orchards from the soil can induce soil erosion, alter neighbouring soils, and increase the habitat of microorganisms, all of which are detrimental to soil conservation. Cultivation of numerous trees in the

Annual Methodological Archive Research Review
http://amresearchreview.com/index.php/Journal/about
Volume 3, Issue 11 (2025)

Online ISSN 3007-3197
Print ISSN 3007-3189
http://amresearchreview.com/index.php/Journal/about

upper home than in carrots used in agriculture, where wood waste is eliminated, is both harmful and beneficial. Endophytes from a 3-year potato crop, for example, show greater anti-fungal capabilities than those separated from a shorter sowing period of the seeding process (Tapfuma et al., 2018).

Plants

The inner material's lifespan is inextricably linked to that of other fruits, and they are a combination of plant, plant life, and health. Some elements of endophonic dominance might be challenging, such as weeding; however, weeding affects endophytes both before and after. As a consequence, several tree species grow on the same soil, yielding distinct inside species. Root canal conflicts, bacterial acceptance/selection/patterns of input, or the kind of root secret that draws the plant in may all be important. Its roots affect root-zone microbial populations, which govern the quantity and diversity of diseases that control host plants (Mukherjee et al., 2019). Chemicals exuded by plant roots can reveal beneficial microorganisms and help bacteria select suitable hosts (Guerrieri et al., 2019).

Indoor crop spikes are prevalent in vetiver during early development. Plant physiology and hormonal changes can be affected by changes in endophyte populations. It remains a mystery how endophyte populations evolve over time, much as other plant species do. As a result, long-term transplanting has been employed to limit the reproduction of plant-specific diseases. At the same time, comparable methods can also be used to prevent the dominance of fungal endophytes. Researchers may be able to create systems that minimise infections while increasing total expenses by improving our understanding of the drivers of native endophytes (Rabiey et al., 2019).

Microbes

Endophytes that can access roots via chemical interactions, kill other types of microorganisms to be planted in roots, express accumulated genes and seek to infiltrate plant tissue and its neighbours, refuse acceptance by host plants, and preserve niches in plant tissue are all required for roots. In any radical system of administration, demonstrations of microbial-microbial and microbial implants are required. Endophyte roots may differ from atmospheric roots, suggesting that root material can select and support microorganisms (Harman et al., 2019).

Annual Methodological Archive Research Review
http://amresearchreview.com/index.php/Journal/about
Volume 3, Issue 11 (2025)

Online ISSN 3007-3197
Print ISSN 3007-3189

http://amresearchreview.com/index.php/Journal/about

Conclusion

This work investigated the role of endophytic genetic cells in promoting plant health. The researchers also want to call attention to the significance of viral endophytic cells in ISR function, particularly for timely safety. With low-cost wood, renowned rotating lamp makers offer unique protection. Although research in this area is growing, the processes underlying endotrophic plants' binding activity against biotic stress are still being investigated, owing to functional differences across plant species and the fact that some species have a niche. This research section presently has several open topics. One is the potential to investigate a single endophyte or a mixture of endophytes and their resistance to biotic stress; the other is the discovery of a problem that could lead to the spread of different illnesses. This is a three-way interaction study that enhances the experimental procedure by identifying plant linkages as sites of microbe accumulation. Because the agricultural system supports recovery and experimentation, while the non-agricultural system supports the analysis of population growth disparities, it is advised that the two techniques be combined in a single research project. Overall, this research indicates that pathogen populations, as well as internal cells that show growth associated with plant growth and development, change over time. The bacterial community discovered is tiny compared to the entire bacterial population, yet it contains hundreds of distinct bacteria. As a result, the plant is likely to act as an excellent "filter" for living organisms, selecting effective and efficient endophytes.

Thus, from the beginning of the root canal of a developing plant, growing in cities that appear to have been transferred to mature trees, the methods by which germs might create and sustain, as well as their appearance, are not entirely known. Surprisingly, there is substantial evidence in the literature on the mechanism of action of plant extracts in the phytosphere, leading to increased bacterial contact. It is critical to stress the significance of the curriculum and program.

Refrences

Chenicheri, S., & Komeri, R. (2020). Integration of dental implants: molecular interplay and microbial transit at tissue–material interface. In *Biointegration of Medical Implant Materials* (pp. 221-243). Woodhead Publishing.

Online ISSN 3007-3197
Print ISSN 3007-3189
http://amresearchreview.com/index.php/Journal/about

Datta, S. C. (2021). Weed Plant Act as Vaccine against Plant and COVID-19 Diseases: Enriched Agriculture Health Development Socioeconomy Sciences Technology Communication Application. *BR Nahata Smriti Sansthan International Journal of Phramaceutical Sciences & Clinical Research*, *1*(1).

Dudeja, S. S., Suneja-Madan, P., Paul, M., Maheswari, R., & Kothe, E. (2021). Bacterial endophytes: molecular interactions with their hosts. *Journal of basic microbiology*, *61*(6), 475-505.

Fernandez-Llamosas, H., Diaz, E., & Carmona, M. (2021). Motility, adhesion and c-di-GMP influence the endophytic colonization of rice by Azoarcus sp. CIB. *Microorganisms*, *9*(3), 554.

Guerrieri, A., Dong, L., & Bouwmeester, H. J. (2019). Role and exploitation of underground chemical signaling in plants. *Pest management science*, *75*(9), 2455-2463.

Hamzazai, A. (2020). *Factors shaping endophyte communities associated with selected cultivated plants in Arizona* (Doctoral dissertation, The University of Arizona).

Harman, G. E., & Uphoff, N. (2019). Symbiotic root-endophytic soil microbes improve crop productivity and provide environmental benefits. *Scientifica*, *2019*(1), 9106395.

Kisiriko, M., Anastasiadi, M., Terry, L. A., Yasri, A., Beale, M. H., & Ward, J. L. (2021). Phenolics from medicinal and aromatic plants: Characterisation and potential as biostimulants and bioprotectants. *Molecules*, *26*(21), 6343.

Kumar, A., & Verma, J. P. (2018). The role of microbes to improve crop productivity and soil health. In *Ecological wisdom inspired restoration engineering* (pp. 249-265). Singapore: Springer Singapore.

Kurosaki, T., Popp, M. W., & Maquat, L. E. (2019). Quality and quantity control of gene expression by nonsense-mediated mRNA decay. *Nature reviews Molecular cell biology*, *20*(7), 406-420.

Mashiane, A. R., Adeleke, R. A., Bezuidenhout, C. C., & Chirima, G. J. (2018). Community composition and functions of endophytic bacteria of Bt maize. *South African Journal of Science*, *114*(7-8), 88-97.

Mnich, E., Bjarnholt, N., Eudes, A., Harholt, J., Holland, C., Jørgensen, B., ... &

Annual Methodological Archive Research Review
http://amresearchreview.com/index.php/Journal/about
Volume 3, Issue 11 (2025)

Online ISSN 3007-3197
Print ISSN 3007-3189
http://amresearchreview.com/index.php/Journal/about

Ulvskov, P. (2020). Phenolic cross-links: building and de-constructing the plant cell wall. *Natural product reports*, *37*(7), 919-961.

Mukherjee, D. (2019). Microbial interventions in soil and plant health for improving crop efficiency. In *Microbial Interventions in Agriculture and Environment: Volume 3: Soil and Crop Health Management* (pp. 17-47). Singapore: Springer Singapore.

Paudel, D. B., & Sanfaçon, H. (2018). Exploring the diversity of mechanisms associated with plant tolerance to virus infection. *Frontiers in plant science*, *9*, 1575.

Pierroz, G. (2021). *Foundational Research Towards Plant Microbiome Engineering Capability* (Doctoral dissertation, University of California, Berkeley).

Rabiey, M., Hailey, L. E., Roy, S. R., Grenz, K., Al-Zadjali, M. A., Barrett, G. A., & Jackson, R. W. (2019). Endophytes vs tree pathogens and pests: can they be used as biological control agents to improve tree health?. *European Journal of Plant Pathology*, *155*(3), 711-729.

Shahzad, R., Khan, A. L., Bilal, S., Asaf, S., & Lee, I. J. (2018). What is there in seeds? Vertically transmitted endophytic resources for sustainable improvement in plant growth. *Frontiers in plant science*, *9*, 24.

Shi, Y. M., & Bode, H. B. (2018). Chemical language and warfare of bacterial natural products in bacteria–nematode–insect interactions. *Natural product reports*, *35*(4), 309-335.

Shyi, C. T. C. (2019). *An Investigation of Benzene-degrading, Nitrate-reducing Bacterial Cultures: Strategies for Countering Nitrite Buildup and for Assaying Anaerobic Enzymatic Activation of the Benzene Ring*. University of Toronto (Canada).

Siegel, D. J. (2020). *The developing mind: How relationships and the brain interact to shape who we are*. Guilford Publications.

Tapfuma, K. I. (2018). *Isolation and identification of fungal endophytes from Datura stramonium and in vitro cytotoxic evaluation of their secondary metabolites on UMG87 glioblastoma cells* (Master's thesis, University of Johannesburg (South Africa)).

Teixeira, P. J. P., Colaianni, N. R., Fitzpatrick, C. R., & Dangl, J. L. (2019). Beyond pathogens: microbiota interactions with the plant immune system. *Current opinion in microbiology*, *49*, 7-17.

Online ISSN 3007-3197
Print ISSN 3007-3189

Umesha, S., Singh, P. K., & Singh, R. P. (2018). Microbial biotechnology and sustainable agriculture. In *Biotechnology for sustainable agriculture* (pp. 185-205). Woodhead Publishing.

Verhelst, E. (2021). *The characterization of nodule bacteria from legumes of Northeast Thailand* (Doctoral dissertation, Ghent University).

Verma, S. K., Kharwar, R. N., & White, J. F. (2019). The role of seed-vectored endophytes in seedling development and establishment. *Symbiosis*, *78*(2), 107-113.

Wang, R., Wang, H. L., Tang, R. P., Sun, M. Y., Chen, T. M., Duan, X. C., ... & Wang, S. Y. (2020). Pseudomonas putida represses JA-and SA-mediated defense pathways in rice and promotes an alternative defense mechanism possibly through ABA signaling. *Plants*, *9*(12), 1641.

Weiland-Bräuer, N. (2021). Friends or foes—microbial interactions in nature. *Biology*, *10*(6), 496.