Journal of Applied Biology & Biotechnology Vol. 13(1), pp. i-iii, Jan-Feb, 2025
Available online at http://www.jabonline.in
DOI: 10.7324/JABB.2024.1729492181

Endophytic microbiomes for agricultural sustainability

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EDITORIAL

Plants have been known to interact with different biotic and abiotic agents existing in the environment which forms a beneficial mutualism. Among various agents, the interaction of plants with microbes is one of the significant interactions that have global implications too. Microbes interact with belowground (rhizosphere), aboveground (phyllosphere), and internal (endophyte) parts of plants and these interactions have a different significant role in each other's survival. Among all endophytic interactions are known to provide greater benefits to its host, especially in stressed (biotic and abiotic) conditions. The endophytic microbes are known to interact with each of the single plants existing on the earth and they are present within the whole plant even seeds. Various microbial groups such as archaea, bacteria, and fungi are recognized as endophytes. Microbial species belonging to phyla *Euryarchaeota Acidobacteria, Acidobacteriota, Bacteroidota, Deinococcus–thermus, Bacillota, Pseudomonadota, Verrucomicrobia, Ascomycota, Basidiomycota,* and *Mucoromycota* were found as endophytic microbiota so far. Endophytic microbes protect plants by various mechanisms such as N2- fixation, siderophores production, phosphorus solubilization, phytohormones production (auxin, cytokinin, and gibberellins), ammonia, and hydrogen cyanide production.

Plants are inhabited internally by different group microbial communities including archaeal, bacterial, and fungal [1]. These microbiomes show lifestyles inside tissue and play important roles in plant fitness, growth, development, and diversification (Fig. 1). The distribution of the endophytic microbiome inside plants is mostly determined by how efficiently the plants distribute their resources along with how well they can colonize emerging regions [2]. As chemical substances produced from plant roots interact, the root endophyte community mediates the exchange of molecules. This interaction emphasizes the growth and health of plants. In specific conditions, endophytic microorganisms mitigate the adverse effects of high temperatures, droughts, nutritional deficiencies, and phytopathogenic infestations on crops [3]. Endophytes have become increasingly employed as bioinoculants in agriculture, replacing conventional techniques for improving crops and preventing plant diseases. This assists in helping crops resist phytopathogens and thus encourages healthy plant growth [4]. The use of bioformulation (biofertilizer, biopesticides, and bioherbicides) that are sourced from microbial endophytes proved beneficial for agricultural management [5]. In addition to being a cost-effective and environmentally responsible way to increase the delivery of nutrients to plants and shield them from a variety of abiotic and biotic stressors, endophytic bacteria may also be able to increase crop yield and sustainably maintain the overall health of the soil [6].

Plants including trees, climbers, creepers, herbs, and shrubs growing in diverse habitats are home to a huge diversity of endophytic microbes which was ratified by various published reports. In a report, bacterial species belonging to genera *Stenotrophomonas, Serratia, Pseudomonas*, *Pantoea*, and *Bacillus*, were reported from the wild pistachio trees [7]. In another investigation, from *Quercus*, bacterial genera *Bacillus*, *Pseudomonas*, and *Stenotrophomonas* were reported [8]. In an investigation, different species of *Bacillus, Methylobacterium, Paenibacillus, Pseudomonas, Rhizobium*, and *Rummeliibacillus* were reported from forestall, medicinal, and ornamental tree *Handroanthus impetiginosus* [9]. Microbial species belonging to genera *Bacillus, Escherichia*, and *Providencia* were reported from a climber annual herb *Gloriosa superba*. [10]. In a similar report, from *Pyrenacantha volubilis* endophytic bacterial strains *Bacillus subtilis* and *B. amyloliquefaciens* were reported [11]. In a report, bacterial species belonging to phyla *Actinobacteria*, *Proteobacteria*, and *Firmicutes* were reported from Poaceae plants in which *Arthrobacter*, *Bacillus,* and *Rhizobium*, were the most abundant species [12].

Streptomyces spp., an endophyte of sorghum was reported for improving the plant growth of rice, wheat, and sorghum as the bacterium was able to inhibit the plant pathogens like *Magnaporthe oryzae* and *Rhizoctonia solani via* the production of ammonia [13]. In a report, *Gordonia terrae* from mangrove propagules were reported for promoting mangrove propagule germination and the plant growth of rice plants under salt-stressed conditions [14]. In another report, an endophytic bacterium of wheat, *Acinetobacter guillouiae* exhibiting multifarious attributes of plant growth promoting (PGP) such as fixation of nitrogen, phosphorus solubilization, and indole-3-acetic acid (IAA) production, siderophores and hydrogen cyanide, was reported for enhancing the growth of wheat plants [15]. In a similar report, endophytic nitrogen-fixing bacteria, *Pseudomonas brenneri*, *Pantoea agglomerans*, and *Ewingella americana* were reported for enhancing the PGP of maize plants upon inoculation [16]. In another investigation, the endophytic bacterium, *Rahnella* sp. from *Aegilops kotschyi* was reported for exhibiting N2-fixation ability, and its inoculation on host plants was found to promote the growth and physiological parameters [17]. Endophytic bacterium of seed, *Bacillus*

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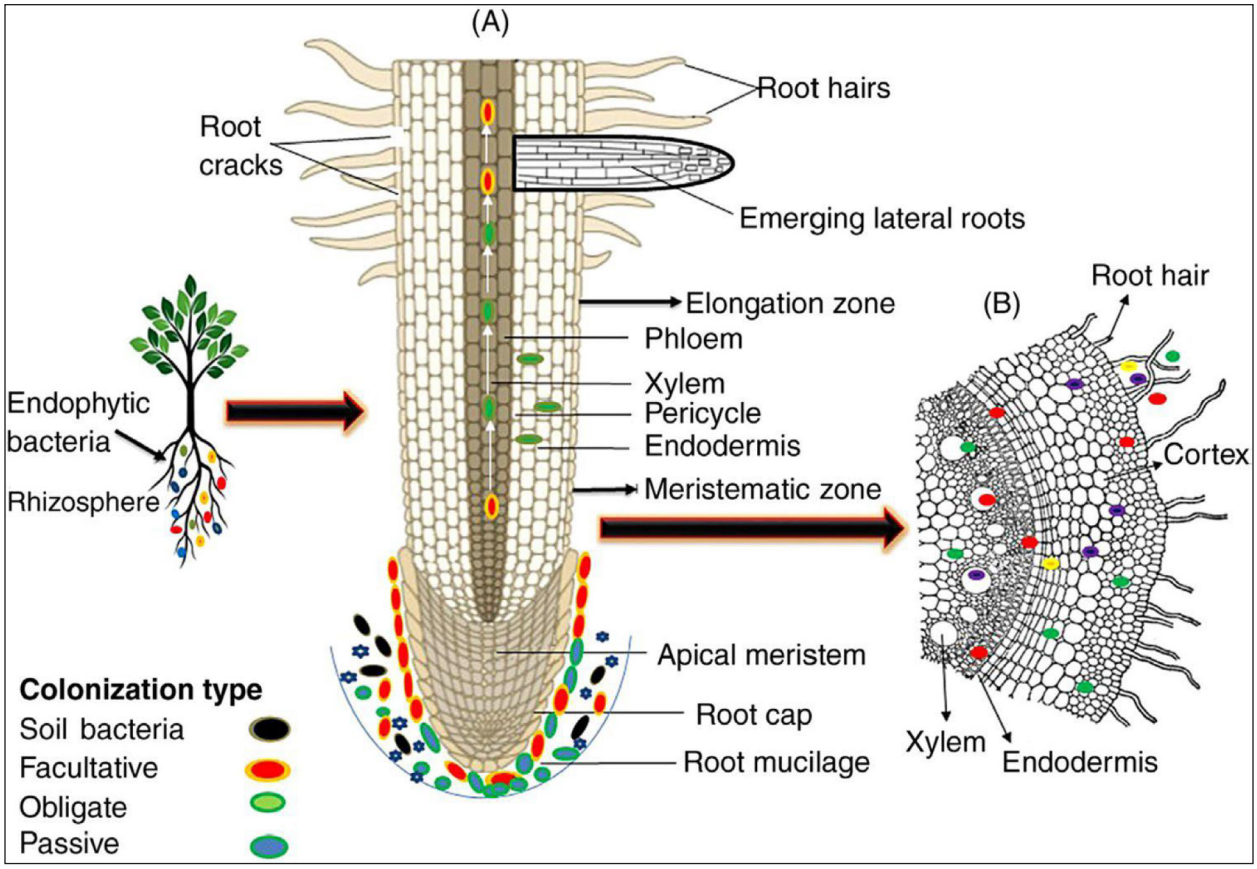

Figure 1. A schematic representation of endophytic microbiomes and their interaction with plant. Adapted with permission from Kumar *et al.* [18].

velezensis was reported for having siderophores, cell wall degrading enzymes such as protease and cellulases, and IAA production, nitrogenase activity which inhibits the growth of phytopathogen *Rhizoctonia solani.* The inoculation of *B. velezensis* was reported to promote the germination of wheat seeds and promotes growth of seedlings [19]. In another investigation, *Enterobacter cloacae* subsp. *cloacae* and *Penicillium citrinum,* the endophytes of drought-resistant plant *Calotropis procera* were reported for producing IAA, solubilizing phosphorus, and exhibiting 1-aminocyclopropane-1-carboxylic acid deaminase activity and their inoculation on host plants growing under non-irrigated and irrigated condition were found to enhance the growth plants [20]. The recognized mechanisms have unraveled various applications of endophytic microbiomes in the field of agriculture, which have received considerable limelight among plant biologists, ecologists, microbial biotechnologists, evolutionary biologists, and agronomists [21]. The endosymbiont of plants could be used as bioinoculants for pest-pathogen control and nutrient supplementation and its usage will not impart any type of harmful effect [22].

The scientific field of endophytes has received more attention lately owing to their ability to stimulate plant growth via a variety of mechanisms and functions. Numerous endophyte species that have been identified from a wide variety of agricultural plants demonstrate their significant contribution to phytoremediation, nutrient restoration, and plant physiological balance. In the last several years, the field of endophytes has drawn a lot of researchers. The requirement for inexpensive, environmentally benign inputs and self-sufficient operations is well recognized for sustainable agriculture. The main impact regarding the application of endophytes in agriculture is a notable decrease in the haphazard use of agrochemicals such as pesticides, inorganic fertilizers, and other synthetic chemicals. A successful use of endophytes would improve the sustainability and environmental friendliness of crop production. Ultimately, and probably most important of all, further study would be needed to have a deeper comprehension of associative and endophyte ecology to make greater use of these endo-microbiomes. Biologists have been searching for sustainable inputs for a very long period to reduce the indiscriminate usage of hazardous synthetic agrochemicals that have ruined the sustainability of agriculture, so endophytic microbes could be used in the future.

ACKNOWLEDGMENTS

The author is grateful to the Department of Genetics, Plant Breeding and Biotechnology, Dr. Khem Singh Gill Akal College of Agriculture, Eternal University, Baru Sahib, and Eternal University Funded Project "To establish culture collection of bacteria/fungi/algae/cyanobacteria from hilly areas" Reference number: EU/VCO/72/36 for providing the facilities support, to undertake the investigation.

CONFLICTS OF INTEREST

The author declares that there are no conflicts of interest.

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How to cite this article:
Yadav AN. Endophytic microbiomes for agricultural sustainability. J Appl Biol Biotech 2025; 13(1):i–iii.