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EDITORIAL PAPER

Current trends in plant science and plant microbiome for sustainability

Ajar Nath Yadav[1,2*], Tanvir Kaur[3], Joginder Singh[4] & Abd El-Latif Hesham[5]

[1]Department of Genetics, Plant Breeding and Biotechnology, Dr. Khem Singh Gill Akal College of Agriculture, Eternal University, Baru Sahib, Sirmaur 173 101, Himachal Pradesh, India

[2]Research and Innovation Cell, Rayat Bahra University, Mohali 140 301, Punjab, India

[3]Department of Biotechnology, Graphic Era Deemed to Be University, Dehradun 248 002, Uttarakhand, India

[4]Department of Botany, Nagaland University, Lumami 798 627, Nagaland, India

[5]Department of Food Sciences, Faculty of Agriculture, Beni-Suef University, Beni-Suef, 62521, Egypt

*Correspondence email - ajarbiotech@gmail.com

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Editorial

Plants, the covering more than 55 % of the ice-free part of earth is one of the most essential organisms. Since ancient times, plants have been worshiped and used for various important needs of humans like food, medicinal and for manufacture of various goods required in daily lives. Plants can also be one of the major reasons of the existence of humans on the earth as it provides most essential oxygen to humans. Over millions of plants classified as trees, shrubs, subshrubs and herbs, have been studied and found that millions of species exist on the earth various parts including forests. The plants species can be harmful and which can heal the diseases which could be categorized into medicinal plants. Medicinal plants known to produce various bioactive compounds and secondary metabolites which have different properties like antimicrobial, anti-inflammatory and anti-cancerous which makes these plants more economically important. As plants are very important, humans have researched more and found that all plant species existing on plants coexist in association with uncountable microbial species around, within and on them. Microbes associated with plants can be both beneficial and harmful to plants. The beneficial microbes help the plants to exist on the earth and protects them from various stressed exerted on plants from environment i.e. biotic (pests and pathogens and abiotic (drought, cold, time temperature, salinity, flooding conditions and nutrients deficient stress). Microbes associated with plants also increase the capability of photosynthesis and maintains the functioning of the internal cellular structure. Plant associated microbes can be bacteria, fungi and archaea which collectively plants important functions in the plants lives by undergoing various plants growth promoting mechanisms such as fixation of nitrogen, nutrients solubilization, production of siderophores, antibiotic, hydrolytic enzymes, phytohormones production (auxin, cytokinin, gibberellins, ethylene, abscisic acid) and 1-aminocyclopropane-1 -carboxylate- or ACC-deaminase activity.

The plants microbes have been known to have wide range applications in the different such as agriculture, environment and pharmaceutical industries. In agriculture these microbes can be utilized as biopesticides and biofertilizers to protect the plant from pest and to enhance the plant growth by supplying nutrients and phytohormones. The environmental sector, which have been destroyed by anthropogenic activities of humans, microbes and plants collectively remediate by reducing the pollutions and contaminants. Microbes and plants both have been known to produce various bioactive compounds which may have medicinal properties that can cure various diseases, so these compounds can be made as medicines in the pharmaceutical industries. All these applications of plant microbes are getting hype because all these are sustainable methods which ease the life the humans. As microbes associated with plants are applauded widely, so their discovery is much needed, so different techniques have been applied including omics sciences. Omics tools are of different types which helps in the identification of microbes which cultivations. The present editorial provides the insight of the plant sciences; plant associated microbes and their role in various sectors for sustainability.

Plants are known to harbour by plants from in and around. According to the parts of the plants, microbes have categorized into three different types i.e. epiphytic, endophytic and rhizospheric microbes (Fig. 1). Epiphytic microbes are those which harbour the above ground surface of the plants and these microbes protect plants from UV radiations and pathogens. Diversity of microbes including bacteria, fungi, algae and archaea have been reported from this region belonging to genera *Alternaria, Aspergillus, Aureobasidium, Azotobacter, Bacillus*, *Beijerinckia, Bipolaris, Camelliae, Cercospora, Cladosporium, Dioszegia, Enterobacter, Hyphomicrobium, Klebsiella, Kocuria, Methylibium, Methylobacterium, Moesziomyces, Mucor, Nostoc, Phoma, Pantoea, Penicillium, Pseudomonas, Stenotrophomonas, Venturia* and *Wardomyces* (1). The endophytic microbes are

those which found in the internal tissues of the plants. *Alternaria, Arthrobacter*, *Bacillus, Bradyrhizobium, Herbaspirillum, Escherichia, Fusarium, Pantoea, Pseudomonas, Paenibacillus, Rhizobium, Stenotrophomonas* and *Serratia* (2). Rhizospheric microbes are those which harbours around the root area and these microbes helps in the acquisition of various nutrients from soil. Microbes belonging to *Achromobacter, Acinetobacter, Alcaligenes, Arthrobacter, Alternaria, Bacillus, Chitinophaga, Dyella, Delftia, Enterobacter, Erwinia, Exiguobacterium, Flavobacterium, Gluconacetobacter, Herbaspirillum, Klebsiella, Micrococcus, Methylobacterium, Paenibacillus, Phoma, Rhodobacter, Serratia, Salmonella, Sphingobium, Staphylococcus and Stenotrophomonas* (3).

Plant associated microbes have multiple applications in various sectors and their discovery is very important. Among all the microbes harboring the plants, very few microbes have been cultivated and huge numbers of microbes are unknown. The huge number of microbes are undiscovered because those cannot be cultivable, so omics strategies can be used to discover the microbes without cultivation. Different omics tools genomics, metagenomics, transcriptomics, meta transcriptomics, proteomics, meta proteomics and metabolomics (5). The genomics tools helps in providing the information of microbes on genome level which helps in the discovery of novel genes which codes of the various metabolic compounds and plant growth promoting mechanism (6). Another tool i.e. metagenomics allows the direct analysis of genome of the microbes from the environmental samples. On the other hand, transcriptomics and proteomics provides the knowledge about the gene expression profiling and proteomes. Metabolomics tools, can provide the information about the microbes interactions with the host plants (7). Other tools including meta proteomics and meta transcriptomics helps in the providing the detail of intricacies involved in the microbes especially endophytes establishment (8).

Humans require a lot of stuff for their survivability from which some are naturally produced by the environment and some are chemically synthesized. Chemically synthesized products such as could be injurious to the health of humans, environment as well as other living kinds. After many decades of over-exploitation, mankind in the last few decades has become aware of the planet's health (9). Now mankind is trying to sustain the environment by replacing the chemical products with naturally occurring products with modifications. In the mission of sustainability, plant sciences and plant microbes play a significant role because maximum of products plant origin. Plant sciences and plant microbes have a wide range of applications in the agriculture, environment and pharmaceutical industrial sector (10).

The agriculture sector is one of the most important sectors for mankind as it is the source of food. In the past decades, demand of agriculture products has risen because of increasing population and in search of increasing production, tons of chemical fertilizers and pesticides were sprayed in the fields. As a result, these chemicals started deteriorating the soil quality and affected many organisms. Plant associated microbes serve as a solution to this problem as microbes have

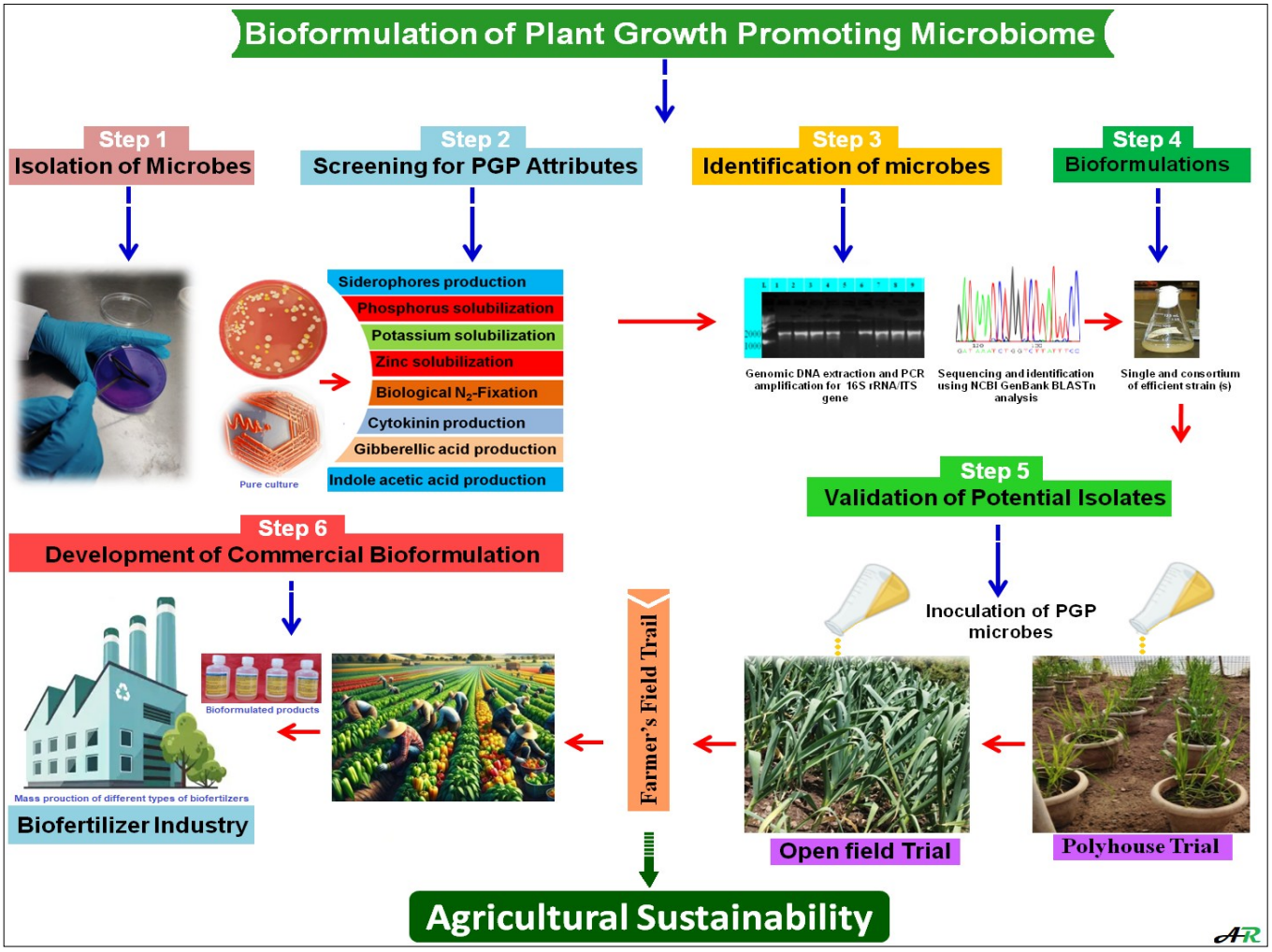

Fig. 1. Plant microbiome for sustainability adapted with permission from (4).

capability to enhance the plant growth indirectly and directly both by protection by the plants from pathogens and supplying required nutrients (nitrogen, phosphorus, potassium, zinc and iron), respectively (11). The plant associated microbes also found to enhance the plant growth when harsh environmental factors exerts stress such as drought, salinity, temperature and pH (12). In a report, *Bacillus subtilis,* having ability to produce auxin, hydrogen cyanide, ammonia, phosphorus solubilization and ACC deaminase activity was reported for having antagonistic activity against *Fusarium oxysporum* and *Botrytis cinerea*. The inoculation of strain in tomato was found to enhance the plant growth and control the pathogen growth (13). In another report, endophytic bacteria *Pelomonas aquatic* and *Solibacillus silvestris,* having nitrogen fixation, auxin, cytokinin and gibberellins production potential were reported as multi-stress (salinity and heavy metals) and have potential to enhance the crop production and growth (14).

The environment is another sector which needs urgent curing. Due to the atherogenic activities of humans such as industrialization, afforestation and pollution, the health of environment has badly depleted. The sustainability of the environment is an important and urgent need for the existence of humans and other organisms. Pollution is one of the major problems which could be resolved by the bioremediation and phytoremediation approaches. In both the approaches, microbes and plants interconvert the hazardous pollutants into less harmful products which may exist over years (15, 16). Various microbes and plants collectively have been found to remediate environmental pollution. In a report, rhizospheric and endophytic bacteria, *Agrobacterium. Bacillus, Rhizobium and Rhodopseudomonas,* from roots of *Larrea divaricata* were found to as potential remediators of heavy metals such as lead, cadmium and zinc (17). In a similar report, fungal endophyte, *Fusarium falciforme* from *Convolvulus arvensis* was reported for removing the cadmium (18).

Plants (especially medicinal) and microbes are great sources of bioactive compounds which may have pharmacologically important properties. These bioactive compounds can be used to cure many humans' diseases and disorders (19). Many microbes isolated from important medicinal plants are reported for producing bioactive compounds which have antioxidant, antimicrobial, anti-cancerous, antidiabetic, anti -inflammatory properties. In a report, endophytic bacteria, *Alcaligenes faecalis* and *Stenotrophomonas maltophilia* from *Moringa oleifera* leaves were found produce different 11 bioactive compounds namely, octadecanoic acid, oleic acid, hexadecanoic acid, 3-dioxolane-4-methyl, diethyl phthalate, pentadecanoic acid, cis-2-phenyl-1, ergotamine, diisooctyl phthalate. These compounds were having antibacterial, antioxidant and anticancer pharmacological activities (20). In another report, from root bark of *Strychnos innocua,* compounds such as linalool, umbelliferone, nerolidol, campesterol, β-sitosterol and 2,13-octadecadien-1-ol were isolated which were having antimicrobial potential comparable to ciprofloxacin (21).

In conclusion, plant sciences and plant microbes are in high demand as mankind are becoming aware of sustainability to protect the environment. Plant sciences and plant microbes are used in the different sectors including agriculture for plant growth and protection from biotic and abiotic stresses; environmental for the bioremoval of hazardous materials caused due to anthropogenic activities and industries to produce high valuable products like medicines. In recent years, many of the microbes and their applications have been uncovered, however new discoveries could be found better technologies and applications for coming challenges of future in sake of development.

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Authors' contributions

All authors read and approved the final manuscript.

Compliance with ethical standards

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