Advances in Horticulture crops and their challenges

Volume-2

Chief Editors

Dr. Jitendra Kumar Sahu

Department of Floriculture, School of Agriculture
Lovely Professional University.

Dr. Vishal Tripathi

Department of Horticulture, School of Agriculture
Lovely Professional University.

SR
edu publications
Publisher & Distributors

Title of the Book: Advances in Horticulture crops and their challenges (Volume-2)

Edition: First- 2023

***Chief Editor*: Dr. Jitendra Kumar Sahu, Dr. Vishal Tripathi.**

ISBN: **978-93-92941-19-1**

MRP Rs. 720/-

SR edu publications

Publisher and Distributor

12-51/d/13/a, Kalyan Nagar

Kalwakurthy, Telangana-509324

Phone: +919553211467

Email: sredupublications@gmail.com

Website: www.Sredupublications.com

PREFACE

The purpose of this book, "**Advances in Horticulture Crops and Their Challenges (Volume-2)"** is to provide an overview of horticulture crops and their challenges. This book has been updated, expanded, comprehensive, and advanced for production, management, quality improvement and value addition of horticulture crops. This book gives a broad overview of the concisely stated horticulture crop principles and techniques. The goal was to present pertinent issues and management of horticultural sciences. Based on my knowledge of the field and the aforementioned points of view, I have tried to gather the most recent data, facts, and aspects of horticulture. To increase the book's acceptability, the literature used it to compile it has been duly acknowledged and full utility of this book some chapters with modifications have been incorporated from literature survey scientists and officials, who helped me during this period. Despite our best efforts and meticulous proofreading, there may have been a few mistakes. We are especially grateful to everyone who assisted us in finishing this book. We hope that readers, teachers, and students will find the book fascinating and helpful and that it will spark in them a desire to learn more about current horticulture issues. We also want to thank SR edu publisher for their interest in publishing the book.

Contents

Chapter- 6

The Living Soil: Fundamentals of Soil Biology

Authors

Rajshree Verma

Department of Plant Pathology, GBPUAT, Pantnagar, Uttarakhand, India

Manisha Dev

Department of Plant Pathology, GBPUAT, Pantnagar, Uttarakhand, India

Neha Chakrawarti

Department of Genetics and Plant Breeding, GBPUAT, Pantnagar, Uttarakhand, India

__Chapter-6__

The Living Soil: Fundamentals of Soil Biology

Rajshree Verma, Manisha Dev and Neha Chakrawarti

Abstract

The soil is home to a large number of living organisms thus also known as the soul of infinite life. Living organisms in soil are broadly grouped into macro-organisms such as macroalgae, termites, earthworms, etc. and microorganisms include fungi, actinomycetes, bacteria, protozoa, etc. Soil acts not only as a medium for plant growth and microbiological activity, but also as a sink and recycling factory for numerous dead organic matter. The breakdown of organic matter leads to the availability of nutrients for plants and other organisms in the soil. Without the activities of microbes, the dead and un-degraded matter would accumulate and litter the soil surface, and there would be no available food in the soil to sustain plants. Soil organisms play an important role in preventing nutrient losses through leaching, maintaining soil structure and promoting plant growth and health through the production of various secondary metabolites. This chapter highlights soil-plant relationships, plant growth and microorganisms, microbial diversity, nutrient cycling, and nutrient pathways and mechanisms.

Keywords: Actinomycetes, Bacteria, Carbon cycle, Fungi, Nitrogen cycle, Plant growth promoting rhizobacteria, Soil borne pathogens

Soil biology: Introduction

"Without life, there is no soil and without soil, there is no life on the earth planet"

Soil is a naturally occurring body composed of inorganic and organic components and has a nature of its own. Soil covers the earth in a thin layer and is formed by the combined influence of climate and other organisms. It acts as a medium for plant growth and microbiological activity. Along with living and dead animals and plant material, soil also contains elements such as air, water, and minerals. These soil elements can be divided into two groups. Biotic factors fall under the first group and include all the living and once-living things in the soil, including plants, insects, bacteria, fungus, etc. Abiotic variables, which encompass all non-living materials including minerals, water, and air, make up the second group of factors. The composition of the soil is determined by its biotic and abiotic components.

The soil is a live, dynamic system because it is teeming with millions of living species. Under the microscope, a complicated arrangement of soil particles and pore spaces filled with air and water can be seen. Millions of species, ranging in size from microscopic to macroscopic develop in these pore spaces. Apart from aiding in soil development, soil organisms also perform several transformations that make it easier for plants to get nutrients. Life on earth would have halted if these activities of microorganisms in the soil had not occurred. The study of all the living organisms residing in the soil is known as soil biology.

Organisms number, biomass, and metabolic activity

The weight of organisms per volume of soil is referred to as biomass (Table 1). Numerous variables, including climate, vegetation, and the physical and chemical properties of soils, affect the number of soil organisms. A humid forest area's species composition will undoubtedly differ from that of an arid desert, which in turn will differ significantly from that of cultivated soil. Species found in alkaline soils and those found in acidic soils are very different. From tropical forest zones to cool temperate regions, similar variations are anticipated. Although more diversified wildlife can be found in forests than in grasslands, grasslands have higher levels of flora and fauna activity. In terms of numbers and biomass of soil organisms, cultivated fields often rank lower than untouched native lands.

Table 1: Number and biomass of different micro-organisms in soil

Organisms	Number (per gram) ODS	Biomass (kg/HFS)
Bacteria	10^8-10^9	450-4500
Actinomycetes	10^7-10^8	450-4500
Fungi	10^5-10^6	1120-11200
Algae	10^4-10^5	56-560

Soil–plant relationship

The soil environment contains microorganisms such as bacteria, actinomycetes, fungi and algae; the microflora and the arthropods, protozoa and worms; and the microfauna and fauna (Russell, 1973) (Fig. 1, 2). Soil organisms need food for two reasons: to provide energy for critical and vital functions and to build body tissues. However, the food sources for specific species for these two goals may be different.

Fully autotrophic organisms require much more energy to grow than many heterotrophs because more energy is required to convert carbon (C) from inorganic sources than from organic substances such as sugars (Russell, 1973). To meet the nitrogen (N) requirement, autotrophic organisms prefer ammonium or nitrate salts. The majority of heterotrophs use glucose as their primary energy source and produce an enzyme when needed to convert a variety of carbohydrates into sugars.

The interaction of plants and soil is defined by a zone called the rhizosphere, where the root system affects microbial activity. The active interaction between soil-plant-microbial communities distinguishes this zone from the rest of the soil mass (Russell, 1982; Herman *et al.*, 2006). The interaction of soil, plant and microbes is crucial for nutrient cycling processes such as the mineralization of organic nitrogen in soil and the conversion of phosphorus (P) for nutrient supply to plants. Contact between microorganisms and the root system in the soil environment involves a variety of activities that contribute to plant growth. Such interaction between soil and microbes is important to increase plant bioavailability and uptake of mineral nutrients (Glick *et al.*, 1999). Plant growth-promoting bacteria or fungi such as Mycorrhizae and Penicillium bilaii can increase nutrient bioavailability (Saleh-Lakha and Glick, 2007). Plant growth-promoting bacteria can help develop plants that are better able to withstand adverse growing conditions such as disease, pathogens, and drought stress (Saleh-Lakha and Glick, 2007).

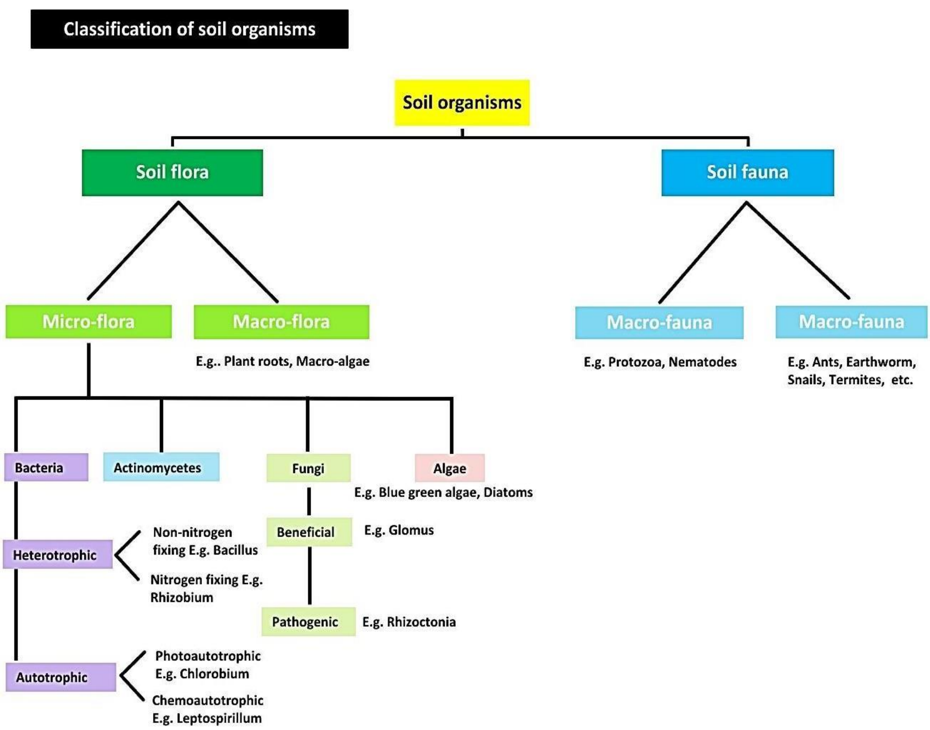

Fig. 1: Classification of soil organisms

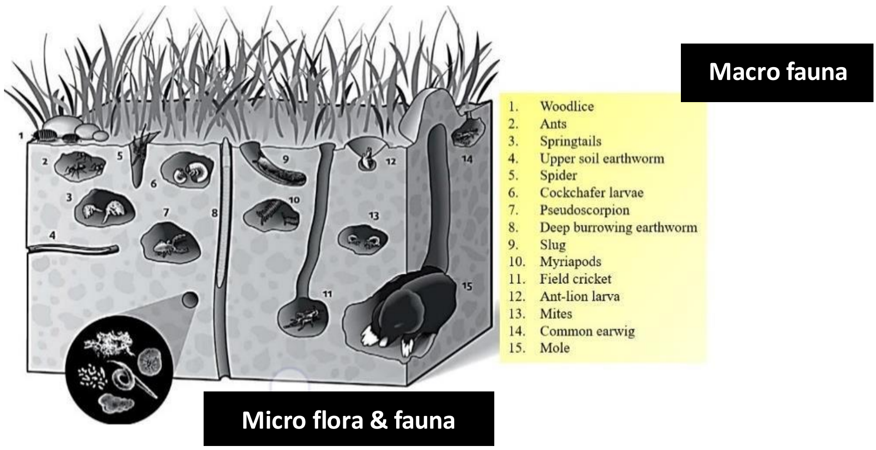

Fig. 2: Various macroorganisms and microorganisms in soil (cwppra.wordpress.com)

Mechanisms associated with the promotion of healthy plant growth include (Glick *et al.*, 1999):

- Associative fixation of the Nitrogen
- Reducing ethylene levels, which would otherwise hinder plant growth.
- Siderophores' ability to bind iron
- The synthesis of phytohormones such as cytokinins and auxin.
- The solubilization of nutrients like Phosphorus, Sulphur
- The development of disease resistance in the plant
- Improvement of mycorrhizal activity
- Changing the shape of the roots
- Strengthening the symbioses between legumes and rhizobia
- Reducing the toxicity of pollutants (organic or heavy metal)

Soil–Root Interface and Nutrient Cycling

Root systems are the crucial part of the soil's biological environment, in addition to their basic functions of absorbing water and minerals, anchoring, storing and producing various organic compounds (Klepper, 1990). In a symbiotic relationship, plants interact with soil organisms through their roots. All of the plant's natural nutrients and water intake pass through its root system. In soil, microorganisms perform most of the mechanisms and processes involved in nutrient cycling. However, during the process of nutrient cycling, the organic compounds provided by the root system, dead plants and animal materials, along with some inorganic compounds, serve as energy and food sources for microorganisms (Prosser, 2007). The formation of organic compounds, which are crucial for the formation of soil aggregates, are influenced by interactions between plant roots and various microbes. The two cycles of major soil nutrients, including nitrogen and carbon, are highlighted in the following sections. The interaction between plant roots and various microorganisms affects the process of nutrient cycling and the production of organic compounds that are essential for building soil aggregates. The following sections highlight two main cycles, namely the nitrogen cycle, the carbon cycle, and phosphorus solubilization.

Nitrogen cycle

Nitrogen (N) is essential to both plants and soil organisms. Despite being abundant at the earth's surface, only around 2% of nitrogen is made available to organisms. Most of the nitrogen is tied up in various pools that require energy sources and processing in order to be converted into available forms for use by organisms (Fig. 3). The N cycle is complex and not just a simple two-step process of nitrification and denitrification. The nitrification process involves the oxidation of reduced N-forms such as ammonia (NH_3^+) to nitrate (NO_3^-). In the presence of various bacteria and enzymes, NH_3^+ is oxidized to nitrite (NO_2^-), then NO_2^- is oxidized to NO_3^-. Denitrification is the reduction of NO_3^- to N-gas via NO_2^-, nitrogen oxides (NO) and nitrogen oxides (N_2O). It is an anaerobic process in which NO_3^- from heterotrophic bacteria acts as an electron acceptor (Fig. 4).

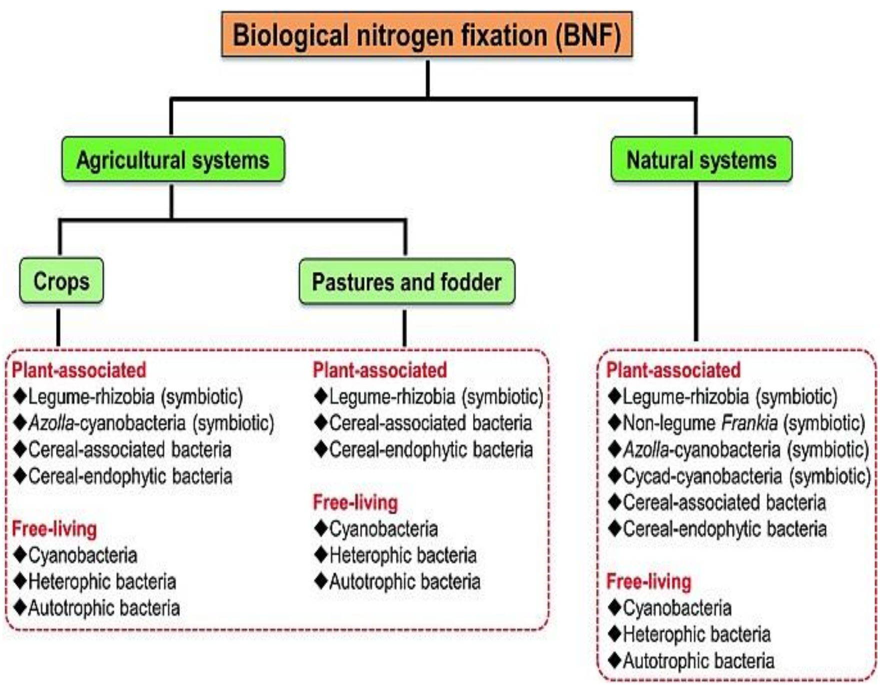

Fig. 3: Nitrogen fixation in different systems **(**Raza *et al.*, 2020)

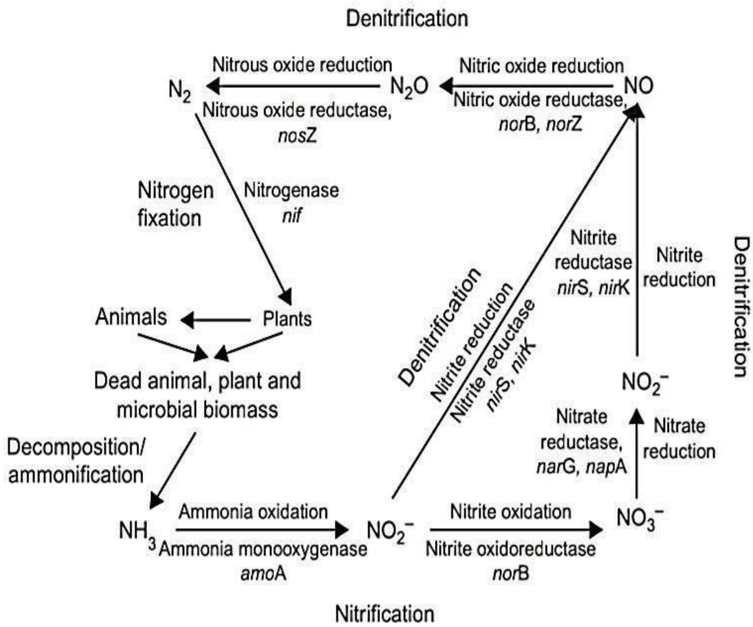

Fig. 4: The terrestrial nitrogen cycle, including enzymes catalyzing particular transformation and associated functional genes that have been used for analysis (*Prosser, 2007)*

Carbon Cycle

The carbon (C) cycle involves the fixation of CO_2 in organic materials, followed by the decomposition of fixed C. The fixation of CO_2 in organic materials occurs by autotrophic organisms that derive energy from photosynthesis or the oxidation of reduced inorganic compounds. Solid C is broken down in soil organic matter (SOM) by heterotrophic organisms to CO_2. This cycle also involves the oxidation of methane (CH_4) by anaerobic archaea, which is a crucial step in regulating levels of a key greenhouse gas (GHG). The balance between the uptake of CO_2 by photosynthesis and the release of C from living and dead matter determines the net exchange of C between the atmosphere and the terrestrial system (Post *et al*., 1990). The intricate organic matter (OM) degradation process is influenced by a variety of parameters, including the heterogeneity of the SOM, the availability of C-compounds, the stability of organic compounds within plant cells, the connection to other nutrient cycles such as N, and the functional Diversity of microbes, especially in the degradation of organic matter (Prosser, 2007).

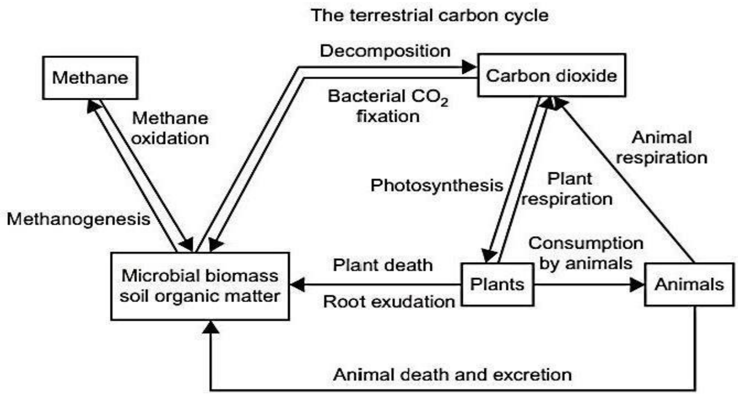

Fig. 5: The terrestrial carbon cycle, indicating the major processes mediated by soil microorganisms (*Prosser, 2007)*

Phosphorous Solubilisation

During mineralization, the phosphorus (P) is converted to an insoluble inorganic compound. It is known that some bacteria and other microbes solubilize these compounds and make phosphorus available to plants. Fungi are more effective than other phosphorus solubilizers but are not used commercially because they can also cause disease in agriculturally important plants. VAM (vesicular arbuscular mycorrhizae) is helpful to explore more area and utilize immobile phosphorus.

P Solubilisers

- Bacteria - *Bacillus megatherium*, *Pseudomonas* spp.
- Fungi- *Aspergillus awamori*, *Penicillium bilajii*

P Absorber

- VAM fungi, *Glomus fasciculatum* and *Gigaspora margarita.*

Organic Matter Decomposition

When organic tissue is introduced into the soil, three general reactions occur. They are as follows:

- The majority of the substance is subjected to enzymatic oxidation, where primary by-products are CO_2, H_2O, energy, and heat being the primary
- A sequence of particular reactions that are largely unique to each element release and/or immobilize the important elements, such as nitrogen, phosphorous, and sulfur.
- Microbe-resistant chemicals are created either by altering molecules in the original plant tissue or by microbial synthesis.

Organic matter is broken down by the soil's native flora, which includes bacteria, fungi and actinomycetes. Various soil enzymes (protein compounds) produced by these bacteria directly contribute to decomposition by lowering the activation energy required to break the bonds of various organic molecules. The simple end products of organic matter decomposition in aerobic soil conditions include CO_2, NH^{4+}, NO^{3-}, $H2PO^{4-}$, $SO4^{2-}$, H2O, resistive residues, and numerous other crucial plant nutrients like Ca^{2+}, Mg^{2+}, Fe^{2+}, Mn^{2+}, Zn^{2+}, ,Cu^{2+}, etc. The end products of anaerobic processes include CH_4 (swamp gas), some organic acids (R-COOH), such as lactic, propionic, and butyric acid, etc., $NH^{4\ +}$, different amine residues (R-NH_2), poisonous gas H_2S and ethylene ($H_2C=CH_2$), and the resistant humus material.

Plant Growth-Promoting Rhizobacteria (PGPR)

The term "plant growth-promoting rhizobacteria (PGPR)" refers to the bacteria which colonize roots and aid in plant growth. *Bacillus, Beijerinckia, Burkholderia, Enterobacter, Erwinia, Flavobacterium, Gluconacetobacter, Klebsiella, Pseudomonas,* and *Serratia* are among the main taxa represented by these PGPR (Podile and Kishore, 2006). These PGPRs enhance plant growth through multiple processes including the synthesis of a chemical that is critical to plants by aiding the host in nutrient uptake and also preventing disease (Glick, 1995).

Direct and indirect mechanisms form the two main groups of PGPR working mechanisms (Fig. 6). Direct growth promotion involves phosphorus solubilization, phytohormone production, and siderophore synthesis (Kloepper *et al.*, 1989; Glick *et al.*, 1995), while indirect growth promotion involves plant disease prevention (Glick and Bashan, 1997; Persello-Cartieaux *et al*., 2003; Ravindra *et al.*, 2008). In addition to these specific mechanisms, PGPR also protects the plant from the harmful effects of environmental stress. These include controlling food intake, increasing antioxidant enzyme activity, reducing stress-induced ethylene, and producing exopolysaccharides (Sandhya *et al.*, 2009; Glick *et al*., 2007). Numerous studies demonstrate the extraordinary contribution of this naturally occurring microbial community to enhancing plant growth and development in both stressed and normal environments (Zahir *et al*., 2004; Glick *et al*., 2007; Tank and Saraf, 2010; Nadeem *et al*., 2010).

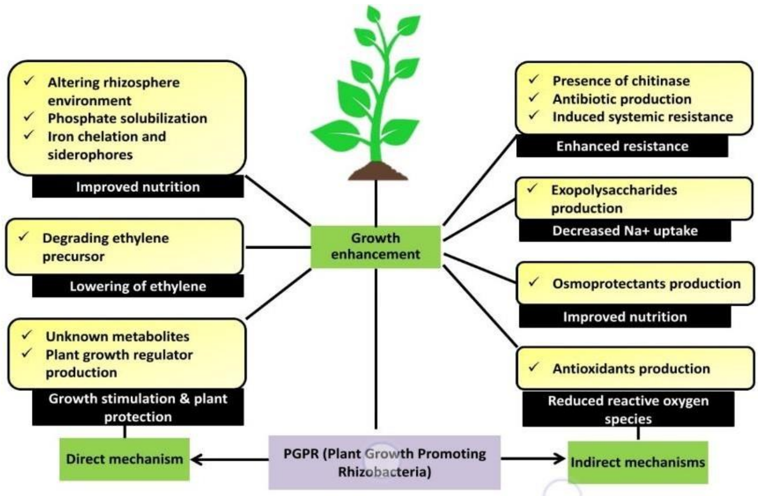

Fig. 6: Mechanism of action of PGPR

Harmful Activities of Soil Organisms

- Plants suffer significant damage from rodents, snails, slugs, termites, insect larvae, and nematodes.
- Many soil-borne diseases of crop plants are caused by fungus, while bacteria and actinomycetes are also involved.
- Create a lot of competition for higher plants while trying to use the nutrients in the soil, especially if there are carbon sources present.
- When drainage is inadequate, it reduces the amount of available oxygen and prevents plants from growing normally.
- Under anaerobic conditions, bacteria convert some nutrients to inaccessible forms (such as

K and Zn) and some nutrients to be available at toxic levels (Fe and Mn, etc.)

Soil borne plant pathogens

There are several nematodes, fungi, oomycetes, and bacteria that are well-known to cause soil-borne plant diseases. Plants affected by soil-borne pathogen develop root rot, blackening of the roots, wilting, stunting, or damping-off symptoms. In order to cause root disease, soil-borne pathogens prefer to reside in the soil. In addition to damaging a plant, these pests may also have an impact on the soil.

- Fungal pathogens: *Fusarium* spp., *Verticillium* spp., *Phytophthora* spp., *Macrophomina phaseolina, Rhizoctonia solani,* etc.
- Bacterial pathogens: *Agrobacterium tumefaciens*, *Ralstonia solanacearum,* etc.
- Actinomycetes: *Streptomyces scabies.*
- Nematodes: Root-knot nematodes, cyst nematodes, *Pratylenchus, Xiphinema, etc.*
- Viruses: Soil-borne wheat mosaic virus, Beet necrotic yellow vein virus.

References

1. Ayyadurai, N., Ravindra, N. P. and Sakthivel, N., (2007). Functional characterization of antagonistic fluorescent pseudomonads associated with rhizospheric soil of rice (*Oryza sativa* L.). *Journal of Microbiology and Biotechnology*. **17**: 919–927.
2. Bardgett, R. D. and Wardle, D. A., (2003). Herbivore mediated linkages between aboveground and belowground communities. *Ecology*. **84**: 2258–2268.
3. Bregliani, M. M., Ros, G. H., Temminghoff, E. J. M. and Riemsdijk, W. H., (2010). *Communications in soil science and plant analysis*. **41 (11)**: 1383–1398.
4. Glick, B. R. (1995). The enhancement of plant growth by free-living bacteria. *Candian Journal of Microbiology*. **41**:109–117.
5. Glick, B. R. and Bashan, Y. (1997). Genetic manipulation of plant growth-promoting bacteria to enhance biocontrol of fungal phytopathogens. *Biotechnology Advances*. **15**: 353–37.
6. Glick, B. R., Patten, C. L., Holguin, G. and Penrose, D. M. (1999). Biochemical and Genetic Mechanisms Used by Plant Growth-Promoting Bacteria. Imperial College Press, London.
7. Herman, D. J., Johnson, K. K., Jaeger, C. H., Schwartz, E. and Firestone, M. K. (2006). Root influence on nitrogen mineralization and nitrification in *Avena barbata* rhizosphere soil. *Soil Science Society of America Journal*. **70**: 1504–1511.
8. Klepper, B. (1990). Root growth and water uptake. In: Stewart BA, Nielsen DR (Eds.), Irrigation of Agricultural Crops. ASA–CSSA–SSSA, Madison, pp. 281–322.
9. Kloepper, J. W., Lifshitz, R. and Zablotowicz, R. M. (1989). Free living bacterial inocula for enhancing crop productivity. *Trends in Biotechnology*. **7**: 39–44.
10. Nadeem, S. M., Zahir, Z. A., Naveed, M., Asghar, H. N. and Arshad, M. (2010). Rhizobacteria capable of producing ACC-deaminase may mitigate the salt stress in wheat. *Soil Science Society of America Journal*. **74**: 533–542.

11. Persello-Cartieau, F., Nussaume, L. and Robaglia, C. (2003). Tales from the underground: molecular plant-rhizobacterial interactions. *Plant Cell Environment*. **26**:189–199.
12. Podile, A. R and Kishore, G. K. (2006). Plant growth-promoting rhizobacteria. In: Gnanamanickam S. S. (eds.) Plant-associated bacteria. Springer, Dordrecht.
13. Post, W. M., Peng, T. H., Emanuel, W. R., King, A. W., Dale, V. H. and DeAngelis, D. L., (1990) The global carbon cycle. *American Scientist*. **78**: 310–326.
14. Prosser, J. I. (2007). Microorganisms cycling soil nutrients and their diversity. In: van Elsas, J. D., Jansson, J. D. and Trevors, J. T. (Eds.), Modern Soil Microbiology, second ed. CRC Press, New York.
15. Ravindra, N. P., Raman, G., Badri, N. K. and Sakthivel, N. (2008). Assessment of genetic and functional diversity of phosphate solubilizing fluorescent pseudomonads isolated from rhizospheric soil. *BMC Microbiology*. **8:** 230.
16. Raza, A. (2020). Nitrogen Fixation of Legumes: Biology and Physiology. In: Hasanuzzaman, M., Araújo, S. and Gill, S. (Eds) The Plant Family Fabaceae. Springer, Singapor.
17. Russell, E. W. (1973). Soil Conditions and Plant Growth. Longman Group Limited, New York.
18. Russell, R. S. (1982). Plant Root Systems, first ed. McGraw-Hill, New York. 214.
19. Saleh-Lakha, S. and Glick., B. R. (2007). Plant growth-promoting bacteria. In: van Elsas JD, Jansson JK, Trevors JT. (Eds.), Modern Soil Microbiology, second ed. CRC Press, New York.
20. Sandhya, V., Ali, S. K. Z., Grover, M., Reddy, G. and Venkateswarlu, B. (2009). Alleviation of drought stress effects in sunflower seedlings by the exopolysaccharides producing *Pseudomonas putida* strain GAP-P45. *Biology and Fertility of Soils*. **46**:17–26.
21. Tank, N. and Saraf, M. (2010). Salinity-resistant plant growth-promoting rhizobacteria ameliorate sodium chloride stress on tomato plants. *Journal of Plant Interaction*. **5**: 51–58.
22. Zahir, Z. A., Arshad, M. and Frankenberger, W. T. (2004). Plant growth-promoting rhizobacteria application and perspectives in agriculture. *Advances in Agronomy*. **81**: 96.