ISSN: 2582-8118 ***Volume 4, Issue 2; March 2024***

INTERNATIONAL JOURNAL OF RESEARCH AND ANALYSIS IN SCIENCE AND ENGINEERING

Web: https://www.iarj.in/index.php/ijrase/index

The Role of Microbial Signals in Plant Growth and Development

Dr. Gudepu Renuka
Assistant Professor,
Department of Microbiology,
Pingle Govt. College for Women(A) Hanumakonda,
Telangana, India.

ABSTRACT

The spatial and temporal organization of cell division, cell expansion, and cell differentiation must be tightly coordinated for plant growth and development. Both biotic and abiotic variables can influence the interchange of signaling molecules between the root and shoot, which is necessary for the coordination of these activities. Understanding the interactions that take place between plants and the microbes that are linked with them has long been of interest since it may help develop new uses in agriculture. Plant metabolism, hormone balance, and signaling are all significantly impacted by plant growth-promoting rhizobacteria (PGPR). Additionally, they create antibiotic chemicals that stimulate plant growth by preventing the growth of harmful rhizospheric microorganisms. In addition to promoting resilience to biotic and abiotic stressors and increasing nutrient availability and uptake, the PGPR promotes agricultural sustainability. Beneficial fungi that exist in the soil microbiome and are free-living effectively spread across the rhizosphere, where they use competitive inhibition to eradicate harmful fungal strains. They also aid in the synthesis of antibiotics and the induction of plant defense mechanisms. This paper will talk about. Plant Growth and Development and the Function of Microbial Signals.

KEYWORDS:

Microbial Signals, Development, Plant Growth, Rhizobacteria, Antibiotic, Compounds, Agricultural Sustainability, Fungi, Soil, Microbiome, Reproduction, Seed Dispersal.

Introduction:

All day long, microbes can be found inside the plant, on the surface, in the rhizosphere, and in the surrounding environment. Numerous interactions arise from the ongoing relationship between microorganisms and plants. Microbes are crucial to the enhancement of plant growth and development. Microbes are found inside, on the surface, and in the rhizosphere of plants. They are part of the plant environment. Plants and microbes interact differently. Plant development and growth are influenced by these interactions.

By using the many secretions that plants produce, microorganisms and plants cohabit. While some bacteria survive inside plants and are known as endophytes; they use the water and nutrients found in plant tissue, the plants also emit a number of substances that aid in the growth and multiplication of bacteria that reside on their surfaces and in the rhizosphere. Plant exudates from the roots, such as sugars, amino acids, and organic acids, are the main metabolites that microbes can benefit from.

Conversely, microorganisms have the ability to impact plant growth and development by means of colonization and growth within the plant's tissues, on its surface, and in the rhizosphere. Multiple secondary chemicals and enzymes that may be beneficial to plants are secreted by microorganisms, which facilitates their colonization and growth. [1]

As sessile, multicellular organisms, plants grow through changes in development and metabolism. In a developing plant, at least three distinct parts can be identified:

(1) the root, which is the portion of the plant below ground and serves as anchorage as well as a conduit for water and nutrients to be taken up from the soil; (2) the stem, which supports the leaves and facilitates the movement of nutrients and water throughout the plant; and (3) the shoot, which develops leaves, flowers, and fruits to allow for effective light capture as well as seed dispersal and reproduction. Plant architecture is the anatomical arrangement of the root, stem, and shoot systems to construct a plant. Plant breeders must take into account plant architecture since it plays a critical role in the agronomic performance of crops. [2]

Review of Literature:

Plant growth-promoting rhizobacteria (PGPR) are bacteria that can promote plant growth through a variety of processes and can be found in the soil close to plant roots, on the surface of plant root systems, in the spaces between root cells, or inside the specialized cells of root nodules (Smith 2005). PGPR use a range of strategies to encourage the growth and development of plants. [3]

The primary reason why microorganisms are deemed dangerous is because they can cause diseases. Nonetheless, some are useful in agriculture and are currently employed in the cultivation of food crops that are sustainable. Research has demonstrated the involvement of beneficial microorganisms in various processes such as atmospheric nitrogen fixation, decomposition of organic wastes and residues, pesticide detoxification, inhibition of plant diseases and soil-borne pathogens, improvement of nutrient cycling, and synthesis of bioactive substances like vitamins, hormones, and enzymes that stimulate plant growth.

Microorganisms such as plant-growth-promoting rhizobacteria (PGPR) and plant-growth-promoting fungi (PGPF) have been employed to mitigate the effects of abiotic stress (Ferreira C.M.H, 2019). [4]

Every plant has a unique form of microbiota, and the microbiota's structure in the rhizosphere is influenced by the signal molecules that both the plant and the microbes create as well as the makeup of the exudates that the roots of the plant emit (Chaparro et al., 2014). Different kinds of interactions between microorganisms and the roots of plants are formed with the aid of these signaling molecules. [5]

The rate of population expansion globally necessitates a rise in food production. However, increasing agricultural output frequently necessitates the use of chemical fertilizers, which can have a detrimental effect on the environment and are financially unaffordable for many farmers worldwide.

Furthermore, Asghari et al. (2020) suggest that environmental stressors can also provide significant obstacles to plant growth and output, leading to low agricultural productivity and compromising global food security.

Therefore, it is necessary to utilize less chemical fertilizers and raise plant resistance to abiotic stresses in order to increase global agricultural production in a way that is more environmentally and economically sustainable. In more environmentally friendly and sustainable agricultural systems, the use of plant-growth-promoting microbes (PGPM) is a potentially beneficial strategy for increasing crop yield, food security, and quality. [6]

Objectives:

- Plant growth microbes played direct and indirect roles for growth and productivity.
- Microbial signaling and plant growth promotion
- Plants interact with microbes in rhizosphere via signaling molecules.

Research Methodology:

This study's overall design was exploratory. The research paper is an endeavor that is founded on secondary data that was obtained from reliable online resources, newspapers, textbooks, journals, and publications. The research design of the study is mostly descriptive in nature.

Result and Discussion:

Promising is maybe the application of microorganisms that promote plant growth and the substances they generate. Since the first terrestrial plants colonized land, plants and the microorganisms that accompany them have likely coexisted.

This is known as the holobiont. This relationship—known as the holobiont—is dynamic, with the plant exerting significant control over the characteristics of the phytomicrobiome, particularly in the rhizosphere.

This effect is mostly ascribed to the makeup of the plant's root exudates. Regarding the plant, damaging, neutral, and beneficial microbes may be found in the rhizosphere, endospheric, and phyllosphere. Plant growth promoting microorganisms (PGPM) are microbes that support plant growth.

These microbes could live in the endosphere, phyllosphere, rhizosphere, or rhizoplane. Plant growth-promoting microorganisms (PGPM) including rhizobia, mycorrhizae, and bacteria have long been known to promote plant development in both stressed and unstressed environments.

Over the past three decades, the use of microbial inoculants has become increasingly commonplace, despite being an ancient practice. A great deal of study has been done on rhizobia, and a lot more is being done right now on chemicals produced from PGPR and rhizobacteria that promote plant development. Numerous researchers have looked at the potential of microorganisms to inhibit plant diseases and lessen the impact of abiotic stress on plants, and the results are promising. [7]

It is advised to isolate PGPMs from their natural environments and multiply their populations before reintroducing them into the soil or onto the plant as microbial inoculants, even though they naturally occur in the rhizosphere and plant tissue.

This is because PGPM populations are frequently insufficient to induce desired effects. Microbe-produced compounds are becoming more and more popular among researchers, but farmers are not as familiar with them as they are with microbial cell inoculants, which come packaged as either single microbial strains or consortia and have been on the market for a while.

Microbe-based inoculants typically come from subgroups of fungi (particularly Trichoderma) and bacteria (such Bacillus and Rhizobia), while other archaea groups have also been shown to promote the growth of plants.

On the other hand, microbially generated chemicals as plant growth enhancers, including lipochitooligosaccharides (LCO), are relatively new to the market, which may account for their lower availability. The methods PGPM uses to lessen the impacts of biotic and abiotic stress on plants are outlined in Figure 1 below; these methods are covered in more detail later. [8]

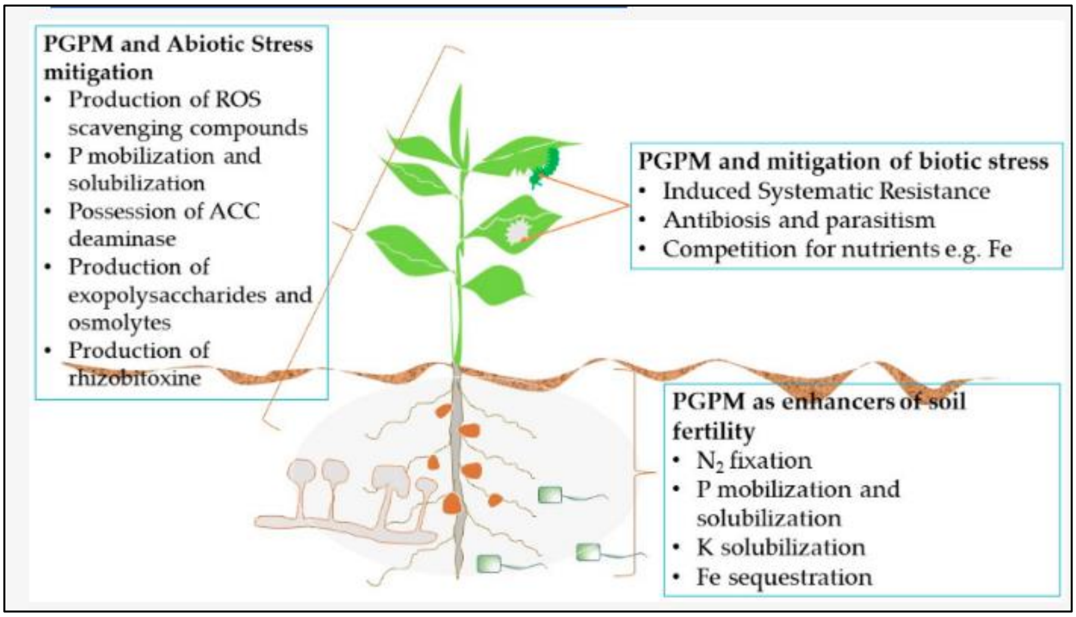


Figure 1. Mechanisms employed by plant growth promoting microorganisms (PGPM) to mitigate effects of biotic and abiotic stress on plants. [9]

A gradient of intimacy exists in the soil between the roots of plants and microbes that extends away from the plant roots; the degree of plant control on the microbial community rises in proximity to the root surface (Figure 2).

Although the term "rhizosphere" was first used by Hiltner (1904) to refer to the soil microorganisms surrounding and inside roots, it is now commonly used to refer to this zone. Microbes that reside within the root are referred to as endophytes, while those that live on the root surface are known as rhizoplane inhabitants.

Among the earliest and closest components of the phytomicrobiome are mitochondria and plastids, which include the chloroplasts. They developed into the permanent subcellular structures we see today from microbes linked with plants. [10]

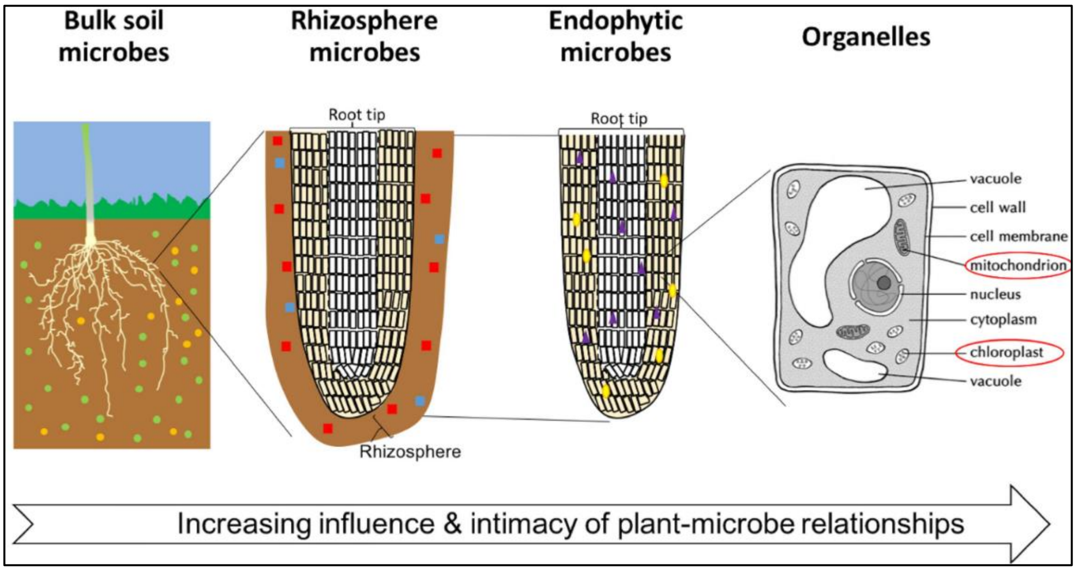


Figure 2: The degree of intimacy and influence of the plant-microbe interactions. Microbes are represented by small colored (red, green, yellow, purple, and blue) shapes. Diversity and number of microbes is variable between soils, distance from plant roots, crop species, and plant tissue. [11]

Signaling Molecules at Plant Root Interface:

Phytohormones are the primary molecular signals that control the growth and development of plants. They have demonstrated a significant involvement in developmental signaling and a variety of environmental stressors. In the rhizosphere, PGPR are known to create a variety of hormones that function as signal molecules and facilitate PGPR contact with plant roots and development.

Research has shown that PGPR, which includes Brady rhizobium japonicum, Pseudomonas fluorescence, and Bacillus amyloliquefacians, significantly produce plant growth hormones such zeatin, ET, ABA, and indole-3-acetic acid (IAA) (Figure 3). [12]

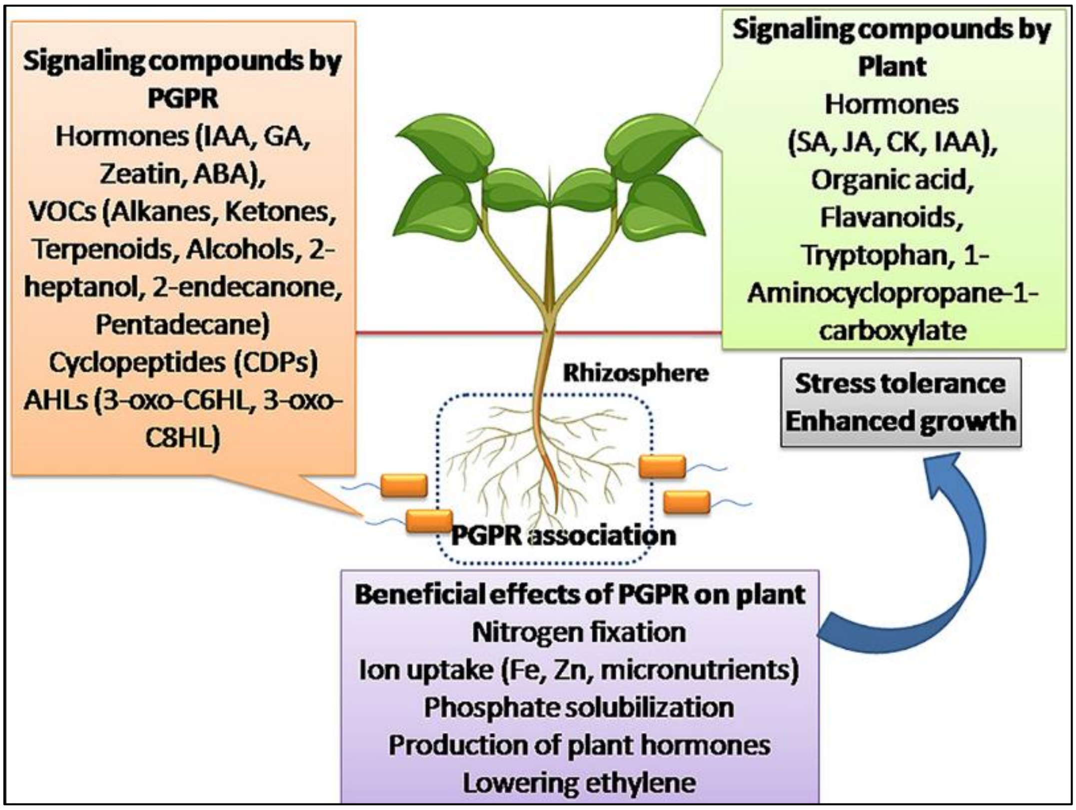
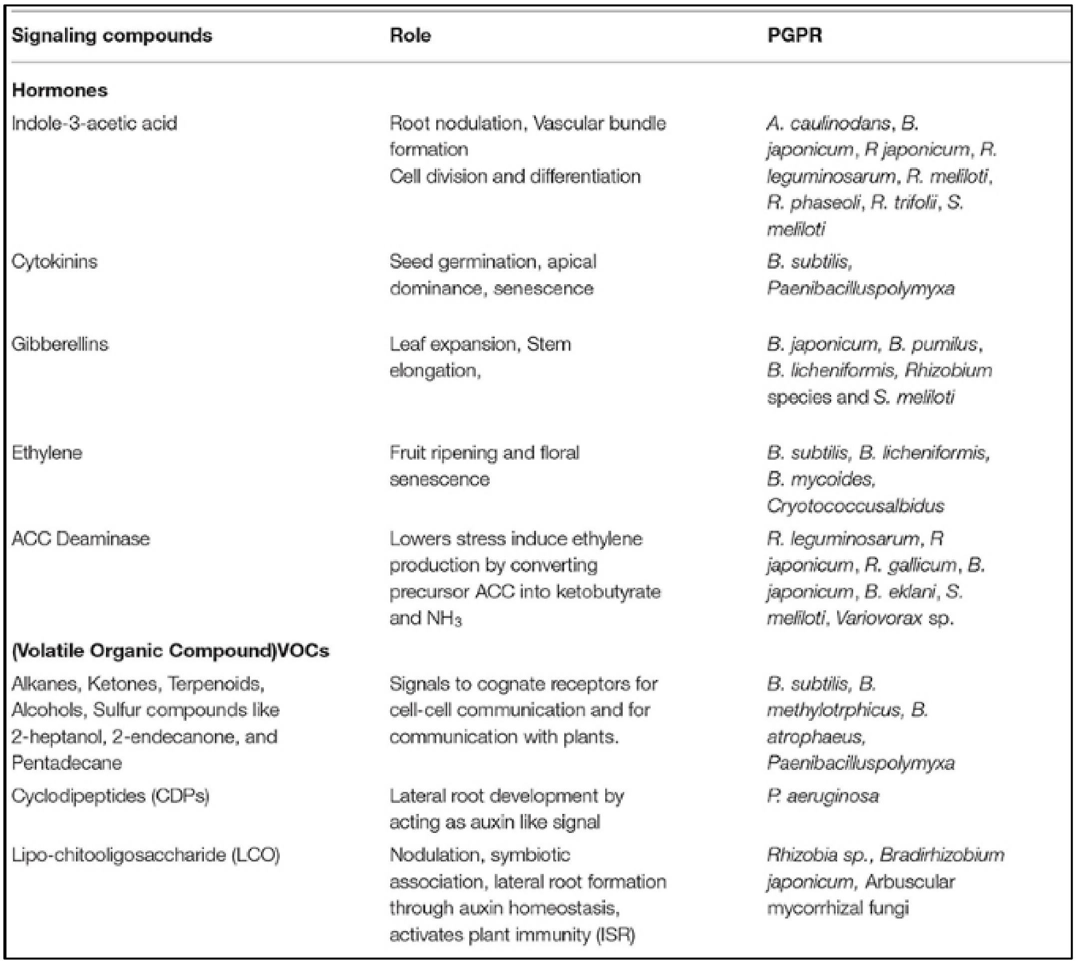


Figure 3: Signaling compounds produced by PGPR and plants for setting up the beneficial rhizosphere association.

Hormones (IAA, GA, Zeatin, ABA), ACC deaminase, VOCs (Alkanes, Ketones, Terpenoids, Alcohols, 2-heptanol, 2-endecanone, Pentadecane), cyclopeptides (CDPs), and acyl homoserine lactones (AHLs) like 3-oxo-C6HL and 3-oxo-C8HL, which prompt plant signaling and aid in stress tolerance and plant growth promotion are among the substances produced by PGPR. Similar to humans, plants respond to PGPR by producing signaling molecules that aid in signaling and the stress response, such as plant growth hormones (SA, JA, CK, and IAA).

By supplying necessary minerals through nitrogen fixation, ion absorption (Fe, Zn, micronutrients), and phosphate solubilization, the related PGPR enhances plant growth. [13]

The hormone indole-3-acetic acid, which is generated by rhizobacteria, is crucial for the creation of vascular bundles, cell division, and root nodulation. Environmental and genetic variables influence rhizobacteria's ability to biosynthesise IAA. The majority of rhizobacteria under study, including Azorhizobium caulinodans, B. japonicum, Rhizobium japonicum, Rhizobium leguminosarum, Rhizobium meliloti, Rhizobium phaseoli, Rhizobium trifolii, and Sinorhizobium meliloti, are capable of producing IAA via the indole-3-pyruvic acid and indole-3-acetic aldehyde pathway (Table 1).



Signaling compounds	Role	PGPR
Hormones		
Indole-3-acetic acid	Root nodulation, Vascular bundle formation Cell division and differentiation	*A. caulinodans*, *B. japonicum*, *R japonicum*, *R. leguminosarum*, *R. meliloti*, *R. phaseoli*, *R. trifolii*, *S. meliloti*
Cytokinins	Seed germination, apical dominance, senescence	*B. subtilis*, *Paenibacilluspolymyxa*
Gibberellins	Leaf expansion, Stem elongation,	*B. japonicum*, *B. pumilus*, *B. licheniformis*, *Rhizobium* species and *S. meliloti*
Ethylene	Fruit ripening and floral senescence	*B. subtilis*, *B. licheniformis*, *B. mycoides*, *Cryotococcusalbidus*
ACC Deaminase	Lowers stress induce ethylene production by converting precursor ACC into ketobutyrate and NH_3	*R. leguminosarum*, *R japonicum*, *R. gallicum*, *B. japonicum*, *B. eklani*, *S. meliloti*, *Variovorax* sp.
(Volatile Organic Compound)VOCs		
Alkanes, Ketones, Terpenoids, Alcohols, Sulfur compounds like 2-heptanol, 2-endecanone, and Pentadecane	Signals to cognate receptors for cell-cell communication and for communication with plants.	*B. subtilis*, *B. methylotrphicus*, *B. atrophaeus*, *Paenibacilluspolymyxa*
Cyclodipeptides (CDPs)	Lateral root development by acting as auxin like signal	*P. aeruginosa*
Lipo-chitooligosaccharide (LCO)	Nodulation, symbiotic association, lateral root formation through auxin homeostasis, activates plant immunity (ISR)	*Rhizobia sp.*, *Bradirhizobium japonicum*, Arbuscular mycorrhizal fungi

Important hormones called cytokinins (CKs) control apical dominance, senescence, seed germination, and the interactions between plants and microorganisms. Furthermore, strains of rhizobacteria have been shown to effectively generate the hormone cytokinin, which promotes the growth of shoots and lateral roots as well as the secretion of root exudates, hence enhancing the positive bacteria-plant interaction (Table 1). [14]

Conclusion:

The technology whose time has come is the integration of PGPB as a fundamental aspect of agricultural operations. Many developing nations now successfully employ such bacteria, and it is anticipated that this practice will spread. The application of PGPB fills a little but expanding niche in the advancement of organic agriculture in the more industrialized countries, where agricultural chemicals are still comparatively cheap. Additionally, phytohormones regulate and coordinate different stages of development and defense responses through their control over signaling pathways. There is signaling crosstalk between phytohormones and other chemicals secreted by the plants and the PGPR, which is a result of the PGPR giving plants enhanced growth and stress tolerance. Rhizobacteria that promote plant growth are known to exhibit a variety of direct and indirect ways to improve the growth and development of plants.

The chemical compounds that act as signaling molecules that are released by both microbes and plant roots determine their interactions with plants and the kind of bacteria that live in the rhizosphere area of plant roots. At the plant-root interface, PGPR generate several sets of signaling molecules, which are necessary to establish advantageous connections.

References:

1. Gray E. J., Lee K. D., Souleimanov A., Di Falco M. R., Zhou X., Ly A., Charles T. C., and Smith D. L. A novel bacteriocin, thurici 17, produced by PGPR strain Bacillus thuringiensis NEB17: isolation and classification J. Appl. Microbiol. 2006a 100 545 -554.
2. Jung W.-J., Mabood F., Souleimanov A., Zhou X., Jaoua S., Kamoun F., and Smith D. L. Stability and antibacterial activity of bacteriocins produced by Bacillus thuringiensis and Bacillus thuringiensis ssp. Kurstaki J. Microbiol. Biotechnol. 2008b 18 1836 -1840
3. Smith D. L. Intracellular and extracellular PGPR: commonalities and distinctions in the plant-bacterium signaling processes Soil Biol. Biochem. 2005 37 395 -412
4. Ferreira C.M.H., Soares H.M.V.M., Soares E.V. Promising bacterial genera for agricultural practices: An insight on plant growth-promoting properties and microbial safety aspects. Sci. Total Environ. 2019; 682:779–799. doi: 10.1016/j.scitotenv.2019.04.225.
5. Chaparro, J. M., Badri, D. V., and Vivanco, J. M. (2014). Rhizosphere microbiome assemblage is affected by plant development. ISME J. 8, 790–803. doi: 10.1038/ismej.2013.196
6. Asghari, B., Khademian, R., and Sedaghati, B. (2020). Plant growth promoting rhizobacteria (PGPR) confer drought resistance and stimulate biosynthesis of secondary metabolites in pennyroyal (Mentha pulegium L.) under water shortage condition. Sci. Hort. 263, 1–10. doi: 10.1016/j.scienta.2019.109132
7. Ahmed A, Hasnain S (2014) Auxins as one of the factors of plant growth improvement by plant growth promoting rhizobacteria. Pol J Microbiol 63:261–266.
8. Arkhipova TN, Veselov SU, Melentiev AI, Martynenko EV, Kudoyarova GR (2005) Ability of bacterium Bacillus subtilis to produce cytokinins and to influence the growth and endogenous hormone content of lettuce plants. Plant Soil 272:201–209
9. Timmen M, Bassler BL, Jung K. AI-1 influences the kinase activity but not the phosphatase activity of LuxN of Vibrio harveyi. J Biol Chem 2006; 281:24398 – 24404
10. Cao JG, Meighen EA. Purification and structural identification of an autoinducer for the luminiscense system of Vibrio harveyi. J Biol Chem 1989; 264:21670 – 21676
11. Zhu, Q., Riley, W. J., Tang, J., and Koven, C. D. (2016). Multiple soil nutrient competition between plants, microbes, and mineral surfaces: model development, parameterization, and example applications in several tropical forests. Biogeosciences 13, 341–363. doi: 10.5194/bg-13-341-2016
12. Asghar HN, Zahir ZA, Arshad M, Khaliq A (2002) Relationship between in vitro production of auxins by rhizobacteria and their growth-promoting activities in brassica junceal. Biol Fertil Soils 35(23):1–237.
13. Aloni R, Aloni E, Langhans M, Ullrich CI. 2006. Role of cytokinin and auxin in shaping root architecture: regulating vascular differentiation, lateral root initiation, root apical dominance and root gravitropism. Annals of Botany 97, 883–893.
14. Artner C, Benkova E. 2019. Ethylene and cytokinin: partners in root growth regulation. Molecular Plant 12, 1312–1314.