CURRENT SCIENCE

Volume 116 Number 6 25 March 2019

EDITORIAL

Beneficial microbes for sustainable agricultural production

The Indian agricultural scenario has witnessed a sea change in production and productivity over the past decades – from a mere 522 kg/ha of food grains that include cereals and pulses in 1950–51 to over 2040 kg/ha during 2015–16 (www.indiaagristat.com). Similarly, the horticulture sector has also made a tremendous and impressive progress, and horticultural production during 2018–19 is expected to be an all-time high of 314.67 million tonnes from 25.87 million hectares. The major challenge in the years to come is to sustain the production from the diminishing natural resources of land, water and non-availability of skilled manpower. The National Agricultural Research System (NARS), under the Indian Council of Agricultural Research (ICAR), has been developing agricultural technologies through 101 research institutes, and 71 agricultural universities to enhance the agricultural production across the country. From 1951 to 2017, the increased production is impressive with food grains by 5.4 times; horticultural crops 10.1; fish 15.2; milk 9.7 and eggs by 48.1 times (www.icar.org). The agricultural technologies followed were mainly new crop varieties, fertilizers and pesticides. The green revolution era enhanced the production and India emerged from 'begging bowl to bread basket'. According to M. S. Swaminathan, the high-input production system is unsustainable, and there is need for a sustainable production system; he named it 'evergreen revolution' in which the technologies developed are ecologically, socially and economically sustainable (Kesavan, P. C. and Swaminathan, M. S., *Curr. Sci.*, 2018, **115**(10), 1876–1883). The intensive cropping system has brought in a unsustainable production system through indiscriminate use of agricultural inputs such as fertilizers and water. The input use efficiency is far lower than expected and has affected the soil as fertilizers and pesticides started accumulating in the environment leading to environmental degradation and affecting human health. The biotic components of soil, especially beneficial microbes, would play a prominent role in sustainability. The beneficial microbes mobilize nutrients, secrete growth-promoting substances and suppress the soil-borne disease-causing pathogens.

Plants take up the required nutrients in the form of elements and convert them into complex molecules of carbohydrates, proteins and all essential compounds. There are 16 nutrients out of which 13 are mined from the soil and three elements, namely carbon, hydrogen and oxygen are extracted from the atmosphere and water. The three primary nutrients are nitrogen, phosphorus and potassium; the secondary nutrients are calcium, magnesium and sulphur and the micro-nutrients are boron, chlorine, copper, iron, manganese, molybdenum and zinc. Nitrogen in plants is found in amino acids, nucleic acids and chlorophyll. This element is also a component of enzymes and proteins, and essential for maintaining plant health. Nitrogen deficiency in plants and grains leads to reduced protein content. Phosphorus is a major component of both RNA, DNA and the ATP system in plants. It facilitates photosynthesis, controls and monitors cell division and regulates the use of starch and sugar. Phosphorus deficiency leads to delayed maturity, poor plant and root growth, early fruit drop and reduced yield. Potassium is ranked as the third main primary nutrient required by plants. Potassium deficiency in plants leads to reduced plant yield and it also weakens the stems. Potassium in plants facilitates water usage, helps in disease resistance and metabolizes other nutrients. For most crops, the secondary nutrients are needed in lesser amounts than the primary nutrients. However, they are growing in importance in crop fertilization programmes due to more stringent clean air standards and efforts to improve the environment. Calcium is used for cell division, nitrogen metabolism, reducing plant respiration, trans-locating photosynthates to fruiting organs, increased fruit set and stimulating microbial activity. Magnesium is the essential element of chlorophyll production, it improves utilization and mobility of phosphorus and iron; it is a component of many plant enzymes and influences earliness and uniformity of maturity. Sulphur is an integral part of amino acids; it helps in the synthesis of enzymes and vitamins, promotes nodule formation on legumes and helps in seed production.

For human health a balanced diet is required and primarily plants are the source of complete nutrition. Hence discussions are often not only regarding food security but also nutrition security. When the soil has inherent deficiency of nutrients, it affects the productivity of plants and also human health. If nutrient uptake through plants is not adequate, deficiencies of minerals lead to deficiency in populations. An estimated 3 billion people suffer from inadequate nutrients globally, and this is severe in developing countries including India (Welch, *Plant Soil*, 2002, **247**, 83–90).

A healthy soil includes biotic components of microfauna and microflora that are essential for the recycling of nutrients and play a crucial role in mobilizing them, enhancing soil health and productivity of crop plants. Plants absorb nutrients from the soil in ionic form, irrespective of the source being organic or inorganic. Microorganisms are ubiquitous and the plant surface provides a specialized niche for them. The association of rhizobia with legumes and AM fungi in crops is well known. Several organisms are adapted to survive on various parts of the plant such as phyllosphere-leaf surface, rhizosphere-root surface, etc. The term rhizosphere was coined by Hiltner in 1904, to describe the soil surrounding a plant root extending a few millimetres but put together the area it occupies is quite formidable; a single wheat plant is estimated to occupy 70,000 m. The rhizosphere is associated with intense biological and chemical activity influenced by compounds exuded by the roots such as amino acids, organic acids, carbohydrates, sugars, vitamins, mucilage and proteins. The rhizosphere microbes help in mobilizing nutrients and also secrete growth hormones that help in growth promotion. Occupying a prime niche, these microbes have certain arsenals like enzymes and antibiotics to prevent other rhizosphere colonizers, including disease-causing microbes. Some of the rhizosphere organisms enter the roots and reside as endophytes and augment the internal defences, a phenomenon known as induced systemic resistance (ISR). The rhizosphere is often compared to the gastrointestinal tract of human beings, which is important for the digestion of food, absorption and maintaining a delicate equilibrium between the useful beneficial organisms and the harmful ones. Similarly, in the rhizosphere of plants both beneficial and harmful organisms exist. Most often the plant recruits its own microbes by modulating its secretions. Rhizosphere microbes are also known as 'the plant microbiome or as the "plants'" other genome', as they play a vital role in nutrient mobilization and plant growth and serve as the first line of defence against soil-borne pathogens. There are several free-living nitrogen fixers like *Azospirillum*, *Azotobacter*, etc. that are involved in the nitrogen cycle. Other rhizosphere microbes include *Acinetobacter*, *Burkolderia*, *Bacillus*, *Thiobacillus* and *Microbacterium*. Several fungi and bacteria mobilize nutrients like phosphorus, potassium, iron, aluminum, etc. The prominent fungi are species of *Aspergillus*, *Penicillium*, *Trichoderma*, *Mucor*, etc.

As plant roots grow through the soil and release root exudates, this attracts microbes and it varies according to the stages of plant growth. The rhizosphere soil is significantly wetter than bulk soil, which protects roots from drying out. Exudates released from the roots at night allow expansion of roots into the soil. When transpiration resumes with daylight, the soil begins to dry and its hydraulic potential decreases; the exudates lose water to soil. They help the roots adsorb and store ions for plant use. For example, flavonoids in legume roots activate *Rhizobium meliloti* genes responsible for root nodulation that enable the plant roots to obtain nitrogen from the air. Exudates enable the transfer of up to 20% of all photosynthetically fixed carbon to the rhizosphere; it may also be responsible for encouraging VAM that colonize roots and send out miles of thread-like hyphae into the soil, increasing the surface area and distance covered by the roots and taking up nutrients for the plant. Most *Trichoderma* species function almost similar to the mycorrhiza. When a root is colonized by mycorrhiza, the microbial community changes around the rhizosphere and hence is known as 'Mycorhizosphere'. These organisms besides surviving on the surface depending on the host exudates for their energy requirements, also help the host plant by mobilizing vital nutrients and augmenting the defence of the plants against invading pathogens. A recent article on black pepper explains the 'Trichorhizosphere effect' (Umadevi *et al.*, *BJM*, 2018, **49**, 463–470). The mechanism of enhanced plant growth is not only by the introduced *Trichoderma*, but by the combined activity of native soil organisms including mycorrhiza inducted by the inoculated *Trichoderma*.

The beneficial microbes are isolated from the rhizosphere and screened for important agronomic traits for plant growth promotion and disease suppression. Further, these organisms are tested in laboratories, greenhouses and under field conditions to identify efficient strains with multiple traits. Once the beneficial organisms like plant growth promoting rhizobacteria and *Trichoderma* are identified, they are cultured in the laboratory, mixed with a carrier medium and delivered to the field by making formulations with inert materials such as talcum or lignite, or agricultural by-products like coffee husk, rice bran, sorghum grains, etc. The main drawback of these formulations is the short lifespan or shelf-life of the product. Besides, dry and liquid formulations are bulky, heavy and need more space for storage; they are also expensive to transport over long distances and the task becomes difficult in undulating terrains. Secondly, the population of bio-inoculants during storage gets reduced making the product less effective.

In order to be effective, the microbial delivery methods must be simple, efficient, technically sound and easily followed by end-users. Some of the microbial technologies like biocapsules and seed coating developed by the Indian Institute of Spices Research, Kozhikode (www.spices.res.in/bpd) are simple and easy for the farmers to adopt. In capsule formulation, the bulk has been reduced from 1000 to 10 g with enhanced shelf-life. This technology has been commercialized and entrepreneurs are using it to deliver biofertilizers and biocontrol agents, especially in states like Chhattishgarh, Karnataka, Kerala, Madhya Pradesh and Maharashtra. In agricultural production system, soil microbes play a vital role. There must be appropriate microbial technologies to optimize the use of natural resources for sustainable agricultural production in India.

M. Anandaraj

48A 'Madhoovan' 2nd Main,
Railway Men Layout, Thanisandra,
Bengaluru 560 077, India
e-mail: arajiisr@gmail.com