Chapter 4
Microbial Mediated Natural Farming for Sustainable Environment

Asha Rani and Beenam Saxena

Abstract India is an agriculture-based country, and agriculture is the backbone of Indian economy. More than half of the population depends upon agriculture. The majority of the farmers rely on conventional farming in comparison to natural or organic farming. To fulfil the food requirement, it is necessary to increase yield and production of crops. Different types of chemical fertilizers are used to increase total yield. Due to the large use of these fertilizers, heavy metal ions increased in the soil which may be toxic to animals and humans. The heavy metals are also present in city waste water (CWW) in toxic amount, and when this polluted water reaches to adjoining areas of the city, it contaminates the soil. When these heavy metals are absorbed by the plants, it may lead to some adverse effect on different growth parameters which directly affects the total yield of the crop. The quantity of these chemicals can be reduced with the help of microbes present in soil or by use of biofertilizers. This book chapter describes the importance of organic farming to maintain sustainable agriculture.

Keywords Biofertilizers · Conventional farming · Heavy metal · Soil microbes

4.1 Introduction

Soil is very important and an essential factor for plant growth. However, by the use of enormous number of chemical fertilizers, it can be contaminated (Chao et al. 2014). Continuous use of chemical fertilizers and regular addition of heavy metals may cause the different other types of pollution in soil and water environment (Bhatt et al. 2019a, b; Pankaj et al. 2015a, b, 2016a, b). Soil can be contaminated by heavy metals which reache through city waste water and other industrial wastes to the

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agricultural fields. The heavy metal ions and other chemicals may also cause decrease in nutrients in the soil. Heavy metal-contaminated soil cannot be remediated (Verma et al. 2021). Due to heavy metal pollution, size, composition, and activity of the microbial community are also adversely affected along with plant quality and yield (Wang et al. 2016). Heavy metals can interfere with the enzymatic activity of microbes so organic matter decreases in soil (Shun-hong et al. 2009). Human exposure to these metals occurs through ingestion of contaminated food or water. The high cost of chemical fertilizers and their adverse effect on environment have encouraged scientists to develop alternative method to increase soil productivity (Huang et al. 2021; Singh et al. 2021; Zhang et al. 2020, 2021; Mishra et al. 2020; Feng et al. 2020; Lin et al. 2020; Vaxevanidou et al. 2015). Microorganisms play very important role to increase soil fertility which is contaminated by heavy metals. Phytoremediation is another aspect for the treatment of polluted soil. In this, plants are used to reduce soil contamination. Some plants have the capacity to absorb heavy metals when they are planted at the boundary of fields. Highly resistant plants like sunflower (*Helianthus annuus*), Indian mustard (*Brassica juncea* L.), willow (*Salix alba*), popular tree (*Populus deltoids*), vetiver (*Chrysopogon zizanioides*), etc. can be used for a remediation of the pollution site. For phytoremediation, molecular mechanisms of resistance to heavy metals should be studied in different types of plants. It will be helpful in the near future to find out more plant species having heavy metal resistance. Effected bioremediation of heavy metal-polluted soils can be possible by using combination of both microorganisms and plants. However, success of this approach will depend on species of organisms involved in the process. Bioremediation is very economical in comparison to the other techniques for remediation of contaminated soil. However, it has been found that growth of different plant growth-promoting (PGP) microbes was proper in the organic soil. This was due to the frequent use of green manure. The soil health depends upon the diversity of microbes present in the soil. The productivity of the crop directly depends upon soil health (Bhatt and Maheshwari 2019, 2020a, b, c).

To reduce the amount of chemicals, conventional farming should be replaced by organic or natural farming with use of soil microbes. Indigenous microbial consortium inhabits the soil and has potential to improve soil fertility. By increasing natural farming and use of biofertilizers or organic fertilizer, the food quality can be improved. An "organic fertilizer" can be derived from non-synthetic or organic sources such as plant or animal, microbes, and rock powders; by different processes like drying, cooking, composting (Dadi et al. 2019), chopping, grinding, and fermenting (Mario et al. 2019); or other method (Thanaporn and Nuntavun 2019). The soil enriched with microbes is considered as healthy, and it helps in plant growth and makes them resistant against stress. Although the maintenance of organic soil quality is quite tough in Indian agricultural practices and expensive too. India has 1.94 million hectares of organic farmland in 2018–2019 (Fig. 4.1) accounted for 1.08% of total agricultural land, and certified organic production for all crop categories stood at 2.6 million metric tons (MT). According to World of Organic Agricultural Report 2018, India produces 30% of total organic production and has maximum number of organic producers in world, i.e., about 835,000. In the year

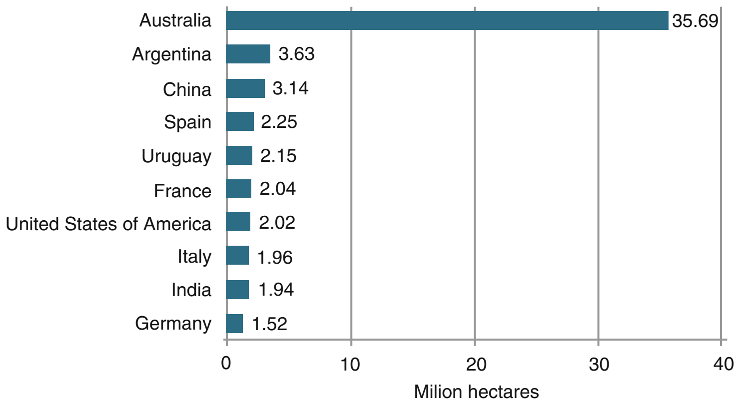

Fig. 4.1 Farmland under organic cultivation of ten top countries in 2018. (Source FiBL 2020)

2018–2019, India exported 6.389 lakh MT, and total earning was around INR 4686 crore (Li et al. 2019).

In India, approximately 3.67-million-hectare agriculture area are used for the organic farming. Among the Indian provinces, Madhya Pradesh represent the large land for organic farming followed by Rajasthan, Maharashtra, Gujarat, Karnataka, Odisha, Sikkim, and Uttar Pradesh. In 2016, Sikkim converts its entire land for organic farming production. Globally, the USA, Canada, Switzerland, Australia, Japan, UAE, New Zealand, etc., pay more attention for organic farming (Li et al. 2019). Despite of development in this field, organic farming has not yet so popular, and it is not an easy task for Indian farmers to switch to organic farming as there is no policy for encouraging the spirit of farmers to opt organic agriculture. Still, it is necessary to promote organic farming over the conventional farming as it is the need of the hour (Bhatt and Nailwal 2018; Khati et al. 2018; Gangola et al. 2018; Bhatt 2018; Bhatt and Barh 2018; Bhatt et al. 2019c; Bhandari and Bhatt 2020; Bhatt and Bhatt 2021).

4.2 Effect of Heavy Metals on Different Crops

Heavy metals are present in toxic amount in the city waste water which goes to the adjoining areas of different cities. It contains considerable quantities of toxic elements. Many unused electronic instruments and heavy metal containing batteries are discarded which also serve as a source of heavy metals in groundwater resources. The various elements Cd, Cu, Zn, and Pb are most likely to cause phytotoxicity when waste water is applied to agricultural field or land where different types of crops are growing (Bhatt and Maheshwari 2019, 2020b, c). However, heavy metals are required for growth and upkeep of plants, but their excessive amounts become toxic to plants. Accumulation of essential metals in plants enable them to acquire other nonessential metals (Zhou et al. 2008). Some heavy metals in the soil also have an effect on the growth of soil microbes (Gulser and Erdogan 2008).

Increased application of agrochemicals and inorganic fertilizers is more in practice which has caused agricultural pollution leading to degradation of the ecosystem and the environment (Malik et al. 2017). Industrial development also caused negative impact on the environment (Dhami et al. 2013); however, due to industrialization, there is rise in global economy over the last century, but it has led to a dramatic increase in production and release of hazardous metals to the environment (Gerhardt et al. 2009; Gallego et al. 2012; Burger 2008; Central Pollution Control Board [CPCB] 2007).

Among the heavy metals, zinc and copper are very essential for plant growth, but when present at elevated levels in soils, they become toxic and can ultimately cause the death of plants. When the effect of these heavy metals studied, it is found phytotoxic to mung bean and have adverse effect on different growth parameters such as seedling height (Narwal et al. 1992), chlorophyll content (Khandelwal 1993), and nitrogen content (Singh 1999; Rani 2011). Reduction in all these parameters ultimately affects the total grain yield of the crops. Except this, Pb and Cd are also found in very low concentration. These are not beneficial for the plants, but even their low concentration has adverse effects on plant growth. High concentration of arsenic showed inhibitory effect on seed germination and seedling growth of wheat (Zhang et al. 2010) as well as on length of plumule and radicle of *Helianthus annuus* (Imran et al. 2013). The vegetable crops production at the heavy metal-contaminated soil showed variability in heavy metal accumulation. The vegetables can be successfully grown into the zinc- and copper-contaminated soils, where some of them such as mustard, soybean, and spinach cannot be cultivated (Singh et al. 2012). The accumulation of the heavy metals into the vegetable crops affect the human health directly due to their entry via food chain (Fu et al. 2008; Bonanomi et al. 2016).

The occurrence of heavy metals in groundwater is reported from western Uttar Pradesh, India, and all four districts Shahjahanpur, Bareilly, Moradabad, and Rampur have excessive presence of cadmium (Idrees et al. 2018). Status of different heavy metals like As, Cd, Pb, and Hg has been investigated in most commonly used cereals and legumes of Bareilly district of Uttar Pradesh (India). Among cereals, rice contains the highest levels of all these heavy metals; however, As, Pb, and Hg accumulation is also found in wheat and maize at lower level. Cd level remains significantly higher in maize than wheat, and levels of arsenic remain similar among different legumes (Lipismita and Garg 2012). Growth reduction as a result of changes in physiological and biochemical processes in plants growing on heavy metal-polluted soils has been recorded (Chatterjee and Chatterjee 2000; Oncel et al. 2000; Oancea et al. 2005).

It has been clear that heavy metal contamination causes loss of bacterial species richness and a relative increase in soil actinomycetes or even decreases in both the biomass and diversity of the bacterial communities in soil (Karaca et al. 2010). By using microbial-based fertilizers, the soil health can be improved, and by doing so, sustainability of environment can be maintained.

4.3 Soil Health in Non-organic and Organic Farming Sites

Soil health is affected by the presence of microorganisms which play an important role for crop production and final yield. Soil bacteria and fungus increase soil fertility. 1gm. of fertile soil may have around 400,000 fungi (Griffiths et al. 1999). During the comparative study of organic and inorganic sites, it has been found that the organic soil has enormous amount of microorganism than inorganic sites. This is due to the frequent use of green manure in organic soil (Khanna et al. 2010). Due to the presence of richness of nutrients in the organic soil, growth of microorganism is directly affected. It has been consistently reported that soil organic matter favours the growth of bacteria present in soil. The studies have revealed that bacterial diversity in soil is approximately 100 times greater than the other microbial diversity (Barns et al. 1999). *Pseudomonas* and *Bacilli* however are found in both types of farming sites, but the richness is much higher in organic sites. Nitrogen (N) is a very essential element for the growth of leaves and stem which also plays an important role in the formation and proper functioning of chloroplast. The organic field has high nitrogen content as compared to non-organic farming site. The higher amount of nitrogen in organic site is due to addition of compost and green manure which increases soil fertility. Although chemical compounds as urea and nitrogen fertilizers are also use in non-organic site, they are not available for plants due to their precipitation (Barns et al. 1999; Sharma and Bhatt 2016).

Soil organic carbon (SOC) of organic farming site was found to be higher as compared to non-organic farming site. Soil acts as a main reservoir of carbon, and the higher SOC value is the direct indication of level of soil health. Soil organic matter (SOM) present in the soil adds more nutrients to the soil. Good soil fertility increases aeration, water holding capacity, proper root growth, and soil microflora which finally affects crop yield. According to a global review, the soils in organic cropping systems have significantly higher levels of SOC than those in conventional systems (Sharma et al. 2016).

Phytohormones also play an important role in plant growth and directly affect the final yield of any crop. Indole acetic acid (auxin) has many physiological roles in plant development. Low concentration of auxin induces the root growth which increases the water absorption. The environmental factors and soil microflora affect the auxin activity.

4.4 Role of Microbes in Treatment of Soil Polluted with Xenobiotics

Agriculture plays an important role in Indian economy. India holds the second largest position in growing wheat and rice, the staple food of the world. It is the need of the hour to increase the soil fertility and productivity of crops to fulfil the food requirements of the large population. Different types of fertilizers and

Table 4.1 Microbial diversity in soil

Microorganism	Plant	Plant growth regulation	References
Bacillus amyloliquefaciens 5113 and *Azospirillum brasilense* NO 40	Wheat	Enhance plant growth under drought condition and increase enzyme activity in wheat	Edwards and Lofty (1974)
Pseudomonas aeruginosa FP6	Chili	Siderophore produced by bio-control strain to reduce metal pollution	Amir and Fouzia (2011)
Bacillus and *Pseudomonas* spp.	*C. annum* L	Plant growth enhancement and bio-control management to control plant disease	Kasim et al. (2013)
Mesorhizobium spp.	Chickpea	Increase nodulation, enhance, and uptake of nutrient yield	Sasirekha and Srividya (2016)
Bacillus thuringiensis	Wheat	Decrease volatile emissions and increase photosynthesis	Kumar et al. (2014)
Trichoderma harzianum Tr6 and *Pseudomonas* sp. *Ps 14*	Cucumber and *Arabidopsis thaliana*	Induced systemic resistance	Verma et al. (2013)

pesticides are being used to increase production; thus further, intensive utilization of chemical fertilizers and pesticides for higher crop production may become destructive and detrimental for soil and food quality (Gattinger et al. 2012). Soil rich in microorganism directly affects the agricultural productivity. Number of microorganism can be increased by use of biofertilizers and biopesticides. With the help of microorganism, plants absorb nutrients at a promising speed. These microorganisms get food from the waste by products of plants.

Plant growth-promoting (PGP) microbes and PGPR play very important role to cope up with heavy metal pollution of soil. They increase soil fertility, bioremediation, and stress management for development of eco-friendly sustainable agriculture. Different types of bacteria such as *Bacillus*, *Pseudomonas*, *Azotobacter*, etc. are beneficial for plant growth (Table 4.1). The bacterial count remains higher in the organic farming site in comparison to non-organic farming site. Regular use of chemicals in fields decreases the C—compound in the soil which is necessary for microbial growth. High CFU counts in organic farming soil may be due to nutrient richness and absence of high concentration of heavy metal ions that are inhibitory for microbial growth (Kang et al. 2016). Organic manure increases the carbon source in the soil which is beneficial for the microbes as it increases the growth and activity. By increasing microbial count, bioremediation of the soil can be done as this is the way to treat heavy metal-polluted soil. Several comparisons of organic and conventional farming systems have indicated significant impact of soil microbial community on agricultural practices (Smith et al. 2012; Liao et al. 2018; Hartmann 2015; Li et al. 2012).

Naturally available technologies for enhancement of agriculture and management of agricultural waste are being aimed by scientist. Indigenous microorganism (IMO)-based technology is being applied in the eastern part of the world for the extraction of minerals, enhancement of agriculture, and waste management (Rajeshwari 2017). Bacteria are helpful in nitrogen fixation and many other biological processes. *Rhizobia* are found in symbiotic association in root nodules of legumes. Cyanobacteria are helpful in binding the soil molecules as they act as cementing material. *Pseudomonas* sp. are used for remediation. Secondary metabolites have very effective and vital role in plant growth. Microbes are also helpful in production of such metabolite which stimulates the growth and development in plants. Micro-organism may also be protective towards the plants, and rhizosphere soil microbes form a physical barrier around the roots of plants and reduce the invasion of pathogens and pests by providing healthy micro-ecological environment (Table 4.1) (Wu and Lin 2003).

Vermiculture is also a very important tool for organic farming. It is low input farming in comparison to conventional farming. Many researchers reported that vermiculture in organic farming sites is more benefited than in conventional farming site (Timmusk et al. 2014). It is reported that biodegradation process is enhanced when earthworms and microbes work together and produce vermicompost, which is worm fecal matter with worm casts. Vermicompost provided macro-elements such as N, P, K, Ca, and Mg and microelements such as Fe, Mo, Zn, and Cu (Lim and Kim 2013).

The indigenous microbial strains are able to remediate the xenobiotic compounds from the soil and water system (Bhandari et al. 2021). The bacterial and fungal strains are able to degrade the pesticides, antibiotics, endocrine disrupting chemicals, and other organic compounds from the environment (Bhatt et al. 2021a). These microbial strains accelerate the residual level of toxic chemicals from the environment and enhance the sustainable developments (Bhatt et al. 2021b). These potential microbial strains are used throughout the globe for the remediation of the toxic xenobiotics from the contaminated sites (Bhatt et al. 2021c).

4.5 Conclusion

It is the need of the hour to fulfil the food requirements of the huge Indian population. Due to the increasing population and industrialization, the discharge of polluted waste water and agricultural waste is also increasing. As a result, the heavy metals are adversely affecting soil health due to their toxic and non-biodegradable nature. An ideal agriculture system should be developed to improve soil health and for sustainable environment. To increase the yield of any crop, chemicals and pesticides are frequently used by Indian farmers; as a result, soil health is continuously deteriorating. There are many techniques to improve the soil health. Microorganisms play very important role for improving soil health contaminated by heavy metals and for the sustainable environment. It has been proved that they are beneficial for society and environment. By using them, we can get social, economic, and environmental benefits. It is well understood that by increasing microbial communities in the soil and by detection of heavy metals present in the soil, total yield can be enhanced. Organic green manure is well suited for the proper growth of PGPRs and other microbes. The frequent use of the chemicals and pesticides in inorganic fields is harmful. Although it is bitter truth that natural and organic farming is costly as compared to conventional farming and the farmers adopting organic farming face difficulty to survive and market the organic products, but to improve soil health and for development of sustainable environment, farmers should be motivated for organic farming as it can provide quality food without any harmful effect on soil health. Organic farming can be done with proper planning for the betterment of mankind and upcoming generations, and economically sustainable organic farming is the prerequisite for ensuring affordability of organic products at consumer's end.

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