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BIOPESTICIDES

ADVANCES IN BIO-INOCULANTS

VOLUME 2

Edited by
AMITAVA RAKSHIT, VIJAY SINGH MEENA,
P. C. ABHILASH, B. K. SARMA, H. B. SINGH,
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Biopesticides

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Contents

6. Entomopathogenic nematodes: a sustainable option for insect pest management

Ashish Kumar Singh, Manish Kumar, Amit Ahuja, B.K. Vinay, Kiran Kumar Kommu, Sharmishtha Thakur, Amit U. Paschapur, B. Jeevan, K.K. Mishra, Rajendra Prasad Meena and Manoj Parihar

7. Scientific and technological trajectories for sustainable agricultural solutions: the case of biopesticides

Alejandro Barragán-Ocaña, Paz Silva-Borjas and Samuel Olmos-Peña

8. Biopesticides: a genetics, genomics, and molecular biology perspective

Pawan Basnet, Rajiv Dhital and Amitava Rakshit

9. *Bacillus thuringiensis*, a remarkable biopesticide: from lab to the field

Igor Henrique Sena da Silva, Marcelo Mueller de Freitas and Ricardo Antônio Polanczyk

10. Biopesticides for management of arthropod pests and weeds

Josef Jampílek and Katarína Kráľová

11. *Salvia leucantha* essential oil encapsulated in chitosan nanoparticles with toxicity and feeding physiology of cotton bollworm *Helicoverpa armigera*

Devakumar Dinesh, Kadarkarai Murugan, Jayapal Subramaniam, Manickam Paulpandi, Balamurugan Chandramohan, Krishnasamy Pavithra, Jaganathan Anitha, Murugan Vasanthakumaran, Leonardo Fernandes Fraceto, Lan Wang, Jiang Shoiu-Hwang and Hans-Uwe Dahms

12. Microbial bio-pesticide as sustainable solution for management of pests: achievements and prospects

Udayashankar C. Arakere, Shubha Jagannath, Soumya Krishnamurthy, Srinivas Chowdappa and Narasimhamurthy Konappa

15. Insights into the genomes of microbial biopesticides

A.B. Vedamurthy, Sudisha Jogaiah and S.D. Shruthi

16. Genetic engineering intervention in crop plants for developing biopesticides

Shambhu Krishan Lal, Sahil Mehta, Sudhir Kumar, Anil Kumar Singh, Madan Kumar, Binay Kumar Singh, Vijai Pal Bhadana and Arunava Pattanayak

17. Medicinal plants associated microflora as an unexplored niche of biopesticide

Ved Prakash Giri, Shipra Pandey, Satyendra Pratap Singh, Bhanu Kumar, S.F.A. Zaidi and Aradhana Mishra

18. *Trichoderma*: a potential biopesticide for sustainable management of wilt disease of crops

Narasimhamurthy Konappa, Nirmaladevi Dhamodaran, Soumya Satyanand Shanbhag, Manjunatha Amitiganahalli Sampangi, Soumya Krishnamurthy, Udayashankar C. Arakere, Srinivas Chowdappa and Sudisha Jogaiah

19. Biological inoculants and biopesticides in small fruit and vegetable production in California

Surendra K. Dara

20. Development and regulation of microbial pesticides in the post-genomic era

Anirban Bhar, Akansha Jain and Sampa Das

21. Microbial biopesticides for sustainable agricultural practices

Indu Kumari, Razak Hussain, Shikha Sharma, Geetika and Mushtaq Ahmed

22. Use of microbial consortia for broad spectrum protection of plant pathogens: regulatory hurdles, present status and future prospects

Ratul Moni Ram, Ashim Debnath, Shivangi Negi and H.B. Singh

23. Biocides through pyrolytic degradation of biomass: potential, recent advancements and future prospects

Avedananda Ray, Sabuj Ganguly and Ardith Sankar

24. *Trichoderma*: agricultural applications and beyond

R.N. Pandey, Pratik Jaisani and H.B. Singh

25. Exploring the potential role of *Trichoderma* as friends of plants foes for bacterial plant pathogens

Narasimhamurthy Konappa, Udayashankar C. Arakere, Soumya Krishnamurthy, Srinivas Chowdappa and Sudisha Jogaiah

26. Advance molecular tools to detect plant pathogens

R. Kannan, A. Solaimalai, M. Jayakumar and U. Surendran

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Chapter 17

Medicinal plants associated microflora as an unexplored niche of biopesticide

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17.1 Introduction

17.1.1 Medicinal plant diversity in India

India is one of the most diverse countries in the world having a rich repository of high value, endemic and rare medicinal plants (Kamboj, 2000; Krishnan et al., 2011). India is one of the 12 mega diversity countries in the world having four biodiversity hotspots. Concerning plant diversity, India's ranks 10th in the world and fourth in Asia (Singh and Chaturvedi, 2017). The reason behind this vast diversity is the presence of different climatic conditions such as alpine in the Himalayas to arid zones in Rajasthan. There are tropical forests in the Western Ghats while plateaus, mountains and valleys in North-Eastern states (Ganie et al., 2020). Apart from varying topography, soil, rainfall, temperature, humidity conditions also differ from place to place which gives rise to huge phytodiversity. The microclimatic variations further leads to differences in the phenology, metabolism, physiology, chemical profile and even morphology of plants in addition to growth patterns across the geography (Ncube et al., 2012).

India is a repository of vast traditional knowledge and a deep-rooted system of indigenous medicine. According to a report from the Government of India, about 75% of the Indian population including the majority of tribal and ethnic communities are mostly dependent on the traditional knowledge and practices for primary health care needs (Kala et al., 2006; Dhakal et al., 2020). The age-old Indian traditional medicine system "Ayurveda" is very extensive in terms of the plants used, owing to the great phytodiversity of the country. In India, there are several traditional systems of the medicine being practiced in different regions.

According to an estimate, more than 45,000 plant species are commonly found in India out of which flowering plants constitute around 15,000—18,000; members of bryophytes are around 1800; algal species are 2500; 1600 lichens; 23,000 fungal species exist in India (Bharucha, 2006; Sharma et al., 2008). The surveys conducted by several workers have revealed that approximately 20,000 plant species are having one or the other medicinal properties (Mukherjee, 2008; Kumar et al., 2019). From Indian Himalayan Region (IHR) itself, 357 species of medicinal plants belonging to 237 genera and 98 families were recorded. Asteraceae, Lamiaceae, Rosaceae, and Ranunculaceae were the dominant families in the IHR region. The IHR alone supports about 8000 species of angiosperms (40% endemics), 44 species of gymnosperms (15.91% endemics), 600 species of pteridophytes (25% endemics), 1737 species of bryophytes (32.53% endemics), 1159 species of lichens (11.22% endemics) and 6900 species of fungi (27.39% endemics) (Sharma et al., 2014).

The worldwide consumption of herbal medicines has markedly increased. According to the Secretariat of the Convention on Biological Diversity, global sales of herbal products were estimated to be the US $60 billion in 2000. The sale of herbal medicines is expected to get higher at an average annual growth rate of 6.4% (Inamdar et al., 2008). In 2008, the global market for herbal remedies was about the US $83 billion with a steady growth rate ranging between 3% and 12% per year (Zhang et al., 2012a,b). The market for herbal drugs has seen a good tendency of growth at a fast rate worldwide.

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There are several factors responsible for growth like increased general awareness in people to protect from the side effects of synthetic medicine (Zahra et al., 2020), more inclination of masses toward Ayurveda and herbal treatment; require upgradation in quality and evaluation of efficacy and safety of herbal medicines in minimal cost (Calixto, 2000; Krishna et al., 2020).

In India, the medicinal plant market is mostly unorganized at present. Most of the herbal drug manufacturers procure the raw material from the wild by overexploitation of available natural resources (Laladhas et al., 2015). Due to unavailability of sufficient quantity of raw material, adulteration of inferior quality raw material or similar-looking plant species to the genuine drug is common practice in many of the herbal drug industries (Dubey, 2004; Kunle et al., 2012; Shaheen et al., 2019a,b). The value of medicinal plants related trade in India is the US $5.5 billion, although its share in the global export market of herbal drugs is less than 0.5%. The export potential of China in medicinal plants is nearly INR 18,000−22,000 crores. India exports crude drugs mainly to developed countries like the USA, Germany, France, Switzerland, the UK and Japan. The Indian herbal drugs exported to foreign countries mainly include Aconite, Aloe, Belladonna, Acorus, Cinchona, Cassia tora, Dioscorea, Digitalis, Ephedra, Plantago and Senna, etc. (Joshi, 2019). About 165 herbal drugs and their extract are exported from India (Prajapati et al., 2003; Ali, 2009). Overall, it can be said that despite having huge biodiversity and endemic medicinal plants, whereas our herbal drug market has not yet grown to its full potential. We are lagging behind in terms of herbal drug manufacture and export in comparison to countries like China due to a lack of proper attention and governmental policy for the Indian herbal drug market potential. However, in recent years the Ministry of AYUSH and related departments are taking care of these issues.

17.1.2 Niche of microflora

Microorganisms are considered as pillars of the existence of life on earth and represent the finest repertoire in molecular, protein as well as chemical versatility in nature (Chatterjee, 2019). After the origin of life on earth, they are evolved in the basics of life such as ecological processes, biogeochemical cycles and food chains even maintaining critical relationships between themselves as well as with other organisms existing on earth (Dick, 2019; Matthews et al., 2020). As a result of all contributions, microbes are efficiently reconstructing the geographical conditions, ecosystems and consequently providing better conditions for the development and proliferation of multicellular organisms (Hunter-Cevera, 1998).

17.2 Plant-microbe association

Traditional medicinal plants have a great impact on pharmaceutical industries by contributing bio-active compounds as herbal supplements and medicine development for human health care along with a nontoxic and cost-effective manner. The World Health Organization (WHO) defined the medicinal plants as “the plant which one or more of their organs contains substances that can be used for therapeutic purposes as well as used as precursors for chemosynthesis of pharmaceutical drugs.” Many countries; Asia, China, Egypt and Africa’s primary health care is dependent on native medicinal plants as written in their historic background. Bioactive compounds of medicinal plants known as their primary and secondary metabolites *viz*: phenolics, alkaloids, steroids, flavonoids, tannins, terpenes, essential oils, saponins, and anthraquinones, etc. used for the treatment of various diseases and body ailments (Egamberdieva and de silva, 2015). The plant microbiome is an important factor for increasing the synthesis of bioactive compounds and the production of secondary metabolites. They commonly reside along with the rhizospheric, phyllospheric, and endospheric region of the plants.

17.2.1 Rhizospheric association of microbes

The relationship between medicinal plants and microbes plays a pivotal role in the biosynthesis of metabolites. Soil, a reservoir of bacterial, fungal and actinomycetes and their activities are the major driving factor for soil and plant health (Compant et al., 2010; Aislabie et al., 2013; Müller et al., 2016). The rhizosphere is the surrounding area of the soil which is intimately associated with the root system of the plant have great availability and activity of heterogeneous microorganisms due to presence of root exudates and other organic nutrients (Hartmann et al., 2008; Poole, 2017; Hu et al., 2018). Root exudates are partially translocate to the carbon and excretory substances that are fixed by photosynthesis and other metabolic pathways in plants (Bais et al., 2006). The rhizospheric microbiome is highly productive than other part of plant microflora associated with the rhizospheric region shows an array of interactions that influence the growth and metabolome of medicinal plants (Huang et al., 2018). Several beneficial microbe’s interactions with plants and their functional features mentioned in Table 17.1.

TABLE 17.1 Beneficial microbe's interaction with plants.

Sr. No.	Microbes	Beneficial activity with plant	References
Bacteria			
	Agrobacterium sp.	Indol-3-acetic acid producing bacteria enhances plant growth and development.	Mohite (2013)
	Rhizobium leguminosarum	Indol-3-acetic acid production; promoting growth after inoculation on axenically grown rice seedlings.	Ruzzi and Aroca (2015)
	Enterobacter sp.	Fixed significantly higher amounts of atmospheric nitrogen and produced higher amounts of Indol 3 acetic acid.	Kumar et al. (2017)
	Azospirillum brasilense	Mutual exchange of resources involved in producing and releasing the phytohormone; production of IAA by the bacterium, using tryptophan and thiamine.	Palacios et al. (2016)
	Bacillus subtilis	Plant growth promotion by spermidine-production.	Xie et al. (2014)
	Paenibacillus polymyxa	Produce plant growth regulating substances such as cytokinin.	Poehlein et al. (2018)
	Methylobacterium	Induces the synthesis of cytokinin in soybean plants	Holland et al. (2002)
	Pseudomonas protegens	Assessing the influence of fatty acid on antibiotic and siderophore production.	Quecine et al. (2016)
	Rhizobium leguminosarum	Nodulation, nitrogen fixation and plasmid transfer.	Boyer and Wisniewski-Dye (2009)
	Staphylococcus arlettae	Reduction of Arsenic and availability of phosphorus.	Srivastava et al. (2013)
	Pseudomonas koreensis	Prevent Heavy metal toxicity like Zn, Cd, As, Pb.	Babu et al. (2015)
	Pseudomonas sp.	Phosphate solubilizing activity	Otieno et al. (2015)
	Gluconacetobacter diazotrophicus	Colonization in rice plant and showing plant growth promotion.	Santoyo et al. (2016)
	Pantoea agglomerans	Up-regulation of aquaporin genes and induction of salt tolerance in tropical corn.	Gond et al. (2015)
	Pseudomonas vancouverensis	Tolerance to cold/chillimg stress and reduction of ROS.	Subramanian et al. (2015)
	Frankia sp.	Induce the formation nodules on the roots of their dicotyledonous host plants.	Van Nguyen and Pawlowski (2017)
	Nocardia sp.	Root nodule formation in host plant and promoting seedling growth.	Ghodhbane-Gtari et al. (2018)
	Kitasatospora sp.	Indole-3-acetic acid production for soil applications.	Shrivastava et al. (2008)
Fungus			
	Piriformospora indica	Colonization in root and induces the plant innate immunity evaluated by determining the phytoalexin and camalexin concentration.	Peskan Peskan-Berghöfer et al. (2015)
	Trichoderma viride	Produce auxins, small peptides, volatile compounds and other active metabolites that promote root branching along with plant growth and development.	López-Bucio et al. (2015)
	Talaromyces wortmannii	Emitted several terpenoids including β-caryophyllene which inducing resistance of *Brassica campestris* L. var. *perviridis* along with growth of plants.	Yamagiwa et al. (2011)
	Aspergillus spp., *Fusarium* spp., *Penicillium* spp., *Piriformospora* spp., *Phoma* spp., and *Trichoderma* spp.	Well-known fungal genera for plant growth promotion activity.	Hossain et al. (2017)

Continued

TABLE 17.1 Beneficial microbe's interaction with plants.—cont'd

Sr. No.	Microbes	Beneficial activity with plant	References
	Piriformospora indica	Symbiotic interaction with *Arabidopsis thaliana* and induces the performance of plant and tolerance against stress.	Vahabi et al. (2015)
	Neotyphodium lolii	Superoxide dismutase (SOD) activity changed in host plants.	Tian et al. (2008)
	Westerdykella aurantiaca	Promotes protein and carotenoid production.	Srivastava et al. (2012)
	Trichoderma longibrachiatum	Increases salt tolerance of Wheat by improving the antioxidative defense system and gene expression	Zhang et al. (2016)
	Aspergillus niger	Promotes accumulation of phenolic, salicylic acid, and chlorophyll contents.	Anwer and Khan (2013)
	Fusarium equiseti	Inhibits proliferation of pathogen and disease resistance.	Kojima et al. (2013)
	Trichoderma asperellum	Biocontrol activity against phytopathogens.	Islam et al. (2016)
	Penicillium chrysogenum	Induces systemic acquired resistance (SAR), which enhances defenses in plants.	Chen et al. (2018)
	Trichoderma virens	Antagonize biocontrol agent against pathogens of crop plants.	Lamdan et al. (2015)
	Aureobasidium pullulans	Contribution in biological treatment slight increase contents of tocols, alkylresorcinols and sterols in grains.	Wachowska et al. (2016)
Actinomycetes			
	Streptomyces rochei	Promotes soil enzyme productivity.	Jog et al. (2012)
	Streptomyces thermolilacinus		
	Streptomyces toxytricini	Promotes the accumulation of phenolics and chlorophyll.	Patil et al. (2011)
	Streptomyces coelicolor *Streptomyces olivaceus*	Promotes the production of ammonia, siderophore, IAA and prevent water stress tolerance.	Yandigeri et al. (2012)
	Streptomyces spp.	Production of Siderophore, ammonia, phosphate solulization activity, nitrogen fixation.	Kaur et al. (2013)
	Thermomonaspora fusca	Production of siderophore.	Dimise et al. (2008)

Several microbes present in the rhizospheric area shows plant growth-promoting (PGPR) activity (Kloepper, 1978), they provide soil nutrients to plants and control the biotic and abiotic stresses. Mainly *Bacillus, Pseudomonas*, *Azospirillum, Burkholderia, Bacillus, Enterobacter, Rhizobium, Erwinia, Serratia, Alcaligenes, Arthrobacter, Acinetobacter* and *Flavobacterium* has the potential to be a competent rhizospheric bacteria and express the PGPR activity (Berg et al., 2011; Kushwaha et al., 2020). The PGPRs used as mainly bio-fertilizers have shown symbiotic behavior by root-nodulation and nitrogen-fixing property, whereas phosphate solubilizing microbial inoculant provides insoluble or bound phosphate into a soluble form (Bhat et al., 2015). Some species of *Bacillus* produce volatile organic compounds for plant growth promotion (Bitas et al., 2013; Köberl et al., 2013). Similarly, Phyto-stimulators produce Auxins which involves in root elongation and development. Several strains of *Azospirillum* enables plant growth promotion by producing the auxins, cytokinins and gibberellins that are essential for plant health and growth (Çakmakçõ et al., 2020). Even though, rhizospheric microbial load distinct in medicinal plants due to the secretion of specific bio-active secondary metabolites (Qi et al., 2012). PGPRs indirectly boots the plant's immune system by secretion of proteins and carbohydrate compounds which initiate signaling and plant system recognized between pathogenic and non-pathogenic microbes (Macho and Zipfel, 2014; Pusztahelyi, 2018). Rhizoremediators; plant microbiome association reveal as a promising tool for the removal of soil pollutants and contaminants. The rate of degradation of pollutants accelerates in the rhizospheric region due to the production of organic acid and biofilm formation (Kumar et al., 2020; Saravanan et al., 2020).

17.2.2 Phyllospheric association of microbes

Above ground portion of plants including stem, leaves, flowers and fruits are prominent compartments where the abundance of the microbial community can be made a direct effect with the host plant (Mechan Llontop, 2020). Phyllospheric microbiome performs several constitutive roles subjected to plant growth and development, in terms of N_2 fixation, 60 kg N/ha only fixed by tropical plant phyllosphere and biosynthesis of various phytohormones for the protection of associated plant against pathogenic invaders. Furthermore, they also have a lot of potentialities which can be useful for the development of new strategies in agriculture practices. The phyllosphere microbial communities containing bacteria, fungi, viruses, and algae their density can be reached up to 105−107 per cm^2 (Alam, 2014). Phyllospheric microbial communities are also beneficial to the survival of plants in harsh conditions such as, limited concentrations of organic substances, variable pH, O_2 concentration, temperature, UV, humidity, etc. (Verma et al., 2017). Because of the close attachment with several environmental factors, the microbial load at the phyllosphere drastically fluctuating in the same species of plants as well as at the same developmental stage (Bulgarelli et al., 2013). These significant alterations in microbial dynamics are also the possible reason that imprinted the great versatility in the nutritional depositions at the phyllospheric region. The appearance of leaf and other areal parts of the plant largely influenced by the microbial load on the plant. Therefore, the narrow leaf containing grasses and wax containing broad-leaf plants having less microbial load as compared to cucumber and beans plants (Sivakumar et al., 2020). Different microbial communities are associated with plants at specific sites presumably because of differences in light or UV intensity, air flow rate, humidity, etc. For instance, pigment-producing bacterial strains are mostly inhabiting at the epiphytic region whereas, mineral and humic acid utilizing bacterial communities are found at the rhizosphere (Rana et al., 2020). This evidence was further authenticated by other findings where common root colonizers such as *Rhizobium* and *Bradyrhizobiaum* are unable to colonize the epiphytic regions of the same plant (Martínez-Hidalgo and Hirsch, 2017).

17.2.3 Endophytic microbiome association with medicinal plants

Plant associated endophytic microbiome strongly affects the quality and synthesis of bioactive secondary metabolites by medicinal plants. Endophytes protect plants against abiotic and biotic stresses by producing secondary metabolites (El-Deeb et al., 2013; Egamberdieva et al., 2017). Recently, Mishra et al. (2018) have observed the effects of endophytic bacteria *B. amyloliquefaciens* (BA) and *Pseudomonas fluorescens* (PF) individual as well as in combination on *W. somnifera* during *A. alternata* (AA) infection. Significant reductions in disease incidence and biotic stress amelioration have been recorded after the treatment of endophytic inoculants, their visual observation represented in Fig. 17.1. Several reports are highlighted the increased secondary metabolites production by endophytes and plant associations. Secondary metabolites rich source of pharmaceutical and modern therapeutic products (Pan et al., 2013), because microbes can produce a diverse range of metabolites includes terpenoids, alkaloids, antibiotics, alkaloids, polypeptides, isocoumarins, quinones, phenylpropanoids, lignans and aromatic compounds (Zhang et al., 2006; Gao et al., 2010). Various novel metabolites have been synthesized to the production of novel products for the anticancer, immune-modulatory agent, anti-parasitic, insecticidal, pesticidal, antiviral, antimicrobial agents at the industrial level, some microbes known for increasing the production of medicinal plant metabolites mentioned in Table 17.2. Apart from this, novel metabolites opens-up an opportunity for the development of new drugs for antimicrobial resistance and *anti*-HIV. Due to the increasing demand for potent metabolites and less availability of medicinal plants, endophytes are grown at a commercial level to enhance the production at large amounts of metabolites. In addition, fungal endophytes are also an essential component of medicinal microflora. Their symbiotic relationship with the mediational plant can considerably influence the secondary metabolite production by participating in a mechanistic way of the metabolic pathway (Gupta and Chaturvedi, 2019).

FIG. 17.1 Effects of endophytic bacteria *B. amyloliquefaciens* (BA) and *P. fluorescens* (PF) singly as well as in combination on *W. somnifera* during *A. alternata* (AA) infection. *Image adopted from Mishra et al. (2018).*

TABLE 17.2 Microbial association with medicinal plants.

Sr. No.	Plant	Microbes	Function	References
1.	*Andrographis paniculata*	*Glomus mosseae* and *Trichoderma harzianum*	Improve Phosphorous uptake and alkaloid production	Arpana and Bagyaraj (2007)
2.	*Neptunia oleracea*	*Rhizobium undicola*	IAA production	Ghosh et al. (2015)
3.	*Ocimum sanctum, Coleus forskohlii, Catharanthus roseus, Aloe vera*	*Azospirillum* *Azotobacter* *Pseudomonas*	N_2 fixation	Karthikeyan et al. (2008)
4.	*Ocimum basilicum,*	*Bacillus lentus* and *Pseudomonas*	ACC-deaminase activity	Golpayegani and Tilebeni (2011)
5.	*Mentha arvensis*	*Bacillus pumilus, Halomonas desiderata* and *Exiguobacterium oxidotolerans*	ACC-deaminase activity	Bharti et al. (2014)
6.	*Origanum vulgare*	*Pseudomonas, Stenotrophomonas*	Antioxidant activity increases	Solaiman and Anawar (2015)
7.	*Mentha piperita*	*Pseudomonas fluorescens*	Essential oil contents (+) pulegone and (−) menthone enhance	Santoro et al. (2011)
8.	*Mucuna pruriens*	*Rhizobium meliloti*	Siderophore production	Arora et al. (2001)
9.	*Piper nigrum*	*Pseudomonas and Azospirillum* sp.	phosphate-solubilizing ability	Ramachandran et al. (2007)
10.	*Ocimum sanctum*	*Achromobacter xylosoxidants*	ACC-deaminase activity and lower ethylene level	Barnawal et al. (2012)
11.	*Bacopa monnieri*	*Glomus mosseae*	Enhance plant growth and salinity tolerance	Khaliel et al. (2011)
12.	*Sorghum bicolor*	*Glomus mosseae* or *Glomus intraradices*	Enhanced production of alcohols, alkenes, ethers and acids	Sun and Tang (2013)
13.	*Artemisia annua*	*Glomus mosseae* and *Bacillus subtilis*	Enhance yield of artemisinin	Awasthi et al. (2011)
14.	Musli	*Piriformospora indica* and *Pseudomonas* *Fluorescens*	Enhance survival rate	Gosal et al. (2010)
15.	*Sphaeranthus amaranthoides*	*Glomus walkeri*	Increases the production of phenols, ortho-dihydroxy phenols, flavonoids, alkaloids, and tannins	Sumithra and Selvaraj (2011)
16.	*Zingiber cassumunar*	*Arthrinium* sp.	Antioxidant and antimicrobial activity against human pathogens	Pansanit and Pripdeevech al. (2018)
17.	Basil	*Bacillus subtilis*	α-terpineol and eugenol	Banchio et al. (2009)
18.	*Teucrium polium*	*Bacillus* sp. *and Penicillium* sp.	IAA production and antimicrobial activity	Hassan (2017)
19.	*Azadirachta indica*	*Phomopsis* sp., *Xylaria* sp.	Ten-membered lactones, Sesquiterpenes	Wu et al. (2008), Huang et al. (2015)
20.	*Rauwolfia tetraphylla*	*Curvularia* sp. and *Aspergillus* sp.	Synthesis of antimicrobial metabolites	Alurappa and Chowdappa (2018)
21.	*Taxus brevifolia*	*Taxomyces andreanae*	Biosynthesis of anticancer; taxol component	Stierle et al. (1995)
22.	*Musa acuminata*	*Phomopsis* sp.	Synthesis of anticancerous compound; Oblongolide	Kharwar et al. (2011), Mishra et al. (2012)

TABLE 17.2 Microbial association with medicinal plants.—cont'd

Sr. No.	Plant	Microbes	Function	References
23.	*Cynara cardunculus*	*Glomus intraradices, G. mosseae*	Increased total phenolic content in leaves and flower heads of *Cynara cardunculus*	Ceccarelli et al. (2010)
24.	*Medicago sativa* L.	*Sinorhizobium meliloti*	Enhance flavonoids in roots of legume plants	Catford et al. (2006)
25.	*Trifolium repens,*	*Glomus intraradices,*	Increases flavonoid content	Ponce et al. (2004)
26.	*Forsythia suspensa*	*Colletotrichum gloeosporioides*	Antioxidant activity, phillyrin	Zhang et al. (2012a,b)
27.	*Mentha arvensis*	*G. fasciculatum*	Increase oil content	Gupta et al. (2002)
28.	*Glycyrrhiza uralensis*	Glomus mosseae and Glomus veriforme	Triterpenoid saponin, Glycyrrhizic acid	Liu et al. (2007)
29.	*Ociimum basilicum*	*G. mosseae*	Enhanced oil yield, Rosmarinic acids, and caffeic acids	Toussaint et al. (2008)
30.	*Pinellia ternata*	*Bacillus cereus, Aranicola proteolyticus, Serratia liquefaciens, Bacillus thuringiensis,* and *Bacillus licheniformis*	Alkaloid production, Guanosine and inosine	Liu et al. (2015)
31.	Opium poppy (*Pappaver sominiferum)*	*Marmoricola* sp.	Enhance alkaloid production, the baine and codeine	Pandey et al. (2016)
32.	*Catharanthus roseus*	*Staphylococcus sciuri and Micrococcus* sp.	Vindoline, ajmalicine and serpentine production	Tiwari et al. (2013)
33.	*Cynodon dactylon*	*Rhizoctonia* sp.	*Anti-Helicobacter pylori* activity, Rhizoctonic acid	Ma et al. (2004)
34.	*Angelica archangelica*	*G. mosseae, G. intraradices*	Enhance monoterpenoids and coumarins	Zitterl-Eglseer et al. (2015)
35.	*Salvia officinalis*	*G. intraradices*	Enhance essential oil content, 1,8-cineole, bornyl acetate, camphor, α-thujone, and β-thujone	Geneva et al. (2010)

Biocontrol activity; many of the microbial inoculants have been recognized for antagonistic activity against phytopathogens. Recently, *Bacillus amyloliquefaciens* and *Pseudomonas fluorescens* have investigated for the biocontrol activity against *Alternaria alternata* causing leaf spot disease in *Withania sominifera* (Mishra et al., 2018). Scanning electron micrographs of biocontrol activity of bacterial endophytes *B. amyloliquefaciens* (BA) and *P. fluorescens* (PF) against *A. alternata* (AA) represented in (Fig. 17.2). Raptured mycelia of AA have shown after the treatment of bio-inoculant BA and PF while untreated control remained healthy mycelia.

Moreover, plant's root endophyte *Arbuscular mycorrhiza* (AM), colonization with the medicinal plant has shown activities in plant growth promotion. 80% of terrestrial plant's roots weaved with AM fungi (Manoharachary and Kunwar, 2015). AM fungi colonize in the root of plants and provide nutrition as well as enhance plant immune system by promoting abiotic and biotic stress amelioration efficacy (Ceccarelli et al., 2010; Hart and Forsythe, 2012). Mycorrhiza *Glomus* colonize with plants and enhance the metabolites *viz*: alcohol, ether, acids (Sun and Tang, 2013).

Some microbes have shown prime importance in pathogen suppression by antibiotic production, which has tremendous industrial importance as *Streptomyces* gram-positive and spore-forming filamentous *Actinobacteria,* used for the production of the largest family of antibiotic for controlling pathogenic microbes (Kemung et al., 2018). *Pseudomonas, Bacillus* and *Trichoderma* spp. are well known for antibiosis responses (Sansinenea and Ortiz, 2013; Contreras-Cornejo et al., 2016; Pandey et al., 2018). These microbes control phytopathogens by producing cell wall degrading enzymes, toxins, bio-surfactants, minerals, etc. (Berg, 2009).

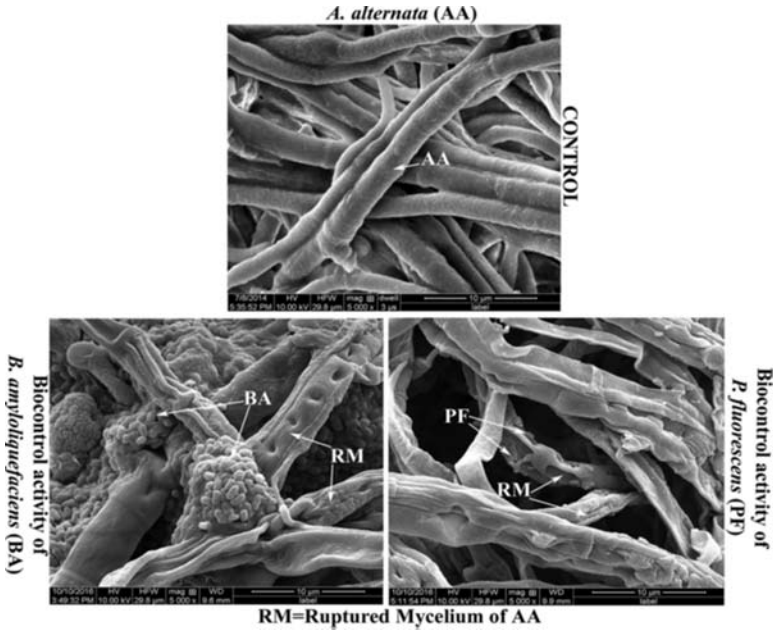

FIG. 17.2 Scanning electron micrographs of biocontrol activity of bacterial endophytes *Bacillus amyloliquefaciens* (BA) and *Pseudomonas fluorescens* (PF) against *Alternaria alternata* (AA). *Image adopted from Mishra et al. (2018).*

17.3 Relative factors between microflora and plants

Endophytes are the next important factor for microbial colonization at phyllospheric region of the plants. This could be also possible that a particular microbial community is found from the plant habitat but the spores are migrating through the flow of wind and colonize at the aerial part of the plant. Based on several studies has been found that air and erosols, water and soil are the most important sources of microbial cells that able to appointed the microbial dynamics at the phyllospheric region of the plants (Bulgarelli et al., 2013).

As similar, plant genotypic variation is also the significant driver of microbial diversity. Even though several plant species are found in the same habitat and environmental conditions but they have specific microbial communities due to diversity of genetic as well as metabolic variations. Geographical parameters also play a constitutive role in the designing of the microbial matrix that influences the quality of the end products manufactured by the host plant (Saad et al., 2020). However, it could be possible to analyze the distinct distribution of microbial matrix. These fluctuations are because of the variations in carbon substrates (i.e. amino acids, glucose, xylose) and nutrients present in the host plants. Despite all, the most common microbial colonizing communities are belongs to proteobacteria, actinobacteria, bacteroidetes and firmicutes (Bodenhausen et al., 2013). Therefore, the introduction of new techniques is should be needed to modify with other taxa of microbial communities associated with the diversified medicinal plants.

17.4 Conclusion and future perspectives

Biodiversity hotspots of India revealed as a rich repository of symbiotically beneficial microbes with endemic and rare medicinal plants. Diverse microflora of medicinal plants leads to exploring an evolutionary relationship with the host plant. Emphasis on novel applications of microbes for developing bio-based solutions that can avoid environmental damage and health effects for humans. Microbiome engineering required purposeful strategies for isolation and identification of indigenous communities for the dynamics of specific host and pathogen partners. A broad group of medicinal plants associated microflora summarized in this chapter that an unexplored biopesticide agent. There is increasing interest in the exploration of microbial inoculants for disease management as well as a mechanistic role in the biosynthesis of the bioactive compound of medicinal plants. Aim of this chapter, introduce novel insight into the microbiome of medicinal plants and their association with a specific host, a noticeable number of phytotherapeutic compounds produces due to the microbial interactions with medically important plant. Besides, it highlighted the possibilities for elevating plant protection along with plant growth and development and encouraging the commercial cultivation of medicinal plants to large scale production of bioactive phytochemicals.

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