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Review Article

Review on - Chili and Its Endophytes and Secondary Metabolites

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Abstract

Chili (*Capsicum annuum L.*) is common vegetable crop in India, which is grown for both unripe (green) and ripe (red) fruit. Damping-off, wilt, anthracnose, dieback, root rot, bacterial wilt and other diseases all damage chili crop. Damping-off caused by *Pythium aphanidermatum* (Edson) Fitz. In nurseries, is major restriction in chili growing, causing 62 percent seedling mortality and 90 percent plant death either as pre-emergence damping off or post-emergence damping off in nursery fields, and is very common issue in fields and greenhouses, where organism kills newly emerging seeps. Chili (*Capsicum annuum L.*) is common vegetable crop in India, which is grown for both unripe (green) and ripe (red) fruit. Damping-off, wilt, anthracnose, dieback, root rot, bacterial wilt and other diseases all damage chili crop. Damping-off caused by *Pythium aphanidermatum* (Edson) Fitz. In nurseries, is major restriction in chili growing, causing 62 percent seedling mortality and 90 percent plant death either as pre-emergence damping off or post-emergence damping off in nursery fields, and is very common issue in fields and greenhouses, where organism kills newly emerging seeps. In mutualistic symbiosis arrangement, endophytes are plant-colonizing microorganisms. They are present in most habitats, where they promote immune responses, exclude plant pathogens by niche rivalry, and engage in antioxidant activities and phenylpropanoid metabolism, which generates plant defense, structural support, and survival molecules.

Keywords: Chili; Endophytes; Bioactive Compound; Secondary Metabolites; Endophytic Enzyme; Disease Managements

Introduction

One of the most common spices that have been used from ancient era till today is Chili which is known for its taste, pungent nature. Beside its flavor adding ability it is also known to have therapeutic values. In spite of its value, this crop is affected by many factors such as physical, biological and also there is continuous loss due to plant pathogens attack. In order to cope up with the scarcity of the bioactive compounds' scientists have started to explore endophytes that are associated with the plant and has the ability to produce more or less similar compound or analogues compounds to that of the host plant. In this review an attempt has been made to provide the information of bioactive compounds, their structure along with therapeutic importance and has also included the reports of endophytes associated with chilli plant and has ability to possess therapeutic properties.

Chillies are enriched with minerals (potassium, manganese, iron and magnesium) that help control heart rate and blood pressure [1]. Besides their commercial and domestic value, Chili has a predominant role in medicine since ancient times. They are reported to prevent diabetes, spread of cancer, stomach ulcers, assists weight loss, anti – inflammatory, clear digestion, boosts immunity, anti - bacterial, and pain reliever [2].

Chili (*Capsicum L.*) is one of most common ingredients in tropical and subtropical cuisines, as well as world's fourth most grown flower. About 400 different types of chilies are grown all over world. Most common variety is "Carolina Reaper," produced by West Indian grower Ed Currie, with maximum pungency of about 2.2. Scoville Heat Units. Million SHU. One of world's hottest chili varieties is "Naga Jolokia," product of Tezpur in Assam, India. Many varieties of chili are cultivated for tomatoes, herbs, condiments, sauces, and pickles and they play important role in Indian cuisine. Apart from its apparent significance in diet, chili is also used in other ways such as medications and drinks, as well as ornamental plant in gardens. In terms of diet, these are high in vitamin and C; high in iron potassium and magnesium material with potential to strengthen immune system. India has been leading producer and buyer, according to Mohd Anuar. 2004 and exporter of chilies, especially in dried form. Cropare is found in India, and its quality varies by state of country. In terms of total area under chili production, India is also leader. Chili fruit is used in sauces and as powder for hot spices raw, fried, pickled, and dried. Chili has many medicinal properties, according to Nadkarni (1927). Its paste is applied to tonsils as rubefacient and local stimulant in case of tonsillitis. Internally, it irritates stomach and causes gastroenteritis. It's mixed with number of other products to produce local remedies. Chili crops are vulnerable to number of biotic and abiotic pathogens, resulting in severe losses for farmers. Damping off disease is one of them and it costs farmers lot of money. It is responsible for 90% of plant mortality in nurseries and fields, either as pre-emergence damping off or post-emergence damping off. These diseases of vegetables and field crops are widely regarded as major stumbling block to good crop plant production around world. Extra-nutritional constituents contained in small amounts in lipid-rich foods and plant products are known as "bioactive" or "biologically active" compounds. Plants and bacteria contain majority of these molecules, which have anticancer, cardiovascular, anti-lipidemic, antihypertensive, anti-glycemic, antithrombotic, anti-atherogenic, and anti-diabetic properties. Bioactive agents are also often used as preferred synthetic drugs for variety of diseases since they have few side effects. Bioactive Compounds from Chilies such as homocapsaicin, nordihydrocapsaicin, and homodihydrocapsaicin have been found to be present in chilies [3,4]. Among all these capsaicin compounds in chilies, almost 80-90% is composed of capsaicin (8-methyl-N-vanillyl-6-nonenamide). This compound has lots of biological potency and has been found to be of profound pharmaceutical importance [5]. Certain compounds such as 2-isobutyl3-methoxypyrazine, 2, 3-butanedione, trans-2-hexenal, linalool, 3-carene, and hexanal are some of the principal compounds recognized to be components of fresh commercial chili (*Capsicum annuum var annuum*) at different stages of ripening. All those six compounds are volatile aromatic compounds. Presence of those compounds in chili was made and confirmed using analytical techniques such as high-performance liquid chromatography, gas chromatography retention time and mass spectrophotometry [6]. In development of bioactive substances, endophytic fungi, bacteria, and actinomycetes play important role. Endophytic microbes spend rest of their lives within plant tissues, causing little visible harm to host plant. Endophytes secrete variety of specialized metabolites and biologically active compounds [7]. Endophytic bacteria have ability to generate plant growth hormones, phosphate solubilization, nutrient acquisition, and N2 fixation, among other things. Gram-positive bacteria are important in activities such as bioremediation, biocontrol, plant development, symbiotic-mutualistic, commensality, trophobiotic interactions, control of soil-borne pathogens, and support of host plant defense against environmental stress. Plant-microbe and microbe-microbe interactions, as well as environmental factors, can all influence structure of endophytic population. Cultivation-based and culture-independent approaches are used to analyze bacterial endophytes diversity. In cultivation research, significant number of bacteria, mainly Proteobacteria has been classified as endophytes with Actinobacteria, Bacteroidetes and Firmicutes phyla being most common. Bacillus and Streptomyces species are most common metabolite-producing Gram-positive bacteria endophytes present in variety of ecosystems. Endophytes can be present in plants from all kinds of habitats are essential in agriculture because they aid in improvement of crops yields by promoting plant development and immune system function as result of niche competition. Plant diseases are pushed out as well as playing role in phenylpropanoid metabolism as well as antioxidant properties among plants most plants have microbiota or endophytic microbes. Roots, branches, stems, and number of other plant parts may all be used to classify species. Small number of flowers, vegetables and seeds, they have ability to manufacture wide range of secondary products metabolites for agricultural and medicinal applications and biotechnology for industry [8].

Use and importance

Chili is used in variety of ways, beginning with fresh green fruits also along with dried powdered form. Salads, stuffing's and salsas are all popular uses for pungent fruits. Non-pungent varieties are used as flavoring agent in cooked meals. Cooked as vegetables or processed with additional food items quite pungent varieties are eaten. In small amounts, it's commonly thought of as condiment or spice. Hot peppers are also used for seasoning and stimulating appetite. Apart from its widespread application, pickled in salt and vinegar is used in ketchup as flavoring agent. Chili varieties are also used in preparation of cooked food's coloring agents in pharmaceuticals, meat products, cosmetics, and uniformity in clothes. Capsicum has wide variety of medical and dietary properties. It's important to remember that fresh green chill fruits have higher vitamin C content than dried chill fruits, whereas dried chill fruits have higher vitamin content than carrots. Capsaicin, spice's active ingredient, is complex of capsaicinoid alkaloids present in varying concentrations in various chili varieties. It's abundant in placental tissues and cross walls of fruits. In rather pungent fruits, however, it is scattered across all of fruit's fleshy parts. Sum of capsaicin in chili variety is used to assess its pungency and is normally expressed in Scoville Heat Units. Capsaicin has antioxidant, antimutagenic, anti-carcinogenic, and immunosuppressive properties, preventing bacterial growth and platelet aggregation. It's also used as anti-inflammatory and anti-arthritic agent. Chili fruit intake is beneficial for haemorrhoids, varicose veins, anorexia, and liver congestion. Chilli extracts are used externally as rubefacient and analgesic in case of back pain, rheumatism, articular and muscle pains and swelling feet, as well as antidote in case of poisoning. Two non-food and non-pharmacological applications of capsaicin are in preparation of "pepper sprays" as self-defense weapons and in preparation of "pure and herbal pesticide" [9].

Synthesis of bioactive compound by endophytic microbes

Endophytes produce bioactive compounds that aid host plant in developing systemic resistance to pathogens. These bioactive compounds are used in pharmaceutical industry as antibiotics, anti-cancer, anti-viral, anti-diabetic, and other bioactive compounds [10].

Endophytic fungi

Endophytic fungi are one of most important possible sources of useful bioactive compounds. *Pestalotiopsis neglecta* BAB-5510, endophytic fungus of *Cupressus torulosa*, is promising source of phenols, flavonoids, terpenoids, alkaloids, tannins, carbohydrates, and saponin, while *Gilmaniella* sp. AL12, another endophytic fungus, can induce *Atractylodes lancea* to develop volatile oils such as b-caryophyllene, Endophytic fungi are one of most important possible sources of useful bioactive compounds. *Pestalotiopsis neglecta* BAB-5510, endophytic fungus of *Cupressus torulosa,* is promising source of phenols, flavonoids, terpenoids, alkaloids, tannins, carbohydrates, and saponin, while *Gilmaniella* sp. AL12, another endophytic fungus, can induce *Atractylodes lancea* to develop volatile oils such as b-caryophyllene. Endophytic species have developed number of enzymes with possible medicinal applications. Europium sp., endophytic fungus isolated from Curcuma longa rhizomes, developed asparaginase, key anti-cancer enzyme. Anti-acetylcholinesterase activity was also observed in endophytic fungus *Huperzia serrata* strains L10Q37 and LQ2F02. *Talaromyces pinophilus*, endophytic fungus isolated from strawberry tree (Arbutus unedo), developed siderophores ferrirubin and herquline B, as well as antibiotic 3-O-methylfunicone. This strain was also shown to be poisonous to pea aphid *Acyrthosiphon Pisum*. *Fusarium oxysporum* 162, endophytic fungus, developed nematode antagonistic compounds such as 4-hydroxybenzoic acid, indole-3-acetic acid, and gibe pyrone D [11].

Endophytic actinomycetes

Endophytic actinomycetes tend to be potential source of bioactive agents that can be used for crop defense and therapeutic drug growth. More than 140 actinomycetes genera have been identified to date, but only few of them are known to produce majority of important antibiotics. Actinomycetes contain variety of secondary metabolites, all of which have biological functions and may be used as therapeutic agents in future. Actinomycetes from sea are under-utilized source of novel secondary metabolites. *Streptomyces Roche* CH1, endophytic actinomycete found in *Cinnamomum* sp., demonstrated antibacterial activity against *Aeromonas caviae*, *Vibrio parahaemolyticus*, and *Pseudomonas aeruginosa*. *Streptomyces cyaneofuscatus* (KY287599) had antimicrobial activity against Escherichia coli MTCC 739, *Pseudomonas aeruginosa* MTCC 2453, *Micrococcus luteus* NCIM 2170, *Staphylococcus aureus* MTCC, and Candida albicans MTCC 3017. Streptomyces KX852460 also had antifungal action against *Rhizoctonia solani* AG-3 KX852461, pathogen that causes tobacco leaf goal spot disease [12].

Endophytic bacteria

In response to biotic and abiotic stresses, majority of endophytic bacteria displayed beneficial effects such as increased biological N2-fixation, development of phytohormones, phosphate solubilization, and inhibition of ethylene (C_2H_2) biosynthesis, as well as biocontrol operation. More than 300 endophytic actinobacteria and bacteria were isolated from various tissues of Dracaena cochinchinensis Lour, including *Streptomyces, Nocardiosis, Brevibacterium, Micro bacterium, Tsukamurella, Arthrobacter, Brachy bacterium, Nocardia, Rhodococcus, Kocuria, Nocardioides,* and *Pseudo nocardia.* (Dragon's blood is traditional Chinese medicine). Antimicrobial and anthracycline-producing strains were shown to have antifungal and cytotoxic properties against two human cancer cell lines, MCF-7 and Hep G2 [13].

Bioactive compound synthesized by endophytic bacteria

Bacterial endophytes have number of possible uses in medicinal and drug development. Endophytes used in ethnomedicinal plants have been identified as possible source of natural products for use in oxidative stress and as new bioactive agents. Multidrug resistance (MDR) in pathogenic bacteria is combated by antimicrobial agents. Many agriculturally important microorganisms have developed resistance to widely used antimicrobial compounds, and interest in natural pathogen control from fresh, environmentally friendly agents is growing by day. Amines and amides are typical endophyte metabolites that are poisonous to insects but not mammals. To build resistance against plant invasions, endophytes generate extracellular hydrolyses such as cellulases, proteinases, lipases, and esterase's*. Arthrobacter, Achromobacter, Bacillus, Enterobacter, Erwinia, Pseudomonas, Pantoea, Serratia,* and *Stenotrophomonas* are among endophytic bacteria present in Hypericum perforatum and Ziziphora capitata. In contrast to *Z. capitata, H. perforatum* with antibacterial activity assisted colonization of more bacteria with antagonistic activity. These isolates were able to prevent *F. oxysporum* from causing tomato root rot [14].

Secondary metabolites

While secondary metabolites are not required for organism's development, they play adaptive role by acting as defensive compound or signaling molecule during ecological interactions and environmental stresses. Antimicrobial agents, phytohormones or their precursors, vitamins like B12 and B1, and bioprotectants are among low-molecular-weight secondary metabolites produced by endophytic microorganisms. Alkaloids, hormones, terpenoids, peptides, polyketones, flavonoids, quinols, and phenols are examples of secondary metabolites. Anti-cancer, antioxidant, antimicrobial, anti-inflammatory, and immunosuppressive agents are just few of therapeutic uses for these substances [15].

Secondary metabolits synthesis

The development of secondary metabolites is regulated by certain endophytic bacteria. Only few primary metabolism precursors are used to make microbial secondary metabolites, and there are only few of them. Endophytes produce secondary metabolites in number of forms, including polyketide, isoprenoid, and amino acid synthesis, biosynthetic pathways; on other hand, are responsible for both primary and secondary metabolite production. Endophytes' high species diversity and tolerance to diverse habitats may be considered rich and virtually untapped source of potential secondary metabolites for pharmaceutical and agricultural applications. Nature has produced wide range of secondary metabolites with different structural characteristics. Ses metabolites function as biofilm, toxins, virulence factors, and hormone signaling disruptors in plants. Endophytic bacteria-plant interactions generate and modulate auxins and C_2H_2, which are essential for plant growth and drought stress management [16].

Figure 1: Routes of entry of endophytic bacteria.

Figure 2: Bioactive compounds synthesized by endophytic bacteria.

Gram-positive endophytes against human/animal pathogens

Actinomycetes are Gram-positive filamentous bacteria with considerable ability as biocontrol agents, producing nearly two-thirds of natural antibiotics, with Streptomyces species accounting for 75%. Actinomycetes, which include genera *Actinomyces, Actinoplanes, Amycolatopsis, Micromonospora, Saccharopolyspora,* and *Streptomyces,* are noted for developing bioactive secondary metabolites that have antimicrobial, insecticidal, and antitumor properties. Lipopeptides, which are formed by cyclic or short linear peptides linked to lipid tails or lipophilic molecules, are one of most essential groups of secondary metabolites produced by endophytic bacteria. Lipopeptides have antimicrobial, cytotoxic, and surfactant properties; they are made up of hydrophobic fatty acid acyl chain of 13 to 17 carbons bound to hydrophilic peptide of 7 - 25 amino acids and are synthesized by non-ribosomal peptide synthetases (NRPS) or polyketide synthase (PKS). Lipopeptides are essential for inducing plant defense mechanisms as well as serving as antibiotics. Single bacterial strain can produce multiple polypeptides is forms. *Lipopeptides* from *Bacillus* and *Paenibacillus* have been studied most, although some *Bacillus amyloliquefaciens* strains have been identified as higher lipopeptide producers. *B. subtilis* produces NRPS *lantibiotics* (lanthionine-containing antibiotics) in addition to lipopeptides; lipopeptides are responsible for biofilm and swarming growth, while lantibiotics serve as quorum-sensing pheromones. *B. subtilis* also produces polyketides, amino sugar, and phospholipids; polyketides include bacillomycin, fengycin, iturin, lichenysin, mycosubtilin, plipastatin, pumilacidin, and surfactin; and polymyxins are produced by *Paenibacilluspolymyxa.* Antimicrobial enzymes are generated by bacterial endophytes in addition to biologically active secondary metabolites, primarily by Bacilli class representatives. Gram-positive bacteria had higher hydrolytic activity than Gram-negative bacteria in sample searching for highly developing enzymes endophytes. *B. infantis* and *B. grenadines* displayed amylase, cellulase, and lipase activity in Rhizophoraceae hosts, while B. safensis showed amylase, cellulase, lipase, lipolytic, and proteinase activity in Rhizophoraceae hosts. *Paenibacillus* sp. and *S. warneri* all had cellulase, lipase, and proteinase activities in *Acanthaceae* family endophytes. Endophytes isolated from Brazilian mangrove plants displayed high enzymatic activity*; Bacillus sp*. (MCR2.56) was reported to have especially high amylase andesterasic activities; six Bacillus isolates had high endocellulolytic activity, while *Microbacterium* sp. (MCA2.54) and *Curtobacterium* sp. had high endoglucanase and protease activity, respectively. Streptomyces's with bioactive endophytic properties can be isolated from plants all over world. Medicinal plants have been used as alternative medicine for disease control for decades. Endophytic actinomycetes from Chinese medicinal plants have been shown to have antibacterial action against *E. coli and S. aureus. Endophytic actinomycetes* have been shown to have antibacterial action against *Acinetobacter baumannii, Enterococcus faecalis, E. coli*, *Klebsiella pneumoniae*, *Pseudomonas aeruginosa*, and *Staphylococcus aureus*, some of which are immune to vancomycin, methicillin, and carbapenem antibiotics. Several metabolites from endophytic Streptomyces species, including kakadumycins, munumbicins, p-aminoacetophenonic acids, andxiamycins, have been identified and related to antibiotic activity, as well as antimalarial (*coronamycin, munumbicin D)* and antifungal activity. *Endophytic B. subtilis* from Malaysian plants had antibacterial activity against *S. aureus,* methicillin-resistant *S. aureus,* and *P. aeruginosa.* Antibacterial activity was found in African Combretum molle-endophytic *Bacillus* and *Lysinibacillus* species against *B. cereus, E. coli, P. aeruginosa,* and *S. aureus.* Munumbicins A, B, C, and D are developed by Kennedianigriscans-endophytic Streptomyces sp. strain NRRL 30562, and are successful against growth of *B. anthracis, E. faecalis*, vancomycin-resistant *E. faecalis*, MDR M. TB, *S. pneumoniae, S. aureus,* and methicillin-resistant. Streptomyces sp. strain SUK06, isolated from Malasian medicinal plant Thottea grandiflora, widely used as alternative way to cure wounds and treat skin infections and fever, develops secondary antimicrobial metabolites against *B. cereus, B. subtilis, Plesiomonasshigelloides,* and *Plesiomonasaeruginii.* Similarly, endophytic *Bacillus sp., Micrococcus sp.,* and *Plectranthustenuiflorus*-endophytic *Bacillus sp., Micrococcus sp.,* and *Plectranthuspolymyxa* metabolites and cell wall-degrading enzymes from

Panax ginseng and Plectranthustenuiflorus-endophytic *Bacillus sp., Micrococcus sp. soil* actinomycete Saccharopolyspora spinosa produces secondary metabolites spinosyn and D, which are highly effective against lepidopteran and dipteran pests, among others, and whose commercial product, spinosad, has been commercialised for 250 countries and implemented in advanced pest control systems worldwide. Endophytic Saccharopolyspora species have also been recorded, but their potential as bioinsecticides has yet to be determined. Compounds formed by *Azadirachta indica* (also known as neem) have wide range of medical and agricultural applications. In fact, 80 percent of A. vera bacterial endophytes developed 1,1-diphenyl-2-picrylhydrazyl, demonstrating scavenging properties of over 75 percent. endophytic bacteria *B. subtilis,* Sphingobacterium siyangensis, and *P. polymyxa* found in leaves and roots of Raphanus sativus (young radish) have been shown to inhibit development of *B. cereus, E. coli, P. aeruginosa,* and *S. aureus,* as well as *Salmonella, Shigella,* and Listeria species. *Endophytic Streptomyces sp.* from Zingiber officinale roots are shown to have antimicrobial activity against B*. cereus, B. subtilis, and S. aureus* [17].

Anthracnose disease of chili

Anthracnose disease has been reported to be major restriction in microbial development in tropical and subtropical countries, resulting in massive losses. India used to be world's largest producer and exporter of chili, but demand has fallen dramatically in recent years, and India now ranks third in terms of chili production. Approximate annual loss of around 29.5 percent, totaling US$491.67 million, has been recorded from India alone. Due to anthracnose disease, calculated loss of 10 - 54 percent in crop yield has been recorded in India. Large losses have been recorded from other parts of world as well, such as significant loss of 20 - 80 percent. The loss is large due to pathogen's post- and pre-harvest presence, which results in loss of 10 - 80 percent of marketable yield of chili fruits. Disease is said to affect nearly every aerial portion of farm. It mainly causes fruit in both green and red stages, primarily targeting ripe fruits, and is thus known as ripe fruit of chili. Disease is transmitted through soil, water, and air, and therefore can inflict harm during seedling stage or on aerial parts of plants. In various countries, several varieties of Colletotrichum have been linked to pepper anthracnose, gives brief overview of various Colletotrichum species that have been linked to anthracnose of chilies in various parts of world. However, in India, disease has been related to three important species: *C. capsici, C. acutatum*, and *C. gleosporoides,* with *C. capsica* Syd. Butlerand Bisby causing significant damage at mature fruit stage of plant [18].

Disease management

Today, no successful control mechanisms have been suggested for management of chili anthracnose, which has been raging problem for agriculturists and farmers. The decrease in chili demand and decline in fruit quality has heightened need for long-term strategy to monitor disease's spread. There is no one treatment strategy that has been discovered to effectively monitor disease. For controlling disease, it is commonly advised to use variety of various techniques such as chemical control, biological control, physical control, and intrinsic tolerance management methods for preventing transmission of Colletotrichum spp. and establishment of disease can be divided into four broad categories: Cultural practices, chemical control, immune varieties, and eventually biological control are all included.

Figure 3: Disease cycle of anthracnose disease of chili.

Use of culture practices

Since pathogen is seedborne, windborne, and waterborne in addition to being soilborne, only way to monitor its spread is to focus on three primary areas of disease-free crop cultivation is proper irrigation, crop rotation and clearance of any weeds in field. In addition, relative humidity helps effective colonization. Pathogen path as consequence, field should be properly drained and irrigated to save epidemic from spreading. Often, correct distance between plants should be preserved in order to preserve thick canopy that allows moisture to be produced. Another significant technique is use of transplants grown from disease-free chili seeds. Keep transplants weed-free and safe from other solanaceous crops. Ideally, crop can be rotated every 2 - 3 years with crops that aren't Colletotrichum hosts [19].

Use of chemical fungicides

Chemical management has been pursued as most efficient measure to control transmission of disease in absence of any accurate means of managing disease. Longer time it takes to grow resistant cultivar and short time it takes for fungicides to work further popularize this method of disease control, especially for anthracnose disease. However, residual toxic residues from chemicals in fruits obstruct planned export of chili goods to other countries, affecting country's economy. Furthermore, focusing on single chemical ingredient leads to production of resistance in pathogenic isolates, making disease control much more difficult. Traditional fungicides for prevention of disease include carbamate and carbendazim, though both have been proven ineffective in serious disease outbreaks. Copper compounds, dithiocarbamate, benzimidazole, and triazole compounds are among chemical fungicides often recommended for managing anthracnose disease. Newer compounds, such as strobilurin-based fungicides (e.g., azoxystrobin, pyraclostrobin), have also been used to control it. However, only few studies on this class of fungicides regulating chilli anthracnose in wide field trials are available. Chemical fungicides can be effectively controlled by applying them at right time during crucial phase where disease is most likely to develop. Fungicides can be used on young, spreading tissues such as fruits, leaves, and flowers to prevent pathogens from entering plant system. Numerous studies on negative effects of fungicide use on farmers' health, economic status, and harmful pollution of atmosphere, especially in developing countries, cannot be overlooked. Different types of fungicides have different modes of action and durations of effect on disease control. As result, farmers in certain region should make informed decisions about fungicides based on current environmental conditions [20].

Future aspects

When our knowledge of endophytic bacteria expands, so does our ability to manipulate their special bioactive compound synthesis characteristics alone or in conjunction with plants. Plant advantages augmented by use of beneficial microorganisms in form of bio-fertilizer have emerged as viable option for organic farming. In order to use endophytic bacteria as plant growth booster, we need to be able to recogniseand use bacterial endophytes in agriculture as part of advanced bio-fertilizer technology programme. Endophytes modulate plant physiology and metabolism, and how they use primary and secondary metabolism intermediate substances as nutrition and precursors to create novel compounds or improve existing essential secondary metabolites, are still largely unknown.

Conclusion

After first findings of endophytic Gram-positive bacteria producing secondary metabolites with industrial potential, further evidence has emerged that endophytic Gram-positive bacteria are one of most valuable sources of novel compounds with known potential for agriculture, medicinal, and/or pharmaceutical applications, thanks to their PGP, antimicrobial, and anticancer activities. Endophytic Gram-positive bacteria do also assist plants in surviving under biotic and abiotic stress conditions. Many endophytic Gram-positive bacteria have been isolated from medicinal plants all over world, and this is not by chance. Many records of endophytic Gram-positive bacteria with such behaviours have been isolated from mangrove and under intense environmental conditions developing plants, such as crops from saline soils and crops and trees from cold regions, where phylogenic study of native strains shows they possess genes to produce various metabolites that, when combined, support host plant, not just host plant. Bacillus class endophytes have been shown to contain aromatic compounds, lipopeptides, plant hormones, polysaccharides, and several enzymes, indicating that they have greater capacity for PGP and crop management strategies in agriculture. Endophytes of Actinobacteria class have also been discovered to develop antimicrobial and antitumor-like action metabolites, suggesting that they have lot of promise in agriculture, medicine, and veterinary medicine.

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