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Endophytes, promising option for pest management in agriculture: Review

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Abstract
Endophytes are the group of minute, microscopic organisms invisible to naked eye normally establish their close relationships with the plant. The relationship may be harmful or beneficial. Some of them complete entire part of their life cycle or some passes at least one part of their life cycle within the plant. By the perusal literature it has been proved that they can offer the greatest opportunity for taking the management strategies against the insect pest and disease alternative to agrochemicals. Their application in plant protection field is ecofriendly and indicates the long term sustainability of ecosystems. Keeping these views in mind, the present article has been written to highlight their contribution in pest and disease management in modern agriculture field.

Keywords: Endophyte, bacterial endophyte, fungal endophyte, insect pest, disease

Introduction
Now a day the modern agriculture system is continuously facing a tremendous challenge against the increasing world population and with the continuous supply of food commodities. To sustain in the competition and make the agriculture more profitable it is manadatory to reduce the cost of cultivation and to maintain the pollution free long term sustainable environment. To shift on this philosophy, there is a need for searching the alternative option in place of the use of agrochemicals. The plant growth and its defence mechanism was enhanced by the use of beneficial microorhanisms viz. Fungi and bacteria and this result was popularize for the opening a wide scope to expose and use of the plant associated microorganisms [45]. These plant associated tiny organisms were termed as Endophyte and they broadly categorized into two main groups' viz. Bacteria and Fungus [5]. Studies on the life cycle of endophytes suggested that they can able entire life cycle or a single part of their life cycle within the plant system [3]. Extensive research work on the bioecology, function and survivability of endophytes reveal that approximately 3,00,000 plant species show their intimate association with the endophytes [60] in different plant parts viz. leaves, stems, branches [23]. Besides it is also true that their interaction with their respective host plant was solely depen upon on their host plant habitat [16]. Endophytes are classified as harmful or beneficial depending on their interaction with their host plant. Many biologists throughout the globe have documented the different beneficial functions of endophytes. They help the plant by enhancing the capacity of essential nutrient elements including both macro and micro from soil environment [80, 40, 46, 6], provide the protection of the plant from major insect pest and disease [58, 20, 76], provide the major contribution in promoting of the plant growth and development [74, 24]. It has been reported that endophytes take part in production of several important secondary metabolic compounds with different mode of actions and sturucture which includes viz. alkaloids, benzopyranones, flavonoids, phenolic acids, quinones, steroids, terpenoids, tetralones and xanthones which showed excellent performance against different destructive plant pathogens [2]. Their association with the field crop make the crop more tolerant against the notorious weeds and suppress the weed floral population in field condition. Due to supreesion of weed problem the plant can able to utilize the natural resources in a better way [81]. It has been proved that endophytic association with the plant boost up the tolerance and resistant capacity of plant against abiotic and biotic stresses [49, 24]. Extensive studies on endophytes showed that they are very much promising and helpful regarding the enhancement of yield attributing characters of crop [21, 68]. The role of endophytes in insect and disease management in agriculture field by their antibiosis and antixenosis activity was proved by several scientists and this is the best weapon in plant protection arena in agriculture which leads to reduction of

the use of plant protection chemicals and make the environment and ecosystem more stable and sustainable for long period [4]. There has no uncertainity in future biocontrol will be the major option in place of chemical control. Considering the all information, here the present review article elaborately discussed about the contribution of bacterial and fungal endophytes in managing the biotic stress of crop special emphasize to insect and disease pest.

Role of Bacterial endophytes in insect pest management

Bacteria are the prokaryotic unicellular microscopic organisms show the great variation in their body shape and size [19]. Bacterial endophytes are the special group of living organisms which survive by the close association with their respective host plant. Besides their survivability they exert the growth promoting nature and defence mechanism to the plant against many insect and deadly pathogens [59]. Extensive studies during the last few several decades discovered many beneficial strains of commercially available bacterial endophytes which showed as very promising in suppression of plant disease, promoting the plant growth and development [34, 41, 1, 31]. Induced systemic resistance (ISR) is one of the most important phenomena in the plant body which is triggered by when a plant come to contact with an endophyte by production of several bioactive metabolic compounds. The development of ISR ultimately produce Systemic acquired resistance (SAR) when the plant gets infested by any insect or pathogen [68]. Among the several groups of bacterial endophytes, *Bacillus amyloliquefaciens* is considered as one of the most promising entomopathogenic endophyte [60, 11, 31] [12] by producing the main metabolic compounds lipopeptide in nature solely responsible for development induced plant resistance against the fall army worm (*Spodoptera furgiperda*) by reducing the body weight [9, 36, 15]. *Enterobacter cloacae* another endophytic rod shaped and gram negative bacteria were reported as good biocontrol agent against the White Backed Plant Hopper (WBPH) (*Sogatella furcifera*), important pest of paddy by production of their Pinellia ternate agglutinin (PTA) protein [83]. Eendophytic bacteria *Clavibacter xyli* subsp. *cynodontis* was made as transgenic by the incorporation of cry1A (Crystal endotoxin) gene isolated from *Bacillus thurigiensis* [64] and this transgenic bacteria showed insecticidal activity against many lepidopteran insect pest specially emphasizing to the European corn borer (*Ostrinia nubilalis*). Diamond back moth (DBM) (*Plutella xylostella*) is the major yield reducing lepidopteran insect pest in cabbage, cauliflower and broccoli throughout the world [18]. Several studies had been carried out for this management aspect of this insect pest by utilizing the bacterial endophytes. The isolates of *Enterobacter cloacae* (ENF14), *Alcaligenes piechaudii* (EN5) or *K. ascorbata* (EN4) were observed to have control action against diamondback moth [55, 61, 62, 63].

Role of Bacterial endophytes in plant disease management

Plant diseases are characterized by any abnormality in plant leads to hindrance to the plant normal growth and reduce the economical yield. Majority of plant disease are caused by fungus belongs to the Ascomycetes and Zygomycetes group followed by bacteria and virus. For suppressing the plant disease indiscriminate use of chemicals has augmented leads to development of hazardous environment. The endophytc bacteria contribute huge impact on plant growth promotion and induce the resistance power into the plant body by production of their secondary metabolites which was considered as natural biocontrol against the disease [34]. Similarly *Bacillus* sp. produce secondary metabolic compounds which is peptidic in nature showing antibiosis property against many plant diseases [60]. Lipopeptide compounds with volatile and low molecular weight nature were produced by many endophytic bacteria showed specific antifungal and antibacterial activities [82]. The isolated lipopeptidic compounds were further categorized based on their chemical nature and mode of action on the plant pathogens viz. surfactin, fengycin, polymyxin, bacitracin and iturin [36, 46]. Among those compounds Fengycin and iturin are reported as antifungal agents [51]. From the research work it was established that Iturin, suppressed the pathogenecity of *Pectobacterium carotovorum* in potato, carrot and onion and *Xanthomonas campestris* in paddy [81]. Fengycin was found to be effective on *Botrycis cinerea*, causing the grey mold disease in many plants especially in apple [65]. Different types of phenazine compounds having antifungal properties like Phenazine-1-carboxamide, phenanazine-1-carboxylic acid and phenanzine-1-carboxamide are released by the *Bacillus* sp. successfully control *Rhizoctonia solani*, *Xanthomonas oryzae*, *Pythium myriotylum*, *Pythium splendens* in different agricultural and horticultural plant by exerting their antibiosis property [41, 40, 53]. Plant growth promoting Rhizobacteria (PGPR) normally colonize in the plant rhizospheric zone help to develop induced systemic resistance (ISR) in the plant and also take part in plant growth promotion. One of the major PGPR, *Pseudomonas fluorescens* strains WCS417R, WCS365 and 89B-61 protect the cucumber plant from their anthracnose disease [68, 25, 69, 76, 26]. Other promising bacterial endophytes are *Bacillus amyloliquefaciens*, *Bacillus pumilus*, *Bacillus subtilis*, *Pseudomonas fluorescens*, *Pseudomonas syringae* and *Serratia marcescens* which were reported as major factor for the development of systemic resistance in the plant against the different diseases [26] and also against different plant parasitic nematodes (PPN) [22]. From the enzymatic study it has been revealed that endophytic bacteria produced different kind of enzymes like peroxidases, lipoxygenases, chitinases and glucanases having diversified activity [10, 50]. These enzymes are found to be effective against the palnt pathogen by inhibition of their growth and development. Peroxidises enzyme effectively reduced the incidence of damping-off pathogen *Pythium aphanidermatum* in rice, wheat and cucumber [80]. Production of phytoalexins ultimately leads to formation of lipoxynase enzyme showed to be inhibitory action against the incidence of many plant diseases [30]. Scientists proved that there was a positive correlationship in between the more production of enzymne and better control of plant disease [17, 35, 49].

Role of fungal endophytes in insect pest management

Fungi are the group of eukaryotic, unicellular to multicellular organisms showed wide diversity in their survivability and sustainability. The pioneering work on fungal endophyes was done on *Phomopsis oblonga*, the endophytic fungus gave protection to the Elm trees against the beetle *Physocnemum brevilineum* [75]. Later many research workers were focused on the study of insect pest management by using the fungal endophytes. Thereafter, many naturally occurring endophytic fungui like *Beauveria bassiana*, *Clonostachys rosea*, *Isaria farinosa* were isolated from their respective host plant [7, 13, 42, 70, 37]. *Beauveria bassiana* was found to be effective against insect pest in many cases. Damage incidence of Poppy stem gall caused by cynipid gall wasp, *Iraella luteipes* was reduced by application of *B. Bassiana* [45]. It was found to be effective against European corn borer (*Ostrinia nubilalis*) and Pink borer *Sesamia calamistis* in maize [8, 28, 14]. *Acremonium* sp., another important naturally occurring endophytic entomopathogenic fungus enhanced the plant defence property by producing secondary metabolites were reported as effective against many insect species. Lolines, aminopyrrolizidine alkaloids produced by *Neotyphodium* sp. showed broad spectrum insecticidal activity [52]. Peramine, pyrrolopyrazine alkaloid produced by fungal endophytes showed effectiveness against the argentine stem weevil [48]. Another report revealed that Lolines and Permaines were very useful in managing the aphids including *Rhopalosiphum padi* and *Schizaphis graminum* in cereal crops [54]. Besides fighting with biotic stress, fungal endophytes were equally effective against the abiotic stress and help the plant to overcome the stress [77, 54]. By application of fungal endophytes in insect pest management in agriculture should be the best alternative in future to protect our environment for long lasting future [71].

Role of fungal endophytes in plant disease management

Like insect pest management, the fungal endophytes were also exposed against the suppression of many plant diseases by production of their many bioactive metabolic compounds. Cryptocin, tetrameric acid analog from endophytic fungus *Cryptosporiopsis quercina* was isolated found to be good suppressing agent against the rice blast disease caused by *Pyricularia oryzae* [29]. *Colletotrichum* sp. another endophytic fungus was used for the isolation of 6-isoprenylindole-3-carboxylic acid, an Indole derivative compound. This compound was effective against the many deadly plant pathogens like *Phytophthora capsici*, *Rhizoctonia cerealis* and *Gaeumannomyces graminis* var. *tritici* [32]. Colletotric acid, a phenolic antifungal compound was isolated from *Colletotrichum gloeosporioides* shown to be effective against *Helminthosporium sativum, Bacillus subtilis, Staphylococcus aureus* and *Sarcina lutea* [84]. Chokols, a sesquiterpene compound produced by *Epichloe typhina*, an found to be antifungal agent to the leaf spot disease caused by *Cladosporium phlei* [27].

Conclusion

Today's agriculture is undergoing through a serious challenge due to indiscriminate use of plant protection chemicals for pest and disease management. In the present scenario the use of biocontrol agents got the considerable attention due to their contribution to shift the environment in a stable and sustainable way. Endophytes play the important role in spression of plant disease and insect management. There is a huge scope to explore the role of endophytes in plant protection field for achieving the best alternative way for promoting the healthy and stable ecosystem and environment for the next generation.

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