EC AGRICULTURE
Review Article

Novel Fungal Endophytes Enhance the Yield of *Pongamia pinnata* and *Salvia miltiorrhiza*

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Abstract

Fungal endophytes are friends of plants, they not only share nutrients but also help each other in development by producing vast variety of novel secondary metabolites including volatile organic compounds. Some specific fungal genera are colonizing in specific plants and maintaining symbiotic interactions. For example *Alternaria* species is a symbiont in *Salvia miltiorrhiza* and helping the plant by stimulating root growth. Similarly, the fungus *Piriformospora indica* enhances the plant fitness by colonizing endophytically in the roots of the xerophytic plants. The present article highlights these unique symbiotic interactions between fungal endophyte and the associated plant.

Keywords: *Fungal Endophytes; Endophytic Fungal Symbiont; Xerophytic Plants; Plant Fitness*

Introduction

Symbiotic relationship is positive association between two partners, in which both of the partners benefit from each other. Fungal endophytes and plant has special bond and long lasting relationship. Both share and help each other in number of ways. In this connection, as part of their survival and development strategies since evolution both have shown specificity and stability. Probably, that is the reason that specific fungal genera are associated with specific plant species. Various research articles and data support this type of interaction in a significant manner. For example *Alternaria* species is an endophytic fungal symbiont in *Salvia miltiorrhiza* (An herbaceous perennial plant used in traditional Chinese medicine since grown in Henan province of China). It helps the plant by stimulating root growth [1]. Similarly *Alternaria solani* is also an endophytic fungal symbiont in *Pongamia pinnata* found in specific regions of Rajasthan, (India) favouring this plant's survival and facilitating its growth. This plant produce significant flavonoids and bioactive compounds [2].

The long term relationship maintained between endophytic fungal symbiont and specific plant, through the secondary metabolites production. The endophytic fungal symbiont produce the metabolite which is utilized by specific plant in association and in reverse the plant not only gives space to fungal symbiont but also provide enzymes to metabolize certain nutrients. For example endophytic fungus *Schizophyllum commune* produce various bioactive compounds which is in association with the traditional oriental herb *Panax ginseng* [3].

Fungal endophytes as a source of bioactive natural products

There are large number of bioactive compounds producing fungal endophytes such as *Taxomyces, Fusarium, Pestalotiopsis, Botrytis, Aspergillus, Penicillium, Metarhizium, Piriformospora* and others. The bioactive compounds obtained from these fungal endophytes possess anti-cancerous, antidiabetic, antioxidant and antimicrobial activity.

Similarly, the fungal endophytes *Alternaria alternata* and *Piriformospora indica* both increase the production of group of enzymes (GOE) such as glutathione reductase (GR), glutathione S-transferase (GST) and superoxide dismutase (SOD). This results in increased root biomass and increased accumulation of total phenolic acid and lithospermic acid A and B (LAA and LAB) and thereby, enhances the yield of crops. These fungal endophytes also switch on defense genes and response genes and provide resistance against biotic and abiotic stress [4].

Ambuic acid is an antifungal and anti-oomycete agent from the endophytic fungus Pestalotiopsis microspora and significantly effective against plant pathogenic fungi *Fusarium* species and *Pythium ultimum* [4].

Fungal endophytes as plant growth promotor in *Pongamia pinnata* and *Salvia miltiorrhiza*

Tiwari [5] and Zhou., *et al.* [1] documented that the *Alternaria* species has shown significant association as endophytic fungal symbiont in various perennial croppy plants such as *Salvia miltiorrhiza* and *Pongamia pinnata*. This fungus commonly colonizes in root, shoot and leaves of these plants and accumulate active ingredients. In the roots of the plant this fungus stimulate root growth, therefore helping the plant in development and growth.

In the roots of the plant *Salvia miltiorrhiza*, this dominant endophytic fungal symbiont *Alternaria* species increases total phenolic acid, enhances biomass of roots and increases content of lithospermic acid A and B under greenhouse and field conditions [1].

Since last decades, these interactions (Plant growth promoting fungal association with specific plant) are being studied and results are giving significant outcome [6]. Still, there is a scope of further research in this area. The strategies and methods by which these fungal endophytes are promoting plant growth needs more attention.

Verma., *et al.* [7], first isolated the facultative endophyte named as *Piriformospora indica* colonizing in the roots of the xerophytic plants of Thar dessert of India. Sarvajeet., *et al.* [8] and Varma., *et al*. [9] further studied and found that this fungus improve plant's fitness and help in plant growth promotion, therefore, can be used at large scale in agriculture, horticulture and floriculture.

Both of the novel endophytic fungal symbiont (*Alternaria* and *Piriformospora*) are producing various enzymes and helping the plant in adverse xerophytic conditions. In fact, these fungi are producing chlamydospores for accumulating nutrients, water, enzymes and related bioactive molecules required for the survival of various plants in xerophytic conditions (Figure 1).

Endophytic fungal symbiont improve fitness of *Pongamia pinnata* and *Salvia miltiorrhiza*

Fungal endophytes in association with various crops provide constant defense and support in biotic and abiotic stress [4]. Endophytic fungal symbiont *Piriformospora indic*a colonizing in the different crops provide constant support in adverse conditions such as water scarcity, salinity and high temperature. Similarly, the endophytic fungal symbiont *Alternaria alternata* produces acids and enzymes and thereby improve fitness of these plants (Figure 2).

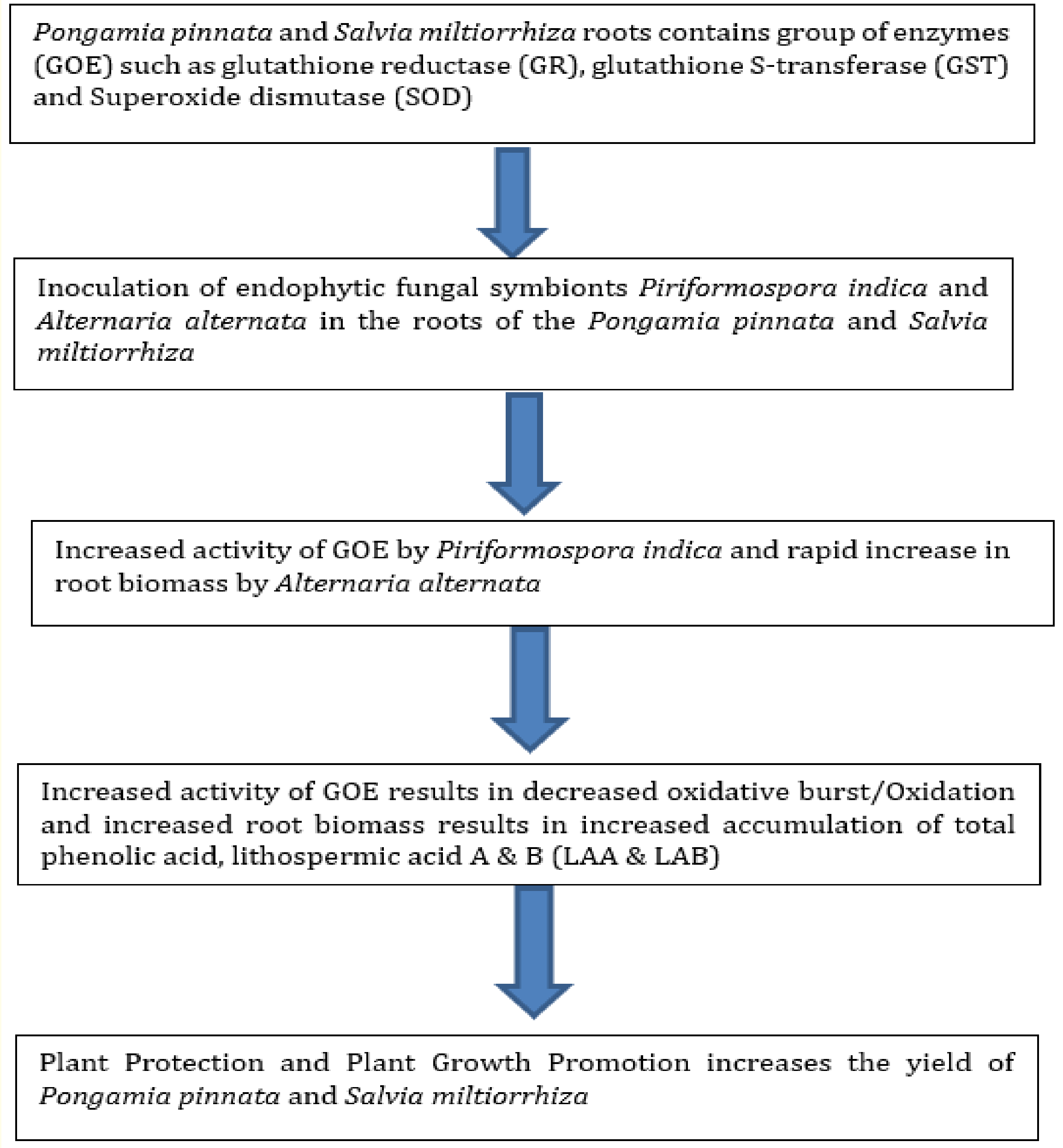

Figure 1: *Probable mechanism of Bio-protection and Plant growth promotion by Endophytic Fungal Symbiont Piriformospora indica and Alternaria alternata (GOE - Group of enzymes, GST - Glutathione S-transferase, SOD - Superoxide dismutase LAA and B - Lithospermic acid A and B).*

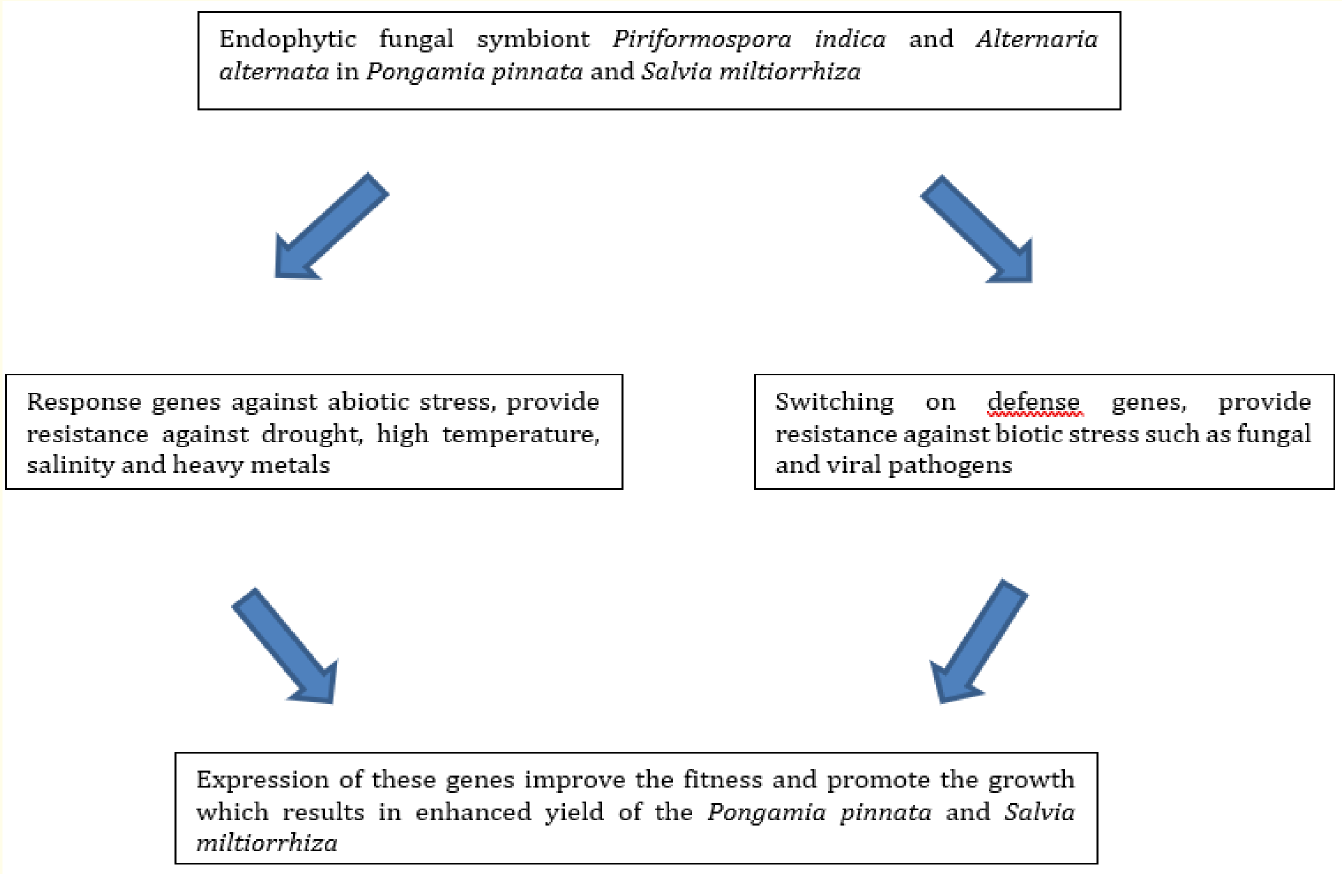

Figure 2: *Probable mechanism of Defense and Fitness in both plants against Biotic and Abiotic Stress by Endophytic Fungal Symbiont Piriformospora indica and Alternaria alternata results in enhanced yield of the Pongamia pinnata and Salvia miltiorrhiza.*

Conclusion

In near future, the agriculture scientists and plant breeders will come out with plant wise endophytic fungal symbiont which not only enhances the yield but also provide constant support of that specific plant (such as *Alternaria* species enhances the growth of the plant *Salvia miltiorrhiza* [4].

Moreover, there is a need of research at molecular level to study the switched on genes, as a result of interactions between plant root and endophytic fungal symbiont specifically associated with that plant. Probably, these genes are producing some novel bioactive compounds for fitness and enhance the growth of that plant [8,9].

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