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EFFECTIVENESS OF MICROBIAL ENDOPHYTES ON CROP IMPROVEMENT AND CURE THE DISEASES

***HARSHA Y. VAGHASIYA[1], R.L. LEVA[1] AND ARTEEBAHEN PATEL[2]**

[1]Aspee Shakilam Biotechnology Institute, Navsari Agricultural University, Surat 395 007, Gujarat, India

[2]Children's Hospital of Philadelphia, 550 S. Goddard Boulevard, King of Prussia, PA 19406 USA

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Abstract– Microorganisms colonize the plant tissue and beneficial to the plant is known as endophytes. Fungal and bacterial endophytes are commonly found in most of the plants. The role of endophytic microorganisms in plants can be divided into two categories based on types of activity: plant growth promotion and disease control in plants. The search for new compounds effective against human diseases is still a priority in medicine. The evaluation of microorganisms isolated from non-conventional locations offers an alternative to look for new compounds with pharmacological activity. Endophytes are a natural source with remarkable chemical and biological properties. Endophytes are considered promising sources of new bioactive natural products. Present review will concentrate on the importance of endophytes for crop improvement and clinical applications of bioactive compounds isolated from endophytes.

INTRODUCTION

The term "endophyte" is derived from the Greek, endon means within and phyte means plant. It was first introduced in 1866 by de Bary. Symbiotic relationship of microbes and plants is often found and it is beneficial for both. Many microbes are found inside the plant tissue. These microbes support plant growth. These beneficial microbes are called endophytes. Endophytes are known to enhance host growth and nutrient gain. Endophytes help plants to improve the ability to tolerate various stresses and increase the resistance of plants to insects and pests. Endophytes can colonize in different parts of the plants, i.e. Leaves, roots, stem, fruit, bud, seeds etc (Patel *et al*., 2016). Mainly two forms of endophytes are found, i.e. bacterial and fungal. Table 1 and 2 shows some examples of endophytic bacteria and fungi.

Endophytes colonize most of the plants. There are no symptoms of diseases found in the plant while endophytes grow inside the plant. Improvement of plant growth and quality has progressively gained interest for the scientific and commercial study. Plants suppress the growth of endophytes, and these endophytes use many mechanisms to get used to their living environments. Endophytes produce compounds that promote plant growth to sustain stable symbiosis. Some endophytes also produce secondary metabolites for the protection of host plant against plant pathogenic organisms. Endophytes are thought to interact closely with their host plants, and therefore could be used as biological control agents in sustainable crop production potentially.

Plant endophytic fungi are one of the important components of plant micro-ecosystems. Plant endophytic fungi can be defined as the fungi which spend the whole or part of their life cycle colonizing inter or intra-cellular inside the healthy tissues of the host plants, typically causing no apparent symptoms of any disease. Fungi are a heterotrophic group of organisms with various life cycles that include symbiotic relationships with a wide variety of autotrophic organisms. Fungal endophytes are highly diverse and their presence in plants is dependent upon the host, the availability of nutrients, the environment, and the community composition of other microorganisms (Porras-Alfaro and Bayman, 2011). Some endophytes exhibit specificity to one tissue type, yet others can be found within multiple locations of the plant (Herrera *et al*.

Table 1. Some examples of endophytic bacteria

Bacterial strains	Family	Host plants	Activities	Reference
Achromobacter piechaudii	Alcaligenaceae	*Sedum plumbizincicola*	Improve phytostabilization of metalliferous soils	Ma *et al*. 2016
Acinetobacter calcoaceticus	Moraxellaceae	*Brassica napus*	Enhance phytoremediation of nitrate-cadmium compound polluted soil	Chen *et al*., 2015
Bacillus subtilis	Bacillaceae	Cacao seeds	Antimicrobial and plant growth-promotion	Falcao *et al*., 2014
Brevibacterium sp.	Brevibacteriaceae	Coral	New cyclic tetrapeptide isolated	Liu *et al*., 2016
Pseudomonas fluorescens	Pseudomonadaceae	*Brassica napus*	Biocontrol of plant pathogens and plant growth promotion	Chlebek *et al*., 2020
Microbacterium sp.	Microbacteriaceae	*Arabis alpine*	Plant growth promotion under multi-heavy metal stress	Sun *et al*., 2019

Table 2. Some examples of endophytic fungi

Fungal strains	Host plants	Activities	Reference
Penicillium oxalicum	*Citrus limon*	Antioxidant and genoprotective activities	Kaur *et al*., 2020
Fusarium solani	*Glycyrrhiza glabra*	Anti-microbial and anti-tubercular activity	Shah *et al*., 2017
Pestalotiopsis pauciseta	*Cardiospermum helicacabum*	Taxol production for antitumor activity	Gangadevi *et al*., 2008
Colletotrichum gloeosporioides	*Piper nigrum*	Piperine production	Chithra *et al*., 2014
Penicillium chrysogenum	Marine algae	Antimicrobial	Xu *et al*., 2020

2010). Endophytic fungi produce some of the most broadly used antibiotic and anticancer drugs.

Isolation of endophytes

Endophytes can be isolated from different plant parts like root, stem, leaf etc. The collected plant parts are washed under tap water. The plant part is disinfected with 70% alcohol and sodium hypochloride. Then, the parts are rinsed with sterile distilled water. Plant material is crushed using sterile mortar and pestle. Sterile distilled water is used as solvent to dissolve crushed plant material. For bacterial isolation, nutrient broth or nutrient agar can be used and for fungal isolation, sabouraud Dextrose agar can be used. Protocol for the isolation of endophytes is as shown below (Figure 1).

Endophytes for crop improvement

Plant pathogenic organisms reduce plant growth and productivity. Helpful organisms for plants, endophytes, can fight against pathogens effectively. These beneficial endophytes produce many compounds that are useful for plant protection against different environmental conditions and enhance plant growth. Endophyte population depends on location and environmental conditions of host plant habitat. Beneficial endophytes are alternative to currently used chemical biofertilizers for plant growth promotion (Fadiji and Babalola, 2020). Many researchers have worked on plant growth promoting potential of endophytes (Table 3).

Endophytes and bioremediation

Microorganisms are commonly used for bioremediation for the removal of contaminants, pollutants and toxins from soil and water. Plants and endophytes play an important role in the degradation of toxic components in the soil environment. Endophytes and soil microbes are more preferred to remove contaminants from soil because they contain enzymes that can tolerate environmental contaminants and take it as their food. Microbes can contact contaminants easily because they are very small in size and grow faster. After using contaminants as food, the microbes give healthy byproducts to the soil environment. Phytoremediation uses plants and associated microbes to remove pollutants from the

Collect the plant material (Leaf/stem/root)
↓
Wash under tap water for 2 min
↓
Disinfect outer side of the plant material with 70% alcohol for 1 min
↓
Wash the plant material with 2% sodium hypochlorite for 30 sec
↓
Wash the plant material with sterile distilled water for 3 times
↓
Crush the plant material in sterile distilled water by using mortar and pestle

For bacterial isolation		For fungal isolation	
Nutrient agar	Nutrient broth	Sabouraud Dextrose agar	sabouraud Dextrose broth
Pour 1 ml of crushed plant material on nutrient agar plates	Pour 1 ml of crushed plant material on nutrient broth flask	Pour 1 ml of crushed plant material on sabouraud dextrose agar	Pour 1 ml of crushed plant material on sabouraud dextrose broth
Incubate N agar plates for 24h at 37 ^{o}C	Incubate N broth flask for 24h at 37 ^{o}C	Incubate sabouraud dextrose agar plates for 72h at 30 ^{o}C	Incubate sabouraud dextrose broth flask for 72h at 30 ^{o}C
Isolate each bacterial colony on nutrient agar slant		Isolate each fungal colony on sabouraud dextrose slant	

↓
Store the slants at 4 ^{o}C until further use

Fig. 1. Isolation procedure of endophytes

environment and is considered a promising bioremediation method (He *et al*., 2020). Endophytes take part in host plant adaptation to polluted environments, enhance phytoremediation by mobilizing/degrading or immobilizing contaminants in the soil, promoting plant growth and decreasing phytotoxicity (Germaine *et al*., 2009).

Chen *et al*. (2010) has studied on four endophytes isolated from Cd-hyperaccumulator *Solanum nigrum* L. grown in metal-polluted soil. These endophytes had ability to degrade cadmium from the soil. Germaine *et al*. (2006) have that reported the bacterial endophyte *Pseudomonas putida* isolated from the plant *Populus trichocarpa* has the ability to degrade 2,4-Dichlorophenoxyacetic acid. 2,4-Dichlorophenoxyacetic acid is a herbicide for the control of broad-leaved weeds. But its residue can contaminate soil and groundwater, so it needs to remove from the soil. Weyens *et al*. (2011) have found that the endophytes have the potential to assist their host plant to deal with co-contamination of toxic metals and organic contaminants during phytoremediation.

Bioactive compounds from endophytes

Endophytes have capability to produce bioactive compounds by evolution time to time for the protection from pathogens, insects and grazing animals. Many bioactive metabolites have found from different endophytes. These metabolites are good source for treatment against many diseases as well as effective in agriculture, medicine, food and cosmetics. Many endophytes have potential to produce active substances against pathogenic microbes, inflammation and tumor.

Anticancer potency

It is characterized by cells in the human body continually multiplying with the inability to be controlled or stopped and forms tumor. Current treatments include chemotherapy, radiotherapy and chemically derived drugs. Current treatments have many side effects that cause damage the health of patient. Therefore, alternative and natural treatment is required to prevent toxic effects on patients. Taxol is an endophyte-related anti-cancer modern chemotherapeutic drug (Miller *et al*., 2008). The endophyte *Taxomyces andreanae* was isolated from the outer bark of *T. brevifolia.* Taxol was isolated from this endophyte as anticancer drug (Stierle *et al.*, 1993). Chen *et al* (2018) has isolated an endophyte strain from *Codonopsis pilosula* to reveal the characteristics and anti-cancer potency of purified exopolysaccharides. Wu *et al*. (2015) has isolated endophytes from *Morinda citrifolia* that was effective against lung, prostate and breast cancer cells. Thus many endophytes have anticancer potency.

Endophytes as antioxidants

Oxidative stress can lead to damage of all types of biological molecules, including DNA, lipids, proteins, and carbohydrates. Thus, oxidative stress may lead to increase of chronic degenerative diseases like coronary heart disease, cancer, and aging. Antioxidants can prevent or slow damage to cells caused by free radicals, unstable molecules that the body produces as a reaction to environmental and other pressures. The antioxidant activity of endophytes from plants is increasingly recognized in natural product research. The antioxidant compounds produced by endophytes likely help the host plant to neutralize ROS. Fungal endophytes and their host plants interact though physical or chemical signals and the former can promote host-plant growth through the production of phytochemicals, including antioxidants, without leading to biotic stress when they invade or live inside host plant tissues (Pan *et al*., 2017).

Antimicrobials from endophytes

The emergence of multidrug resistant pathogens and the increase of antimicrobial resistance constitute a major health challenge, leading to intense research efforts being focused on the discovery of novel antimicrobial compounds (Patel *et al.,* 2018). Endophytes are reported to synthesize a wide variety of antimicrobials which has antagonistic activity against several pathogens and

Table 3. Examples of plant growth promoting potential of endophytes

Endophytes	Action	Reference
Bacillus velezensis	Biocontrol agent in peanut production	Chen *et al*., 2019
Piriformospora indica	Induces growth promotion as well as biotic stress resistance	Li *et al*., 2017
Bacillus sp.	Improving sweet sorghum biomass production and its total metal uptake on heavy metal-polluted marginal land.	Luo *et al*., 2012
Pseudomonas stutzeri	Improves nitrogen fixation	Pham *et al*., 2017
Sphingomonas sp. and *Serratia marcescens*	Increase plant growth hormones	Asaf *et al*., 2017

Table 4. Antimicrobial compounds isolated from endophytes

Endophyte	Host plants	Compounds isolated	Activities	Reference
Lecanicillium genus	*Sandwithia guyanensis*	Stephensiolide	Anti-MRSA	Mai *et al*., 2020
Streptomyces ansochromogenes	*Byrsonima crassifolia*	Metabolites from isolated endophyte	antimicrobial and antibiofilm action against the bacterium *P. aeruginosa* and against *L. amazonensis*	Amorim *et al*., 2020
Chaetomium sp.	*Astragalus chinensis*	differanisole A, 2,6-dichloro-4-propylphenol and 4,5-dimethylresorcinol	Antimicrobial	Liu *et al*., 2019
Epicoccum sp.	*Taxus fauna*	Peptides	Antimicrobioal	Jadoon *et al*., 2016
Epicoccum nigrum	*Ferula sumbul*	2-methyl-3-nonyl prodiginine, Bis (2-ethylhexyl) phthalate, and Preaustinoid A	Antimicrobioal	Perveen *et al*., 2017
Aspergillus sp.	*Mitrephora wangii*	Beta-thujaplicin	Antibacterial	Monggoot *et al*., 2018

commercially utilized for pharmaceutical, medical and agricultural purposes. Table 4 shows antimicrobial potential of endophytes.

Future prospects

Endophytes are a good source of different metabolites for treating various disorders in humans and also produce chemicals for use in agriculture such as growth regulator and pesticides, in several economically important plants. Endophytes have emerged in many clinical applications with molecular approaches. The endophytes formulation based bio fertilizers are used to increase soil fertility and crop yield. The endophytes are also useful for the degradation of plastics, polymers, electrical materials etc. The endophytes can also be used for different fermentation procedures. Nanoparticals form endophytes are useful in medicines and also can be useful to improve plant growth (Rana *et al*., 2020). Further future prospects may involve solving Questions related to how endophytes communicate with each other in the view of their pathogenicity, the biodiversity of Fungal Endophytes functional classes across environmental gradients, their mechanism of plant biogeographic patterns, evolutionary origins, and habitat adaptations and can fungal endophytes be used by rDNA technology successfully. Further research on the metabolites produce by endophytes and their potential has raised hopes in finding different biotechnological activities.

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