Fungal Allies: Investigating the Impact of Endophytic Fungi on Finger millet (*Eleusine Coracana*) Growth and Protection.

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Abstract

Finger millet (Eleusine coracana) is also known as ragi in India. Finger millet are very useful for human health. This review focuses on the effects of endophytic fungi on finger millet plants. Endophytic fungi is the symbiotic microorganisms residing within the internal tissues of plants, have emerged as key players in plant growth, plant health and their stress tolerance. In this review, we explore the effects of endophytic fungi on finger millet, a resilient cereal cereal crop cultivated worldwide. Through a comprehensive synthesis of current, literature, we clarify the multilateral roles of endophytic fungi in mitigating diseases, increasing the growth and improving stress resilience of finger millet plant. Especially, we discuss the mechanism by which endophytic fungi contribute to nutrient acquisition, disease suppression and abiotic stress tolerance in finger millet, highlighting their potential application in sustainable agriculture. Moreover, we examine the biocontrol and biotechnological potential of endophytic fungi in incentive plant health and productivity. Despite significant progress, several knowledge gaps persist, warranting further research to fully understand the complex interactions between endophytic fungi and finger millet. This review, the importance of harnessing the beneficial effects of endophytic fungi for enhancing finger millet cultivation and advancing agricultural sustainability.

Key word: Endophytic fungi, Finger millet, Effect;

1. Introduction

Finger millet (*Eleusine coracana* L. Gaertn) is grown in arid and semi-arid regions of India, mostly under rain-fed and hazardous conditions in soils with reduced fertility and water deficit during the monsoon season. Intercropping with finger millet in rainfed conditions is the rule rather than the expectation, to avoid various risk factors as well as to obtain higher returns per unit area (1). Issues related to inappropriate use of chemical fertilizers in agriculture have led to increased attention to the use of beneficial endophytic microorganisms to enhance plant health and crop production while protecting food quality and environmental sustainability. Finger millet (*Eleusine coracana*) is considered a nutritious crop, used as food and feed in Asian and African countries, and wheat, because millet is more nutrient dense than rice or wheat, because millet grains are rich in zinc, iron, phosphorus, potassium, calcium, magnesium, carbohydrates, vitamins and important amino acids. Also they are particularly high in polyphenols and calcium. It contains nutritious ingredients that are easy to digest, making it a staple food for pregnant women, diabetics, sick, lactating mother and children (2).

The resistance of finger millet grains to mold attributed to abundant polyphenols. Mechanisms involved in endophyte-mediated disease resistance include competition for nutrients and spatial induction of host resistance genes, improvement of nutrient status and production of anti-pathogenic natural compounds. However, an emerging body of literature suggests that microbes living in plants without causing disease, defined as endophytes, may contribute to resistance to fungal pathogens. Finger millet is recognized by local farmers as a crop that tolerates stressful conditions and that resists various pathogens. Finger millet is a new source of endophytic anti-fungal natural products (3). Endophytic fungi and bacteria enjoy unique relationships with plants that range from mutualism to symbiosis. In fact, their interactions with plants are so deeply and intricately linked that the microbiome associated with endophytes and other plants is often referred to as the plant's 'second genome'. Endophytes promote plant health by directly increasing nutrient availability, production of phytohormones, organic acids, or indirectly by inhibiting phytopathogen growth or activity (4).

Finger millet belongs to the Poaceae family which has excellent nutritional properties, such as high dietary fiber content, amino acids (leucine, isoleucine, phenylalanine, tryptophan, methionine and cysteine), iron and calcium. As a member of the minor millets, finger millet is the most climate-resilient crop that can be cultivated under various climatic conditions. Biological stresses include insects, weeds, birds and diseases. The plant-endophyte association us a mutualistic relationship, these microbes help the host cope with a wide variety of biotic and abiotic stress conditions. Endophytes are living organisms that may be bacteria or fungi that live in plant tissues for at least part of their life cycle, causing no visible symptoms with much beneficial effect on their host plant (5). Endophytes, including endophytic fungi, endophytic bacteria and endophytic actinomycetes, exist in various organs, tissues and intracellular spaces of plants without causing immediate sings of disease. They have established a mutually beneficial relationship with the host plant during long-term coevolution. Plants provide nutrients for endophytes, while endophytes contribute to maintaining plant health. Mechanism proposed for disease prevention include competition with pathogens for specific and nutrients, plant resistance secretion of bioactive metabolites and promotion, of plant growth, usually working in concert. Some antimicrobial compounds produced by endophytes are known to strongly inhibit pathogens, hydrolases secreted by endophytic bacteria can degrade the cell wall of pathogens and phytohormones released by endophytes play important roles in plant growth and stress response. Endophytic fungi are known to produce various bioactive compound for anti-inflammatory, antioxidant, anti-fibrosis and antiviral drug development (6).

1.1 Classification of Endophytic fungi effect on Finger millet plant and their application

Effect	Application	Example	References
Beneficial Effect	Endophytic fungi with beneficial effects can be utilized in agriculture for sustainable crop production and disease management.	*Piriformospora indica*	7

Neutral Effect	Although their effects may not be readily apparent, neutral endophytic fungi can still play a role in plant health and ecosystem dynamics.	*Cladosporium spp.*	8
Detrimental Effect	Understanding the mechanisms of pathogenicity associated with certain endophytic fungi can inform disease management strategies in finger millet cultivation.	*Fusarium oxysporum*	9

1.1.1 Plant Growth

The effect of the fungus on plant growth was determine by measuring shoot height, root length, shoot and root fresh weight after inoculation of plant with the fungus (10).

1.1.2 Nutrient Uptake

Inoculation of finger millet plants with these endophytes increased shoot and root length and plant and root dry weight, as well as increased grain zinc content and NPK content compared to non-inoculated controls. These endophytes have shown efficiency abilities to solubilize insoluble zinc compounds such as carbonate, phosphate and oxide, making them valuable sources for zinc absorption and seed fortification, NPK uptake and growth of finger millet crops (2).

1.1.3 Disease Resistance

Blast disease of finger millet caused by the filamentous ascomycetous fungus *Magnaporthe oryzae* is the most devastating diseas3 affecting the growth and yield of this crop in all its growing regions. Breeding strategies currently used to improve disease resistance (11).

1.1.4 Stress Tolerance

Finger millet is known for its ability to tolerate stressful conditions and resist many pathogens, including *Fusarium graminearum* (12).

1.2 Types of endophytic fungi to effect finger millet plant

Analysis the effect of endophytic fungi on finger millet pants in some endophytic fungi can enhance plant growth, increase nutrient uptake and improve resistance to stresses such as drought and pathogens and some may even have neutral or negative impacts on finger millet plants.

Table 2. Beneficial effect of endophytic Fungi on finger millet

Endophytic Fungi	Effect on Finger millet plant	References
Piriformospora indica	Finger millet plant inoculated with *P. indica* exhibited significantly higher growth rates in plant. Higher water content observes in inoculated plant tissue. Plant tissues analysis high concentration of nitrogen, potassium and phosphorus in shoots and roots. Gene expression analysis showed upregulation of stress-responsive genes involved in osmotic adjustment, antioxidant defense and hormone signalling pathway.	7

Trichoderma spp.	Finger millet plant inoculated with *Trichoderma spp.* in this observe biocontrol agents and plant growth promoters. They can enhance nutrient uptake, induce systematic resistance and improve stress tolerance in finger millet.	13
Cladosporium cladosporioides	Finger millet plant inoculated with *Cladosporium cladosporioides* in this shown to beneficial effect on finger millet plant. To enhance plant growth and development by promoting root elongation, increasing nutrient uptake and stimulating plant growth hormone. This fungus helps in the biocontrol of pathogens by producing antifungal compound.	8

Table 3. Negative effect of endophytic fungi on finger millet

Endophytic Fungi	**Effect on Finger millet plant**	**References**
Fusarium oxysporum	Finger millet plant inoculated with *Fusarium oxysporum* in this shown fungus cause Fusarium wilt. It can weaken the plant's vascular system, leading to wilting, stunting and eventually death. This negative impact on finger millet production can result in significant yield losses and economic hardship for farmers.	9
Curvularia spp.	Finger millet plant inoculated with *Curvularia spp.* in this observe fungus cause leaf spot and leaf blight diseases in finger millet. It can reduce photosynthetic efficiency and overall plant vigor. Severe infections can result in defoliation, reduced yield, and even plant death.	14
Colletotrichum gloeosporioides	Finger millet plant inoculated with *Colletotrichum gloeosporioides* in this shown fungus can infect the stems, causing rotting and weakening of plant structure. It causes dark, sunken lesions on the leaves, which can lead to defoliation and reduced photosynthetic activity.	15

Conclusion:

Endophytic Fungi play a major role enhancing growth, yield and resilience of finger millet. Their symbiotic relationship with plants promotes nutrient uptake, disease resistance and overall plant health. The use of endophytic fungi can significantly improve the productivity of finger millet, making it a promising strategy for

sustainable agricultural and food security. Some endophytic fungi have a negative effect, causing damage to the plant but to a lesser extent. Most of endophytic fungi is the beneficial for finger millet plant.

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