

Genomic Insights into Endophytic Fungi and Their Influence on Plant Stress Physiology

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DESCRIPTION

Endophytic fungi inhabit internal tissues of plants without causing visible disease symptoms in most cases. These organisms occur in roots, stems, leaves, and seeds across a wide range of plant species and ecosystems. Their presence is often associated with subtle but significant effects on plant physiology, including improved tolerance to environmental stress, altered metabolic activity, and changes in growth dynamics. Advances in fungal genomics have enabled deeper investigation into the genetic mechanisms that support endophytic lifestyles and influence interactions between fungi and their plant hosts.

Endophytic fungi represent a highly diverse group spanning multiple taxonomic lineages. Many species are closely related to known plant pathogens or saprotrophic fungi, suggesting that ecological lifestyle transitions have occurred repeatedly during fungal evolution. Genome sequencing has revealed that endophytic species often possess gene repertoires that differ from those of pathogenic or free-living relatives, particularly in genes associated with host interaction, metabolism, and environmental sensing.

Colonization of plant tissues requires precise coordination between fungal activity and host responses. Endophytic fungi must enter plant tissues, establish residence, and maintain a stable relationship without triggering strong defense reactions. Genomic studies have identified numerous genes involved in cell wall modification, adhesion, signaling, and immune modulation. These genes contribute to the ability of fungi to inhabit internal plant environments while avoiding host damage. Plant-derived chemical signals play an important role in shaping fungal behavior. Endophytic fungi respond to compounds released by plant cells, including sugars, organic acids, phenolics, and secondary metabolites. Genomic analyses reveal extensive collections of sensor proteins and regulatory systems that allow fungi to detect and respond to these signals. These mechanisms influence colonization patterns and metabolic activity within host tissues.

Metabolic flexibility is a defining feature of many endophytic fungi. Inside plant tissues, nutrient availability differs from

external environments. Fungi must adapt to varying levels of carbon, nitrogen, and micronutrients. Comparative genomic studies show that endophytes often possess expanded gene families related to carbohydrate metabolism, amino acid utilization, and nutrient transport. These adaptations allow them to utilize diverse substrates derived from plant metabolism. One important aspect of endophytic interaction involves modulation of plant stress responses. Plants frequently encounter environmental challenges such as drought, salinity, heat, cold, and pathogen exposure. Endophytic fungi can influence how plants respond to these conditions. Genomic investigations have identified fungal genes associated with the production of metabolites that affect plant hormonal pathways, including those involving auxins, jasmonates, and salicylic acid signaling systems.

Secondary metabolites produced by endophytic fungi contribute significantly to their ecological function. These compounds may influence plant growth, deter pathogens, or alter microbial community structure within plant tissues. Genome sequencing has revealed extensive biosynthetic gene clusters responsible for producing diverse chemical compounds. Variation in these clusters among species suggests adaptation to specific host plants and environmental conditions. Some endophytic fungi exhibit genetic features similar to those found in latent or opportunistic pathogens. This similarity has led researchers to propose that ecological lifestyle may shift depending on environmental conditions and host status. Genomic comparisons indicate that genes associated with virulence, toxin production, and host invasion may be present but regulated differently in endophytic species. This regulatory control appears to determine whether a fungus remains asymptomatic or transitions toward pathogenic behavior.

Root-associated endophytic fungi are particularly important for plant nutrient acquisition. Some species enhance phosphorus, nitrogen, and micronutrient uptake through modifications of root physiology or soil interactions. Genomic analyses identify genes involved in nutrient mobilization, enzyme secretion, and soil organic matter degradation. These traits contribute to improved plant nutrition under limiting conditions. Leaf-

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Received: 27-Feb-2026, Manuscript No. FGB-26-42483; **Editor assigned:** 02-Mar-2026, PreQC No. FGB-26-42483 (PQ); **Reviewed:** 16-Mar-2026, QC No. FGB-26-42483; **Revised:** 23-Mar-2026, Manuscript No. FGB-26-42483 (R); **Published:** 30-Mar-2026, DOI: 10.35248/2165-8056.26.16.309

Citation: Taniguchi K (2026). Genomic Insights into Endophytic Fungi and Their Influence on Plant Stress Physiology. Fung Genom Biol. 16:309.

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associated endophytes often face different environmental pressures compared with root inhabitants. Exposure to light, temperature fluctuations, and atmospheric conditions influences their genetic adaptations. Comparative genomics shows differences in genes related to Ultraviolet (UV) protection, oxidative stress response, and surface colonization. These adaptations support survival within aerial plant tissues. Seed-associated endophytes provide another important ecological dimension. These fungi are transmitted vertically or horizontally and can influence early plant development. Genomic studies indicate that seed-associated species often possess genes related to dormancy, survival, and early colonization ability. Their presence may influence germination rates and seedling establishment.

Horizontal gene transfer has been suggested as a possible contributor to the evolution of endophytic lifestyles. Genetic exchange between fungi and other microorganisms within plant tissues may introduce novel functions. While such events are relatively rare, genomic evidence suggests that they may contribute to metabolic innovation and ecological adaptation in

certain lineages. Endophytic fungi also hold potential for applications in agriculture and biotechnology. Their ability to influence plant growth and stress tolerance makes them candidates for improving crop performance under adverse conditions. Genomic research assists in identifying strains with beneficial traits and understanding the genetic basis of plant-fungal compatibility.

CONCLUSION

The study of endophytic fungal genomics continues to expand, revealing complex networks of interaction between fungi and plants. Through analysis of gene content, regulatory systems, metabolic capabilities, and population diversity, researchers gain insight into how these organisms persist within plant tissues and influence host biology. Ongoing genomic exploration will further clarify the roles of endophytic fungi in plant ecosystems and their contributions to environmental adaptation and ecological balance.