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Growth Promoting Role of Manglicolous Fungi

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Abstract

Mangroves are inhabited by large number of fungal communities, known as *manglicolous fungi*. They include mostly marine fungi and small group of terrestrial fungi and can be categorized into saprophytic, parasitic, and symbiotic fungi. Fungi in mangrove environment play an important ecological role in decomposition of organic matter by production of variety of extracellular degradative enzymes such as cellulase, xylanase, pectinase, amylase, and so on. Such enzymes can be isolated from the mangrove fungi and harnessed for several biotechnological applications; mangrove fungi focused on their ecological roles as their extreme importance in nutrient cycling. Most classical plant hormones are also produced by pathogenic and symbiotic fungi.

Keywords: Manglicolous fungi, fungal diversity, phytohormone, hotspot, coevolution

Mangroves are salt-tolerant forest ecosystems confined to intertidal zones of sheltered shores, estuaries, tidal creeks, backwaters, lagoons, marshes, and mudflats of the tropical and subtropical latitudes. These important ecosystems are a dynamic ecotone between terrestrial and marine habitats and of great ecological, economic, and social significance.

Mangrove forests are biodiversity "hotspots" for marine fungi. These fungi play an important role in the nutritive cycle and support the mangrove ecosystem. They commonly occur as saprophytes on decomposing organic matter, as symbionts of plants and animals and as parasites of plants in mangrove ecosystems.

Mangrove fungi include lower fungi (oomycetes and thraustochytrids) and higher fungi (ascomycetes and basidiomycetes). the marine fungi encountered in the mangrove habitat live on roots, stems, and twigs submerged in water and their terrestrial counterparts inhabit on lower stem, branches, and upper parts of the roots above the water surface. Since aerial parts in mangroves are exposed to salt spray, these fungi can be said to have salt tolerances.

Mangroves being detritus-based, considerable fungal population are involved in detritus processing. Mangrove fungi decompose vegetative material and thereby allow secondary colonization by bacteria and yeasts that further decompose the organic matter. Mangrove fungi being decomposers of dead organic materials act as intermediaries of nutrient flow from organic matter to the higher levels.

As diverse vegetation exists in mangroves, it is considered as a major niche of fungal repository. Mangrove fungal diversity is dependent on the age of the mangrove, diversity of the mangrove plant species, and the physico-chemical features of mangrove habitat including temperature, salinity, and tidal range. Fifty-five mangroves and their associates yielded about 200 higher marine fungi. *Rhizophora apiculata* among the mangrove tree species harbored a maximum of 63 higher marine fungi. Biodiversity of manglicolous fungi on selected plants in the Godavari and Krishna deltas, East Coast of India. *Fungal Divers.*, 6: 115–130. Thirty-five core-group fungi were recovered on woody litter from different mangroves of India (23 ascomycetes, 1 basidiomycetes, and 11 mitosporic fungi) .Terrestrial fungi are common in mangrove water and mud, mangrove leaves, standing senescent stems, seedlings, submerged wood, decomposing mangrove palm, live marine algae, and mangrove rhizosphere.

Mangrove fungi focused on their ecological roles as their extreme importance in nutrient cycling. Fungal endophytes can modify plants at genetic, physiologic, and ecologic levels. Wetland dicots and monocots differ in colonization by arbuscular mycorrhizal fungi and dark septate endophytes. These modifications induce profound changes in how plants respond to their environments, with potential consequences in terms of spatial variation in vegetation dynamics.

Different fungal biopesticides can be used to control plant diseases and some insect pests and weeds. Nowadays, reports about mangrove fungi also revealed that many of them were able to produce insecticidal metabolites.

Most classical plant hormones are also produced by pathogenic and symbiotic fungi. The way in which these molecules favour the invasion of plant tissues and the development of fungi inside plant tissues is still largely unknown.

Fungal-derived molecules have potentially two modes of action: (i) they may perturb plant processes, either positively or negatively, to favour invasion and nutrient uptake; and (ii) they may also act as signals for the fungi themselves to engage appropriate developmental and physiological processes adapted to their environment. Indirect evidence suggests that abscisic acid, gibberellic acid and ethylene produced by fungi participate in pathogenicity.

Many fungi interact with plants in a beneficial manner, as in mycorrhizal symbiosis or in a harmful manner, as in the case of fungal diseases. In order to obtain nutrients, both symbiotic and most pathogenic fungi penetrate their host without breaking the plant cell plasma membrane. The fungal membrane is protected by a cell wall composed of chitin that can be recognized by plants through membrane receptors, which then activate basal immunity. Chitin perception modulates responses during both mutualistic and pathogenic fungus–plant interactions. Fungi have evolved a repertoire of tools, such as protein effectors and metabolites, to impede such plant immunity and/or to establish favourable conditions for their invasion of plant tissues .In addition to the production of canonical effectors, fungi also produce compounds that are similar to plant hormones, such as auxins, cytokinins (CKs), gibberellic acids (GAs), ethylene (ET), abscisic acid (ABA), jasmonic acid (JA) and salicylic acid (SA). These hormones are well described to control plant development and to trigger important plant signalling events during biotic and abiotic stresses.

The role of plant-derived hormones in plant disease resistance has been reviewed extensively. In this review, we summarize the current knowledge on the role of fungal-derived plant hormones in plant–pathogen interactions with a focus on their putative role in virulence.

Fungal Auxins Play a Positive Role in Plant–Fungus Interactions

Auxins are indole-derived hormones Auxins control plant developmental processes, such as cell division, differentiation, organ formation and also biotic and abiotic stress responses in plants. In *Fusarium* sp., like bacteria ,auxins are synthesized from tryptophan, which is converted into indole-3-acetamide by tryptophan-2-monooxygenase enzymes. Indole-3-acetamide is hydrolysed to form indole-3-acetic acid (IAA), which is also the major auxin In some, such as *Fusarium* sp. and *Colletotrichum gloeosporioides*, auxins are synthesized from the indole-3-acetamide.

As observed in other fungal genera, for instance *Ustilago* and *Rhizoctonia* , auxins can also be produced from indole-3-pyruvate.

Many fungal species, and not only plant-interacting fungi, produce and secrete auxins, suggesting that these hormones could have an endogenous role in these organisms. A negative correlation between the speed of fungal growth and auxin production has been shown in several species. By contrast, auxin treatment promotes cellular elongation and sporulation in the yeasts *Saccharomyces cerevisiae* and *S. ellipsoideus*. Similarly, an aberrant production of auxins leads to morphological transition in *S. cerevisiae*, as well as in the human pathogen *Candida albicans*, in which auxin triggers the transition into hyphal growth, a known virulence trait. By measurement of the fungal biomass and auxins in plant tissues, it was suggested that *C. gloeosporioides* f. sp. *aeschynomene* produces auxins during the early biotrophic stages of plant colonization.

Fungal CKs: Positive Function in growth

CKs are diversified plant hormones derived from ATP/ADP/AMP or from the tRNA degradation pathway. CKs are well described for their role in plant developmental processes, such as root and shoot formation, through the regulation of cell cycle and cell differentiation. CKs are also involved in the delay of senescence and in source–sink nutrient distribution. The first step in CK biosynthesis in plants involves isopentenyl transferase enzymes (IPT or tRNA-IPT), which perform the transfer of the isopentenyl chain from the methylerythritol phosphate (MEP) on the adenosine phosphate substrate, leading to the formation of the ribosylated phosphorylated CK forms. Then, these CKs are activated, in part by the LONELY GUY (LOG) enzymes, into free CK active forms, such as *trans*-zeatin and isopentenyladenine. The putative *IPT* and *LOG* genes are present in several fungal genomes.

A large diversity of fungal species, whether saprophytic, pathogenic or symbiotic, have been shown to produce CKs, CKs promote *in vitro* branching of ectomycorrhizal mycelia, affect, in a dose-dependent manner, hyphal membrane viscosity, a During mycorrhizal symbiosis, CKs promote growth of the host and of the symbiont. CK accumulation in the host, root and shoot has been shown in many fungal symbiotic interactions. A model has emerged since the early 1990s on the role of CKs in plant symbiotic interactions, proposing that plants secrete CKs which: (i) promote the growth of symbiotic microbes which are thus able to detect them; (ii) this contributes to a better absorption of nutrients through the symbiont; and (iii) leads to an increase in the photosynthetic process in the host leaves. It is possible that CKs produced by mycorrhizas may initiate this whole process, but this awaits the study of CK-deficient symbiotic fungal mutants to be confirmed. nd therefore influence ion and water transport.

Evidence for a Role of GAs of Fungal Origin

GAs are terpenoid hormonal compounds identified for the first time as being produced by *Gibberella fujikuroi*. This fungus is the causal agent of the 'bakanae' or 'foolish seedlings' disease of rice, in which infected plants are abnormally tall. Following this discovery, the role of GAs in plant physiology was studied. GAs are involved in the control of germination, flowering, cell division and internode elongation The role of GAs during interaction between fungi and plants. In mycorrhizal interaction, the GA content is increased in plants have suggested a model in which the production of fungal GAs is possibly required to initiate a signal leading to enhanced carbon sink activity of the infected cell (probably combined with CKs and Auxins).

Evidence for ABA Used as a Growth Promoting Factor

In plants, ABA is well known to induce stomatal closure and thus to contribute to plant drought tolerance. ABA is the key hormone for plant abiotic stress responses and it is also involved in seed dormancy by acting antagonistically with the GA pathway. In plants, ABA is synthesized from both the MEP and mevalonate pathway.

Fungal production of ABA was first shown in *Cercospora risicola*. Since then, many fungi with different lifestyles (saprophytic, symbiotic and pathogenic) have been described as producing ABA The arbuscular-mycorrhizal (AM) fungus *Glomus* sp. produces ABA, and ABA concentration in the xylem sap is different between mycorrhizal and non-mycorrhizal plants. In several plant–pathogen interactions, ABA has been described to affect plant disease resistance in a positive or negative manner, depending on the host–pathogen interaction.

Gaseous Hormone from Fungi: Involved in Plant Physiology

ET is a gaseous compound first discovered for its role in fruit maturation. ET was later shown to be involved in senescence, germination, flowering and the inhibition of root and shoot growth.

Fungi also produce ET from 2-keto-4-methylthiobutyric acid, derived from methionine, and/or from 2-oxoglutarate, therefore requiring ET-forming enzymes. The first report of ET production by *Penicillium digitatum* in 1940, ET production has been measured in many fungal species, in both hyphae and spores. These fungi belong to different phyla, have different lifestyles and range from pathogenic fungi, such as *B. cinerea*, to symbiotic fungi, such as *F. oxysporum* f. sp. *pini*. In the case of mycorrhiza, the role of ET depends on the type of symbiotic interaction. A low content of ET was measured in mycorrhizal roots and an exogenous supply of ET suppressed AM development. Therefore, it was suggested that a repression of the ET pathway by AM fungi is required to allow the establishment of symbiosis. Indeed, the AM fungus *Glomus intraradices* secretes a protein (SP7: secreted protein 7) which interacts with an ET response factor to suppress ET signalling. In contrast, ET seems to promote ectomycorrhizal symbiosis. Two species of truffle (*Tuber melanosporum* and *Tuber borchii*) have been shown to produce ET (and auxin) for the manipulation of these hormonal pathways in the host and for the induction of root morphological modifications, a plant developmental process in which these hormones are involved. Given the roles of ET in plant defence, this fungal ET production by symbionts could also be required to counteract the establishment of host immunity.

Fungi also Produce the Defence-Related Hormones SA and JA

In most plants, SA and JA trigger defences against fungal biotrophic and necrotrophic pathogens, respectively, in an antagonistic manner. Some fungal pathogens may produce one hormone in order to inhibit the defence pathway which is the most detrimental to their growth.

Some pathogenic fungi produce both SA and JA, such as, for example, *Moniliophthora perniciosa*, which causes witches' broom disease of cocoa. In this case, the production of these hormones could: (i) contribute to manipulate the hormonal pathways involved in the host defence responses throughout its invasion, i.e. causing abnormal shoot development and necrosis; and (ii) have a direct effect on this fungus as both SA and JA promote *in vitro* growth.

SA has a moderate suppressive effect on the spore germination and colony growth rate of *Harpophora maydis*. In *Aspergillus flavus*, the results obtained from *in vitro* experiments show that SA reduces hyphal growth significantly at all concentrations tested. JA by pathogenic fungi, such as *G. fujikuroi* and *Botryodiplodia theobromae*. JAs are derived from lipid peroxidation, and thus belong to the oxylipins. Some fungal oxylipin biosynthesis pathways have been identified and characterized. JA and the other oxylipins can affect both host and fungal physiological processes. The *in vitro* application on *F. oxysporum* f. sp. *lycopersici* of methyl jasmonate reduced spore germination and mycelium growth .

CONCLUSION

This overview shows that plant-fungus interactions suggests a sophisticated coevolution to ensure dynamic plant responses to evolving fungal mutualistic/pathogenic strategies. The plant-fungus communication relies on a rich chemical language. To manipulate the plant defence mechanisms, fungi produce and secrete several classes of biomolecules, whose mode of- action is largely unknown. Upon perception of the fungi, plants produce phytohormones and a battery of secondary metabolites that serve as defence mechanism against invaders or to promote mutualistic associations. These mutualistic chemical signals can be co-opted by pathogenic fungi for their own benefit.

Among the plant molecules regulating plant-fungus interaction, phytohormones play a critical role since they modulate various aspects of plant development, defences and stress responses. Intriguingly, fungi can also produce phytohormones, although the actual role of fungal produced phytohormones in plant-fungus interactions is poorly understood.

Therefore, most fungi have been shown to produce almost all plant-like hormones *in vitro*. The sequencing of many genomes may also help to shed light on the presence of the hormonal biosynthesis pathways already described in some fungal species. This overview shows that most known plant hormonal compounds are produced and perceived by fungi.

Some plant hormones have been shown to affect fungal development, nutrition and reproduction processes, suggesting that these molecules trigger certain signals in fungi

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