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Role of Mites in Insect Fungus Association

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Introduction

The association among insect, mite and fungus are diverse and quite complex. A pivotal role is played by mite in stabilizing insect fungus interaction. They mediate interaction that facilitates fungal associations with insect that are either mutualistic or antagonistic and effect the population dynamics, ecosystem process and biodiversity of the three communities. Many mites and insects rely on fungi for nutrients, and fungi benefit from them in terms of spore dissemination, habitat provision, and nutrient resources. Mites have the ability to change the structure, diversity, and robustness of communities via altering interactions between insects and fungus. The ecological selection factors that drive mite development play a significant role in the community's emergent form and function. Mites have evolved antagonistic, commensalistic, and mutualistic behaviours as adaptations to insect or fungus populations. Mites exploit or compete for resources with conspecifics and heterospecifics, resulting in a complex web of interactions and relationships. To influence the association, mites have to reach their habitat. Other than anemochory, phoresy is the major mode of dispersal of mites. Terrestrial mites are mainly carried by insects of order Coleoptera, Diptera and Hymenoptera. For this purpose, mites have developed a certain degree of specificity to attach with the insect. Mycetophagous mites feed and transport fungi that are associated with several insect and affect the disease epidemiology. Among the best-understood cases of mite-fungus-insect interactions are systems of bark beetles, leaf cutter ants, bees, and wasps. But the impetus has always been given towards studying the binary interactions that are simpler to understand. Mites are under described and many species are yet to be discovered. Considering their immense role in insect fungus association, further studies need to be conducted encompassing the three communities of insect, mite and fungus.

Influence of Mites on Insect Mutualistic Fungi

Mites can help insect-mutualistic fungi by promoting fungal transmission, reproduction, and survival while diminishing antagonistic fungi through feeding or reduced transmission, or by increasing bacteria that kill insect pathogenic fungus. Mites, on the other hand, can have a detrimental impact on insect-mutualistic fungi or interrupt insect-fungus interactions through exploitative competition, predation, or the fostering of hostile fungi. These mechanisms have an impact on the communities' ecological and evolutionary patterns. Mites, for example, might proliferate fungal species that are poor mutualists of their insect hosts, causing bug's fungal connection to alteration or destabilization.

Mite Dispersal and Evolution of Sporotheca in Mite

The term phoresy (Greek phora: to carry, bear) refers to one of the various types of animal associations, the most prominent of which being mites and insects (as carried) (as carriers).

Phoresy has developed several times in the three major mite groups, Mesostigmata, Prostigmata, and Astigmata, in various ways. Phoresy is a phenomenon in which one animal actively seeks out and attaches to the outer surface of another animal for a limited time during which the attached animal (called the phoretic) stops feeding and ontogenesis, presumably resulting in dispersal from areas unsuitable for the individual's further development. Hyperphoresy is a mechanism of dissemination in which some mites employ other phoretic mites.The interaction between the phoront (phoretic guest or passenger) and the host or carrier is only temporary. Mites at the phoretic stage must have the sensory capability to detect and locate possible insect hosts, as well as the mechanical ability to climb on and attach to the host insect once they have been found. Because most mite species are restricted to specific insect species or genera, adaptations for coexistence with insects necessitate a degree of specialisation on the side of mites.

Suski used the name sporotheca to describe paired eversible sac-like structures carrying spores in 1973. Sporothecae have been found in the *Siteroptiidae, Trochometridiidae*, *Tarsonemidae*, and *Scutacaridae* genera of heterostigmatic mites. *Siteroptes* mites have a pouch on the hysterosoma right beyond the fourth pair of legs, while Tarsonemus mites have tergite C on the lateral sides. The coxal plates IV of *Trochometridiumtribulatum* cross have sporothecae apertures.

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Mite-fungus association with southern pine beetle

Dendroctonus frontalis, the Southern pine beetle, is a serious pest of the coniferous forests. By facilitating access to the subcortical environment of the trees, this bug supports a vast array of related species. Ophiostomatoid fungi, which comprise the genera *Ceratocystis*, *Ceratocystiopsis*, *Cornuvesica*, *Gondwanamyces*, *Grosmannia*, and *Ophiostoma*, are usually linked with bark beetles. The southern pine beetle (*D. frontalis*) and the mountain pine beetle (*D. ponderosae*) are two bark beetles that have specialised structures termed "mycangia" or "mycetangia," which means "fungal vessel."Mycangia are specialised invaginations of the integument lined by secretory glands that are employed for fungal transfer. The beetle introduces these mycangial funguses into the tree phloem, where they eventually provide sustenance for the developing offspring. Mycangial funguses are *Ceratocystiopsisranaculosus* and *Entomocorticium sp*., which are transferred between trees in mycangia of adult female beetles. The nutritional substrate for developing *D. frontalis* larvae is provided by these fungi.*Ophiostoma minus*, a fungus, has also been associated to these beetle infestations. Rather than mycangium, it is carried on the exoskeleton of beetles. *D. frontalis*larve is a powerful antagonist of *O. minus*. Blue stained areas show slowed egg production, poor larval growth, and limited larval survival. In addition to fungi, *D. frontalis* adults transport at least 57 different types of mites between trees. *Tarsonemus* mites are ecologically significant because they connect species interactions between *D. frontalis*, mycangial fungi, and *O. minus*. *Tarsonemusips* and *T. krantzi* are common pine beetle companions.Adult females of *Tarsonemus spp.* and *D. frontalis* have a phoresy relationship. Ascospores of *O. minus* or *Ceratocystiopsisranaculosus* can be found in the Sporotheca of *Tarsonemus spp*. The southern pine beetle's mycangial fungal mutualists are *C. ranaculosus* and *Entomocorticium sp.*Hsiau and Harrington. Despite the fact that *Entomocorticium sp.* is the most beneficial of the two mycangial fungus for *D. frontalis* and may be a crucial to the larvae's success, neither *Tarsonemus* mite species has been observed to transfer *Entomocorticium sp. Tarsonemus* mites indirectly influence the dynamics of interactions between their bark beetle hosts, the fungi with which they engage, and the tree host that houses them all by transporting particular fungi to serve as substrate for their own reproduction and development.

Dutch elm disease and the role of mite

The fungus *Ophiostoma novo-ulmi*Brasier (Ascomycota, Ophiostomatales) is the causal agent of Dutch elm disease, a lethal vascular wilt disease of elm species (*Ulmus spp*.) in Europe, Asia, and North America. In Europe and Asia, the fungus is transmitted by native bark beetles belonging to the genus *Scolytus*, and in North America a native bark beetle *Hylurgopinusrufipes*(Eichhoff) and the introduced beetle, *Scolytusmultistriatus*(Marsham), serve as vectors of the pathogen.*Scolytus* carries three mite species, *Proctolaelapsscolyti*Evans, *Tarsonemuscrassus*(Schaarschmidt), and *Elattomafraxini*, feed on *O. novo-ulmi*or carry its spores, thus transmitting the fungus into elm trees. Webber & Gibbs found evidence that *O. novo-ulmi*is detrimental to beetle larval development, similar to the effects of *O. minus* on *D. frontalis*. *O. novo-ulmi*may be essential for the nutrition of the mites *Proctolaelapsscolyti*and *Tarsonemuscrassus*, and it may thus be beneficial for these mites to transmit the fungus on which they rely. Given that these mites transport *O. novo-ulmi*, whereas the bark beetles associated with this system may suffer harm from the fungus, the importance of mites in the epidemiology of this destructive vascular wilt disease needs to be studied.

Mite fungus association with bees

Phoretic mites have a significant impact on bee ecology, and they must be researched in order to effectively manage bee colonies. Varroa mite infection is a major carrier of *A. mellifera* viruses, resulting in death and colony collapse. Chalk brood disease caused by the fungus *Ascosphaeraapis* appears to be more common in bee colonies with Varroa mites. Varroa mites have also been identified with *Aspergillus spp*. spores (the cause of stonebrood disease). *Imparipes* mites found in bee and sphecid wasp nests had *Fusarium* and *Mortierella* fungal spores in their sporotheca, as well as *Aspergillus* on their integuments. When a nest is newly occupied, these fungal spores proliferate and supply critical food for the mites.The mites preserve their independence in their habitat by transferring their own fungus, allowing them to change hosts across a range of soil- and wood-dwelling bees and sphecids. Solitary bee eggs and larvae are eaten by the mites *Trochometridiumtribulatum* Cross and *Imparipesapicola* (Banks). The mites, on the other hand, feed on the fungal mycelia forming on the carcasses after the bee eggs or larvae die. Fungal growth may be reduced when these mites feed on fungal mycelium within bee cells, benefiting the remaining bees.There was a strong association between the presence of mites and the absence of fungi inside the brood cells, as well as between the absence of mites and higher bee mortality, in tropical *Megalopta* bee nests. Bees have developed specialised acarinaria (mite chambers) on their bodies that house distinct mite species. Female *Xylocopa* bees are known to have a metasomalacarinarium with varied levels of specialisation.

Mites as transporters of fungal pathogen of insects

Mites and insects are commonly infected by entomopathogenic fungi such as *Beauveria*, *Entomophthorales*, *Hirsutella*, and *Nosema* species. Mites linked with bark beetles were commonly recovered from *Hirsutella* fungi under the bark of spruce (Picea), pine (Pinus), fir (Abies), and oak (Quercus) trees. The first, *H. minnesotensis* no. 3612, was isolated from a tarsonemid mite juvenile (possibly 1st instar larva) found in Norway spruce bark infested by the bark-beetle *Polygraphuspoligraphus* (L.) in a spruce woodlot near Laufen (Germany, Southern Bavaria). Several bark beetle larvae were infected with the *H. nodulosa* fungus, which was spread by tarsonemid mites. *Beauveria bassiana*, a well-known entomopathogenic fungus, has been isolated from the onion (*Allium cepa*) mites *Tyrophagus, Rhizoglyphus,* and *Histiostoma* (Abdel-Sater&Eraky, 2002). *Beauveria bassiana* is transported by oribatid mites, who play a significant role.

Future aspects

Taking into account the role of mites in insect fungus association, more thrust should be given towards studying the tripartite relationship of insect, mite and fungus. There is a great need to identify the various mite and fungal communities of insect ecosystem. Several mite species are yet to be identified and described and in many cases their role as a facilitator and a transporter is ignored. After correctly identifying the species, the effect they have on fungal and insect community needs to be worked out thoroughly. Predictive models can be erected to study the population dynamics, how they function and interact with other members of the ecosystem. Bringing together molecular and ecological approach will provide deeper insight in this multitrophic interaction.

Conclusion

Mites play a significant role in community dynamics, environmental processes, and biodiversity in insect-fungus relationships by driving diversification and stability. Many mites feed on insects and can spread infections to insects and plants. A change in mite behavior or novel mite relationships could explain the recent increase in tree mortality or

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insect pest switches from dead to living trees. Mites can alter the frequency of recombination in fungus linked with insects and plants, allowing for increased adaptation to different hosts, habitats, and changing temperature. Many insect systems still need to have their mite and fungus compositions determined.It will be critical to apply genetic approaches to identify mites in order to precisely identify mite species. Mites are understudied and require more research. Although there are systems like the ones discussed here in which mites have been researched for a long time and their functions in microbial ecology well documented, their role in many ecosystems is often underestimated or ignored.

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