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Nematophagous Fungi

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Abstract: A broad range of fungi are among abundant organisms occur in the soil such as nematodes and interaction with each other so parasitic and predaceous relationships developed among most larger group of soil fungi from Basidiomycetes and phycomycetes, they are known as nematophagous fungi or nematode-destroying fungi. This paper focus a review of researchers carried out by various researchers on the variation trap formation and mechanisms of capturing nematodes.

Introduction

Fungi live in their original environment in the soil and on decomposing organic matter with other microorganisms in overlapping groups, and interact with each other for performing ecosystem functions.(Treseder and Lennon, 2015). Their interactions can occur in different ways such as cooperate with other microorganisms alternately in the decaying of the organic matter in the soil or in form of predation or parasitism on other organisms in the soil such as nematodes (Topalovic and Heuer, 2019). The fungi feeding on and antagonizing nematodes called nematophagous fungi, this interaction has acted important function to understand fungi–nematode interactions (Nordbring-Hertz et al,2006). The invention of the microscope enabled to discover the hidden world and to examine some of the fungus that parasitism on nematodes and to see the fungal hyphae that carry small rings, hunt free nematodes in the soil. (Zhang et, al; 2020) .The nematophagous fungi grouped into many groups according to the mechanisms which used to attack nematodes: (i) producing expanded hyphal networks to trap nematodes, as well as knobs as trapping tools to hold live nematodes;(ii), the obligate parasitic fungi which act as endoparasitic fungi occur in the environment as conidia , the endoparasitic fungi adhere to the surface of the nematodes or the nematodes ingested them which then germination, growth, and killed the nematodes ;(iii) the facultative parasitic fungi, that grow and parasitize the egg- and cyst of the nematodes that represented the sedentary stages of the nematodes (iv) toxin-producing fungi that produce toxin against nematodes (Liu et al , 2009) (Li et al , 2015). Fresenius (1852) was from the first researchers, who described the nematophagous fungi *Arthrobotrys oligospora* , (Zopf 1888) (Niu and Zhang , 2011). In 1870, Woronin referred the ability of *A. oligospora* to produce a specialized network formed from vegetative hypha by stand lateral branch which curved to fuse with the parental hypha and producing loop or by developing the conidiophores of *A. oligospora* directly into a complex structure of network , while the function of it remained unclear , In 1876, Sorokin indicated that the nematodes could be infected with a ring from *A. oligospora* .

The strategies of nematophagous fungi for living:

1. **Eendoparasites :** they are mostly obligate parasites , they do not output comprehensive mycelium but occur in the environment as conidia which infect the prey either by being ingested or adhering to the surface of it (Poinar and Jansson , 1988). There are diversity among endoparasites fungi .*D. coniospora* produce large numbers of conidia as compared to produce of hyphal material , the researches on single infected nematode showed difference in number of conidia , *D. coniospora* produce 10 000 conidia while *H. rhossoliensis* 100–1000 conidia per infected nematode. the conidia germinate rapidly and by assimilative hyphae pervade entire nematode body and absorb the content, then the fungus break through the external surface of host body to form conidiophores structures of reproduction which support conidia or the tubes of evacuation , the zoospores released from it . An adhesive bud developed on the conidia by these fungi to infect the nematode (Fig: 1) Fungi in the genus Harposporium produce spores with specific shapes ingested by nematodes, this spores due to their shapes be embroiled in the oesophagus and from the initial infection of the nematodes. *C. anguillulae* by their motile infects nematodes zoospores that

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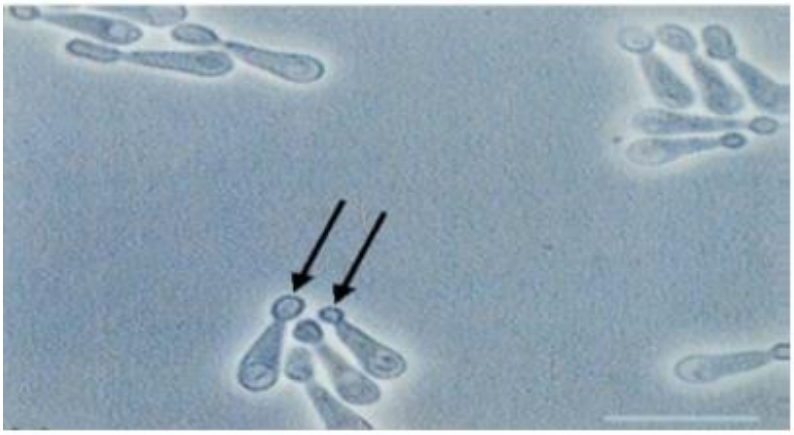
encyst on nematode and adhere to it . Eventually fungi in the genus Haptoglossa the produce spores form an infection 'gun cell' infect nematodes (Nordbring-Hertz et al , 2006) .



***D. coniospora* spores with adhesive buds (arrows).**
(Bar, 10 mm. Nordbring-Hertz et al,1995.)

2. **Predation:** Predation is essential life strategies for nematode-trapping fungi, these traps are substantial devices for the life of these fungi (Veenhuis et al. 1985), 200 fungal species belong to Ascomycota, Zygomycota and Basidiomycota depend on these traps to capture the soil freeliving nematodes (Li et al. 2000). Five kinds of trapping structures have been recognized in predatory fungi (i) adhesive networks, (ii) columns (iii) knobs (iiii) nonconstricting and constricting rings (Barron 1977). Adhesive networks the sparse mycelia of nematophagous fungi will be induced after intimate contact with nematodes to spontaneously differentiate into functional traps which digest and kill the nematode after capture and penetrate them. (Barron 1977). The adhesive network considered the most spread trap, which formed from vegetative hypha by stand lateral branch which curved to fuse with the parental hypha 20–25 μm from the initial hypha (Nordbring-Hertz et al. 1989) and forming more loops on the parent hypha or external to the original loop while the adhesive knob is adhesive cell formally like globose or subglobose , sessile on the hypha or erect, at the top of a slender , as non-adhesive stalk consist of one or three cells. The nonconstricting rings (NCR), which are constantly coupled with adhesive knobs, are produced when stand lateral branch of a vegetative hypha thicken and curve to create ring from three-celled which then combined to the supporting stalk. The detachable knob and the ring support a special advantage for the fungus due to their ability to go with the swimming nematode and to widely extension (Barron 1977). An adhesive column is a small stand column formed from a few swollen cells created on a hypha. These trapping structure act to capture nematodes by adhesive layer which covered all or part of the structure surfaces. The constricting ring, the last type of trapping structure, is the most developed one which captures prey with a various mechanism. as a nematode enters the three cells of the constricting ring are excited to quickly swell inside and firmly lassoed the prey within 1–2 s (Gray 1987; Yang et al. 2007). Nematophagous fungi show various habits as predator:

a. **Adhesive hyphae:** that precipitation specific material at some points for trapping the contact nematode a lot found in zygomycetes the absence of a hyphal septum does not allow complex structure for formation to the nematode capture (Barron, 1977).Adhesive material which produced by these fungi deposited at certain points on the hyphal surface as the nematode contact these certain points it be captured , appressoria have been produced by the hyphae which penetrate via nematode wall then the mycelium grow through all nematode body and consuming all contents of the nematode body and pull out all plasma to the outside of nematode body to develop the sporangia and spores (Chen and Dickson , 2004).
b. **Adhesive branches:** One to three cells are made the erect branches which simply anastomose to produce adhesive hoops or networks with two dimension like crochet or line in appearance. **(fig:2)** the branch totally is covered with a thin adhesive film therefore the nematode captured if contact the branch at any part .Adhesive branches are commonly closely for a part therefore if nematode become contact at any point will rapidly become into attached with other adhesive hyphae as it fight to escape. The most

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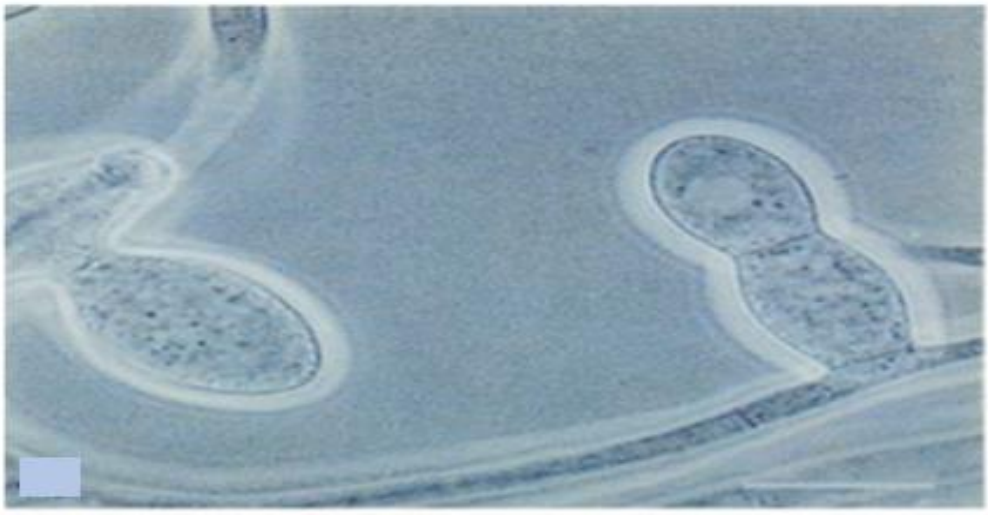
frequently species isolated from temperate soils *Dactylella cionopaga* form adhesive branches (Poinar and Jansson , 1988).



(Fig:2) Adhesive branches of *M. gephyropagum*. Bar, 10 mm. Bar, 10 mm. (Nordbring-Hertz et al,1995.)

c. **Adhesive networks (nets) :** adhesive nets are three dimensional complex network. The most common species known in this kind of trapping structure is *Arthrobotrys oligospora* which widespread over the world. adhesive nets considered as evolutionary development from adhesive branches and created from vegetative hyphae by curving of a stand lateral branch and are created by curving of lateral branch arising from the vegetative hyphae therefore it is capable to fuse with parental hyphae. From the parental hyphae more lateral hyphae are produced or form the loop to produce more loops, after forming the complex of anastomosed loops which evolve away from the potential hyphae in all reasonable direction **(fig :3)**. The total of network is plated with a thin layer of adhesive , nematode are captured on it (Chen and Dickson ,2004) (Martinelli and Santos , 2010).

(Fig :3) Adhesive network of *A. oligospora*, developed from digested nematode. Bar, 20 mm. Bar, 10 mm. (Nordbring-Hertz et al,1995.)

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d. **Adhesive knobs :** They are consist morphologically special cells coated with a thin layer of adhesive , they are either borne at the top of a small nonadhesive stalk such as in *Dactylella ellipsospora* or sessile as in *Dactylella phymatopaga* the shape of adhesive knobs are globose (Fig :4) therefore the contacted area between and captured nematode is very small so the prey being capable to fight free but the fungus take control by producing adhesive flatten mass at the point of contacted with captured nematode forming thick pad , therefore the attachment area increases many fold and ensuring the firmly held of the captured nematode. The fungus penetration is admixture of enzymatic and physical activity for instance the producing of collagenase may help in cuticle penetration, the additional strength force firmness of attachment supplied by the thickly adhesive pad is demanded if penetrating hyphae is to impose its way via the cuticle of the nematode (Poinar and Jansson ,1988). Adhesive knob is commonly very closely spaced over hyphae therefore as nematode being held it is so normal to the knob contacted with other knobs specially when nematode fight to free and make escape unattainable (Gray, 1988) (Barron, 1977). The adhesive knob and its stalk is separated by a septum, Barron referred that the knobs produced by many species were easily separated, from their stalk of hyphae as the nematode struggled however remained connected strength to their prey and penetrating it.

(Fig :4) Adhesive knobs of *M. haptotylum*. Bar, 10 mm.
(Nordbring-Hertz et al,1995.)

e. **Non constricting rings:** the most rarely trapping device exist only in four species of nematode trapping fungi which produced by lateral branches emerge from vegetative hyphae at beginning the branch is so slender and then become thick and curve to make a ring from three or four cells and fuse with support stalk. Nematode is held by passively enter to the ring which be wedged about its body, in case the nematode fight to free itself it became more tightly wedged and resulting a visible constricting about the animal , however the nematode held at the site of capture in ring frequently it can be liberated from the mycelium while the ring stay firmly in place and then invade its prey(Chen and Dickson ,2004) (Poinar and Jansson , 1988) . The contact point of supporting stalk with the ring observed to have degraded which offer that the fungus want the held nematode to escape with the ring which wedged tightly around the prey body this seems to be confer strategy to attain extreme dispersal in the soil. (Poinar and Jansson , 1988) (Askary and Martinelli ,2015).

f. **Constricting ring:** it is the most attacker and effective trapping device exist in Hyphomycetes at tweleve species recognized to form constricting rings, the ring size range from 20 to 40 µm (ID) internal diameter and varies among and within species. The fungus makes the constriction by decreasing the ratio of length to width of the cells achieving the constricting rings (Poinar and Jansson , 1988) (keke et al , 2012) , non-constricting rings like constricting rings as mechanical trap but not adhesive, consist of three arcuate cells that produce ring (Fig : 5) which is connected to the hyphae by a small stalk, the inner surface of the cells that form ring stimulate by nematode entering after a short period 2 to 3 seconds and held the prey by closing around it , according to present formation the fast of ring closing (< 0.1 second) which

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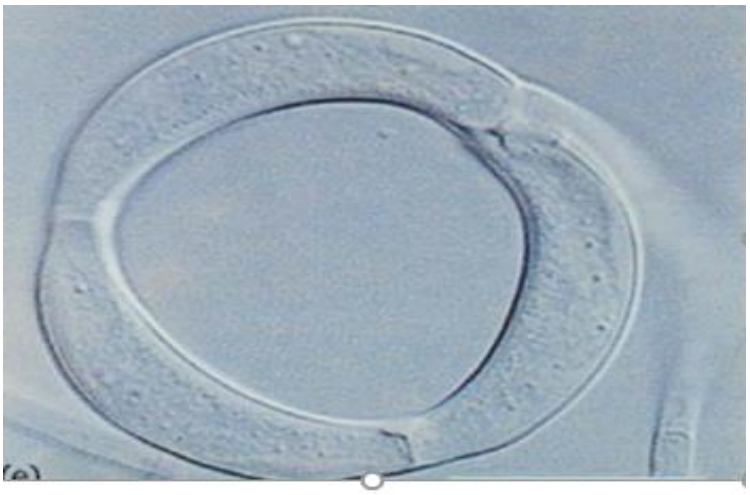
stimulate with heat or tactile also the ring can work as detached from the parental hyphae . The knowledge of constricting ring is like non- constricting though some complex, the lateral branch arise from vegetative hyphae then grows and curved to form the loop and attracted to the bud that create close to base of the stalk on to which it anastomoses , the ring cells at this time distinguished as well as the advanced end of the curved branch are anastomoses together the first cell at the base of the newly created ring , collecting the first and the last ring cells (Poinar and Jansson , 1988) .



(Fig :5) Constricting ring of *A. brochopaga*. Bar, 5 mm. (Nordbring-Hertz et al,1995.)

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