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5. Bio-Control of Plant Parasitic Nematodes

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Abstract:

Agricultural pests are constantly attacked by a variety of natural enemies. The species that harm nematode populations are collectively referred to as nematode antagonists. Interest in nematode-predacious fungi was sparked by efforts to employ them to control plant-parasitic nematodes. Although early studies in France, the USA, England, and the former USSR made significant advances to our understanding of the taxonomy and ecology of the nematode-predacious fungi, there has only been little success in employing them as biological control agents against nematodes (Stirling, 1991). affect nematodes.

From nematodes, several fungi have been isolated. In a key they published in 1964, Cooke and Godfrey listed 97 fungal species that prey on endoparasitic vermiform worms. Certain fungi might not be able to reduce nematode populations below a damage threshold. Nevertheless, a fungus may reduce yield loss brought by worms by reducing nematode inoculum. Incorporating biological control enables the better use of a resistant cultivar or crop rotation than would be possible without them. The biological efficacy and market value of a biological agent determine whether it may be commercialized. When biological control is used, the value of the environmental benefit has not been quantified. Biological control of plant-parasitic nematodes may be more feasible if environmental factors and food product quality are given more thought. The usage of fungal antagonists for nematode control may be a key element in an integrated pest management program in sustainable agriculture and a substantial contribution to the responsible and safe exploitation of the planet's natural resources.

***Keywords**:*

Plant-parasitic nematodes, predacious fungi, endoparasitic, biological control

5.1 Introduction:

Abiotic and biotic variables have an impact on every organism in an ecosystem. Nematodes are not an exception. Many nematode populations might be in equilibrium in an unaltered ecosystem. When humans introduced agriculture into an ecosystem, the balance might have been upset and the community structure might have undergone significant alteration, making some nematodes become serious pests of cultivated crops. Yet, a variety of natural adversaries are always waging war against these agricultural pests. Nematode antagonists are any species that harm nematode populations. Nematode biological control refers to the process through which antagonists keep the average nematode population density lower than it would be in their absence. Many organisms, including fungi, bacteria, viruses, rickettsia, plants, protozoans, turbellarians, tardigrades, enchytraeids, mites, insects, and nematodes, have been found to have nematode antagonists. Of these, nematode populations in soil appeared to be most effectively controlled by fungal and bacterial antagonists, which have been the subject of the most in-depth research.

This chapter focuses on perspectives on the biological management of nematodes employing possible fungal and bacterial agents, as well as nematode suppression by fungal and bacterial antagonists with recent advancements in research. A number of earlier reviews, book chapters, and books provide more details about various aspects (Barron, 1977; Dackman, *et al.*, 1992; Davis, 1998; Duddington, 1957; Gray, 1987, 1988; Jatala, 1986; Kerry, 1984, 1986, 1987, 1988, 1990, 1993; Keny and Jaffee, 1997; Li *et al.*, 2000; Mankau, 1980; Morgan-Jones and Rodriguez-Khbana, 1985, 1987, 1988; Rodriguez-Khbana and Morgan-Jones, 1988; Sikora, 1992; Stirling, 1988, 1991; Tribe, 1977a, 1980).

With Lohde's discovery of the fungus, *Harposporiurn Anguillanematophagous*,'s behavior in 1874, fungi that act as nematode antagonists have been investigated. Interest in the nematode-predacious fungi was sparked by Linford's (Linford, 1937; Linford, *et al.*, 1938) attempts to control plant-parasitic nematodes using predacious fungi. Early studies in France, the USA, England, and the former USSR made significant advances to our understanding of the taxonomy and ecology of the nematode-predacious fungi, but there has been only modest success in employing them as nematode biological control agents (Stirling, 1991).

The discovery of highly efficient nematicides of fumigants in the 1940s to 1950s and of organophosphates and carbamates in the 1950s to 1970s contrasts with the failure of biological nematode control utilizing fungi. Hence, there was a fall in interest in biological control throughout these times. Around the middle of the 1970s, interest in biological control began to resurface. This came about as a result of both the ongoing environmental issues caused by the usage of nematicides (Kerry, 1993; Stirling, 1991) and evidence of nematode suppression by fungal parasites. For the management of nematodes, certain attempts have been made to commercialize biological control agents (Cayrol *et al.*, 1978; Liu *et al.*, 1996; Tirnm, 1987), but the products generally have not been adopted or they have only been utilized on a small basis. The bio-control of plant-parasitic nematodes with fungal antagonists has recently gained increasing support. The use of nematode antagonists in management must show results in order to maintain public and industrial support for the bio-control of plant-parasitic nematodes, which is currently at a critical stage.

Nematode pathogenic fungi are carnivorous fungi that produce toxins to kill nematodes or trap worm-like nematodes with spores, hyphae structures, or hyphae tips. It has been discovered that more than 200 species of fungi from six different classes parasitize nematode eggs, juveniles, adults, and cysts (Mukhtar *et al*., 2013).

Cooke and Godfrey (1964) provided a list containing 97 species of fungi that prey on wormlike nematodes and are end parasites. Recently, numerous more fungus species have been discovered in worms all over the world. In 2000, Lee and colleagues conducted a thorough taxonomic analysis of nematode fungus. Nematode antagonist fungi can be divided into three categories based on their modes of action: (1) predatory fungi; (2) endoparasitic worm-like nematodes; and (3) parasites of females and eggs; (4) antibiotic-producing fungi; and (5) vesicular-arbuscular mycosis (VAM). There is no clear separation between these categories.

A. Predacious Fungi:

The predacious organisms catch, kill, and then eat their prey. Predatory fungi have developed unique tools for collecting animals like vermiform nematodes, just as some herbivorous plants. These tools include adhesive hyphae, adhesive branches, adhesive nets, adhesive knobs, constricting rings, non-constricting rings, and Stephano cysts (Barron, 1977; Liou and Tzean, 1992). However, some nematode-eating fungus may kill nematodes slowly, and they may experience parasitism for a protracted period of time. From this perspective, these fungi are also viewed as parasites of worms.

B. Endoparasites of Worm-Like Nematodes:

Endo parasitic fungi differ from predatory fungi in that they do not have special trapping devices. Most endophytic fungi of worm nematodes are obligate parasites or have limited saprophytic capacity. They do not have widely grown mycelium outside the nematode's body. However, some fungi that attack worms are facultative parasites and can undergo saprophytic activity without the nematodes.

C. Parasite of Sedentary Female Parasites and Eggs:

Female sedentary nematodes, cysts, eggs and egg masses are also attacked by fungi. Unlike mobile worm-like nematodes that can actively move toward and come into contact with predatory or endoparasitic fungi, the sedentary stage of nematodes may not have a chance to come into contact with parasitic fungi unless Fungi have a nematode access mechanism. The sedentary nematode-fixing fungi are ecologically diverse. While a few of them are obligate parasites, most fungi in this group can live in the soil as saprophytes. The attack mechanism of nematodes differs between obligate and facultative parasites.

5.2 Antibiotic-Producing Fungi:

Numerous parasites disengaged from sores and egg masses can be saprophytic. Their impact on nematodes is muddled. Apparently, a portion of these parasites produce poisons to the nematodes or that their presence in the egg mass or pimple hinders or animates the bring forth of the youthful from the egg. Poisonous impacts of contagious culture filtrate on nematodes and worm-like eggs have been accounted for in a few examinations on a few parasitic animal categories like *Paecilomyces, Verticillium, Fusarium, Aspergillus, Trichoderma, Myrothecium* and *Penicillium*. A couple of studies have been finished to describe the poisonous mixtures created by parasites. *Paecilomyces lilacinus* releases chitinase and protease, which can prompt deformity and vacuolation of undifferentiated eggs of *Meloidogyne hapla* (Fitters *et al.*, 1992). Non-enzymatic variables created by *Trichoderma virens* (syn. *Gliocladium virens*) hindered the incubating of *Meloidogyne incognita* eggs and the motility of J2. The poisons favorable to duced by *Fusarium spp*. have been tried on *M. incognita* and some have been demonstrated to be profoundly poisonous to nematodes (Ciancio, *et al.*, 1988). An anti-microbial from *Cylindrocarpon olidum* has been separated, decontaminated and portrayed (Coosemans, 1991). It shows great nematode infectivity and low harmfulness to vertebrates. Unadulterated concentrate of *Penicillium* sp., *Penicillium oxalicum*, *Penicillium anatolicum* and *Aspergillus niger* showed high nematodeicidal action at 100 ppm and 200 ppm (Molina and Davide, 1986). Anti-microbial-delivering growths can be normal in the dirt. Numerous other soil parasites that threaten nematodes through the arrival of poisons, anti-microbial or catalysts presently can't seem to be found. Nematode thickness was conversely connected with the chitinase, and collagenase and supportive of teinase exercises of a few soil microorganisms (Muller, *et al.*, 1982; Rodriguez Kabana, *et al.*, 1989), including parasites, for example, *Cunninghamella elegans* (Galper, *et al.*,1991). Kloepper *et al.* (1991) saw that plants with opposing properties against plant parasitic nematodes have a rhizosphere that is unmistakable from that of the host plant, and they likewise found that A more prominent number of microorganisms in the rhizosphere of the hostile plants are chitin-debasing.

A. Vesicular-Arbuscular Mycorrhizal Fungi:

Vesicular arbuscular mycelia (VAM) are endothelial growths that infiltrate profound into the roots. All VAM growths have a place with the request Glomales (Zygomycetes). Advantageous affiliation is expected for these organisms and they have not been achieved completely refined beyond their host. Throughout the course of recent many years, various examinations on the impacts of VAM growths on nematodes have been distributed. The job of VAM organisms in directing nematode populaces and their method of activity has not been completely clarified. Nematode reactions to VAM growths shift and may rely upon explicit affiliations, soil supplement levels, and term of perception (Ingham, 1988). Both opposing and helpful impacts of VAM on nematode populaces have been accounted for. VAM parasites can go after supplements and space in the roots, modify root emissions, change plant physiology, colonize nematode-feeding locales, decrease monster cell numbers or deliver nematodes or anti-microbials (Ingham, 1988). Then again, VAM organisms can further develop crop development and offset yield misfortunes generally brought about by nematode parasites, while expanding the food hotspot for nematodes, consequently expanding nematode populaces. Francl and Dropkin (1985) announced that *Glomus fasciculatum* could parasitize *H. glycine* eggs however was not adequate to decrease nematode populace thickness successfully. Collectively, VAM growths can't be characterized by any of the gatherings portrayed above and we subsequently think of them as a one-of-a-kind contagious bad guy. A more definite assessment of the communication between VAM organisms and nematode populaces was given by Ingham (1988).

B. Paecilomyces Lilacinus:

Paecilomyces lilacinus is a run-of-the-mill soil parasite that has been accounted for in many regions of the planet yet seems, by all accounts, to be more normal in hotter locales (Domsch, *et al*., 1980). This organism has been tracked down in a wide assortment of territories. Contamination of eggs of *M. incognita*, *Globodera pallida,* and female *M. incognita*, growths isolated from eggs, egg masses, females and blisters of many plant-parasitic nematodes on the planet. To begin with, the organism colonizes the gooey substrates of Meloidogyne, Tylenchulus, Nacobbus, and the pimples of Heterodera and Globodera in the end, an organization of mycelium creates and swallows the roundworm eggs. Infiltration of nematode eggs is finished by a basic mycelium or hyphae (Holland, *et al*., 1999). Mechanical and enzymatic exercises might be involved in the entrance. Morgan-Jones *et al*. (1984) revealed that mycelium penetrated the shell of Meloidogyne arenaria through little dissolvable pores in the yolk sac. Organisms infiltrate Meloidogyne eggs quicker than Globodera and Nacobbus eggs in light of the fact that the shell of Meloidogyne is easier than Globodera and Nacobbus (Rogers, 1966).

After entrance, the organism develops and multiplies in eggs at an early undeveloped stage. In the wake of sucking up the supplements from the egg, the mycelium can enter and get through the contaminated egg's fingernail skin from within, then, at that point, arise to taint other close by eggs. This growth can likewise colonize adolescents inside eggshells and adolescents mature 3 and 4 on agar (Holland *et al*. 1999). The way-of-life filtrate of *P. lilacinus* is harmful to nematodes (Chen, *et al*. 2000). The cuticle of the nematodes is broken and the nematodes are killed inside a couple of long stretches of openness to the way of life filtrate. The peptide anti-microbial P-168 was disengaged from *P. lilacinus* and portrayal (Isogai, *et al*., 1980). This substance has activity against growths, yeasts, and gram-positive microscopic organisms, along these lines permitting parasites to compete with soil microorganisms. *Paecilomyces lilacinus* gives off an impression of being a decent root intrusive animal groups (Cabanillas, *et al*., 1988) and a contender for the rhizosphere. Be that as it may, its conveyance profundity in sandy soils is by all accounts restricted to over 15 cm (Hewlett, *et al*., 1988). This organism can develop above and beyond a wide temperature and pH range and on a wide assortment of plant and creature substrates (Alam, 1990; Jatala, 1986).

The organism is additionally a bug parasite. *Paecilornyces lilacinus* has been widely tried for its true capacity as an organic control specialist and has been displayed to stifle nematode populace thickness and increment crop yield. All tests with *P. lilacinus*, in any case, gave compelling nematode control (Hewlett *et al*., 1988). Contrasts in exploratory outcomes might be expected to vary ences in harmfulness between confines (Stirling and West, 1991) and trial conditions. A detailing called "Biocon", containing P. lilacinus, has been promoted for the control of root knob and pimple nematodes in the Philippines (Tirnm, 1987). A natural control specialist named "Soybean Root Bio-Protectant" has been created and used to control soybean growth nematodes on 12,600 hectares in China. In spite of the fact that *P. lilacinus* have been secluded from natural eyes and sinuses with no proof that nematode confines cause sickness in hu-monitors and circulated around the world (Domsch *et al.*, 1980).

C. Verticilliurn Chlarnydosporium:

Since Willcox and Tribe (1974) discovered its ability to parasitize nematode eggs, this fungus has been found on various nematodes but mainly on Heterodera and Meloidogyne species. Gams (1988) reclassified fungi into two species and two genera of each: *Verticilliurn chlarnydosporium Goddard* var. *chlarnydosporiurn, Verticilliurn chlarnydosporiurn* var. *catenulaturn, Verticillium suchlasporiurn* var. *suchlasporiurn* and *V. suchlasporiurn* var. *catenaturn*. *Verticillium chlamydosporium* enters the nematode cyst through natural orifices or directly into the wall of the cyst (Kerry, 1988). Fungi form a network of branching hyphae and enter eggs by simple branching hyphae or by forming appressoria (Lopez-Llorca and Claugher, 1990). Enzyme activities are involved in penetration. An electron microscopy study showed that the fungus was able to degrade the vitelline layer of eggshells and partially degrade the chitin and lipid layers. A 32 kDa protease has been isolated from infection of *H. avenae* eggs by *V. suchlasporium* and is considered to be involved in the pathogenicity of fungi against roundworm eggs (Lopez-Llorca and Robertson, 1992). *Verticillium chlamydosporium* can produce a toxin that inhibits hatching or kills nematode eggs (Caroppo *et al*. 1990; Meyer *et al*. 1990). Some studies have shown that *V. chlamydosporium* can colonize plant roots (Kerry, 1984; Stiles and Glawe, 1989), while others have shown that *V. chlamydosporium* cannot penetrate the root cortex and is confined to the root plane (De Leij and Kerry, 1991). This fungus does not appear to be pathogenic to plants (Kerry, 1984; Stiles and Glawe, 1989) and does not tend to cause disease in higher animals and humans. *Verticillium chlamydosporium* is one of the main parasitic fungi responsible for *H. avenae* inhibition in Europe (Kerry, 1975). The potential of fungi in nematode biocontrol has been evaluated in numerous greenhouses, micro plot and field studies. The effectiveness of nematode control is influenced by a number of factors. The host plant has a great influence on fungal growth in the rhizosphere and on the effectiveness of control (Borrebaeck, *et al.*, 1984). This fungus was more effective in controlling nematodes at lower nematode densities at higher densities and in nematode-poor hosts than in susceptible hosts (Kerry and Jaffee, 1997). Nodular nematodes in large cavities may escape the fungal attack and control effectiveness may be limited. Different isolates have different pathogenicity against roundworm eggs (Irving and Kerry, 1986). The combination of fungi with *Pasteuria penetrans* increased the efficiency of reducing the number of *M. incognita* nematodes in tomatoes (De Leij, *et al.*, 1992a). *Verticillium chlamydosporium* is a promising biocontrol agent and much effort has been made to develop a commercially acceptable formulation (Stirling, *et al.*, 1998). However, no commercial products of this fungus have been marketed yet.

D. Verticillium Lecanii:

Verticillium lecanii is commonly isolated from soil in different geographical areas (Domsch, *et al.*, 1980). Besides a variety of dead plant and animal substrates, this fungus is a catholic super parasite and parasitic on arthropods, rust fungi, powdery mildew and many other fungi. It has been used commercially to control greenhouse aphids. This fungus can penetrate the wall of the follicle and colonize *H. schachtii* eggs within 60 hours (Hanssler, 1990; Hanssler and Hermanns, 1981). The lytic enzymes secreted by the fungus play a major role in penetrating the follicle wall and eggshell. Gintis *et al*. (1983) observed the chitinase activity of fungi on chitin agar and the ability of *H. glycines* to penetrate eggs. Meyer *et al*. (1990), however, reported that a strain of *V. lecanii* reduced the viability of *H. glycines* eggs without egg invasion, suggesting that the fungus produces a toxin that kills the nematode eggs. This fungus has been evaluated as a biological control agent for soybean cyst nematodes in the laboratory, greenhouse and field for many years. Benomyl-resistant mutants were generated and one more effective at reducing the nematode populations of *H. glycines* and *M. incognita* in greenhouses (Meyer, 1994; Meyer and Huettel, 1991; Meyer and Meyer, 1995, 1996). Application of alginate pellets containing mutant strains of *V. lecanii* at 5 g pellets per pot (530 g soil) significantly suppressed *H. glycines* nematode populations in untreated soil, but was not observed. Reduction in nematode numbers with 0.5 g pellets per pot (Meyer and Meyer, 1996). Microplot assays showed significant control for *H. wisteria* population with *V. lecanii* at 340 kg of alginate seeds/ha; however, nematodes in the field plots were not controlled (Meyer, *et al*., 1997). Further research is needed to determine whether this fungus has the potential as a biocontrol agent for soybean cyst nematodes and other nematodes. A wide range of target pests and plant pathogens warrants the commercial value of the fungus as a biological control agent. If effectiveness in controlling nematodes is proven, the fungus may hold promise for large-scale nematode control in the field.

E. Hirsutella Rhossiliensis:

Hirsutella rhossiliensis was first depicted in 1980 (Minter and Brady, 1980) in view of an example gathered in Ridges in 1953. Sturhan and Schneider (1980) detailed this nematode parasite. named *Heterodera humuli* and named it *Hir-sutella. heterroderae* (equivalent word *H. rhossiliensis*). This growth has a wide host range, including plant parasitic nematodes, free-living nematodes, and bug and tick-borne nematodes, albeit different disengages may have favored has. unique. *Hirsutella rhossiliensis* is types of a hyphomycete with straightforward erect phialides, enlarged at the base and tightening towards the pinnacle. At the point when the nematode has come into contact with the spores of the phialides, the spores can join to the nematode's epidermis and contaminate the host within a couple of days. After entrance, the growth shapes an irresistible bulb in the pit of the nematode, from which the anabolic mycelium creates. In the wake of changing over the items in the nematode body into clusters of mycelia, the growth can rise up out of the nematode cadaver, produce spores, and taint different nematodes. All things considered; 112 conidia could be shaped from mycelium developing from a solitary youthful *H. schachtii* at 20°C (Jaffee *et al*. 1990). KC1 improves the probability of contagious nematode contaminations (Jaffee and Zehr, 1983). Conidia isolated from the phialides may lose its capacity to contaminate. A few conidia bite the dust following division and others can stay feasible and harmful for no less than 200 days (Jaffee *et al*. 1990). Variety in morphology, pathogenicity and hereditary qualities was seen among disconnects (Liu and Chen, 2001; Tedford *et al*., 1994). The nematode parasitism of *H. rhossiliensis* relies upon nematode thickness; the level of nematodes contaminated with parasites is decidedly related with the thickness of host nematodes (Jaffee, *et al*., 1992). The quantity of conidia joined to the nematode cuticle of *H. rhossiliensis* corresponded with the quantity of conidia in the dirt. Since parasites are contenders for supplement unfortunate soils, nearby contagious populaces might be-come terminated except if took care of with insignificant nematodes (limit have thickness) (Jaffee and Zehr, 1985). The normal pestilence of this growth among nematode populations grows gradually and solely after an extensive stretch of high host thickness. Spore spread was more noteworthy in loamy sand than in coarse sand (Jaffee *et al*. 1990). Contrary to the hypothesis that adding natural matter can upgrade nematode contagious activity, adding natural make a difference to the dirt lessens the parasitism of *M. xenoplax* by *H. rhossiliensis* (Jaffee *et al*., 1994). The capability of growths as a natural control specialist has been questionable. Muller (1982) detailed that this parasite had the option to repress sore nematodes in some sugar beet fields in Germany. This parasite is believed to be part of the way liable for stifling populaces of *M. xenoplax* in certain plantations in the southern US (Zehr, 1985). Big numbers and commonness of *M. xenoplax* brought about by *H. rhossiliensis* have additionally been found in certain California peach plantations (Jaffee *et al*. 1989). In nursery studies, *H. rhossiliensis* restrained *G. pallida* on potatoes (Velvis and Kamp, 1996), *H. schachtii* on cabbage (Jaffee and Muldoon, 1989), Pratylenchus penetrans on potatoes (Timper and Brodie, 1994) and *H. glycines* on soybeans (Liu and Chen, 2001). The outcomes acquired by Tedford *et al*. (1993) announced that drawn out collaborations between populaces of *H. rhossiliensis* and root knob or sore nematodes didn't prompt natural control. In a field miniature preliminary, *H. rhossiliensis* neglected to inhibit *H. schachtii* (Jaffee *et al*., 1996). *Hirsutella rhossiliensis* has been formulated into alginate pellets and used to control nematodes in lab and nursery studies (Jaffee *et al*., 1996; Flunky *et al*., 1993). Notwithstanding, more exploration is expected to decide whether this parasite has potential as a business bio-control specialist.

F. Fusarium spp.:

Fusarium is an enormous class that incorporates numerous species with an assortment of nourishment al transformations. A few types of Fusarium have been separated from females, follicles, egg masses and roundworm eggs. *Fusarium oxysporum* and *F. solani* are the most widely recognized species (Maurya *et al*., 2020). Types of these two species are either pathogenic or non-pathogenic, however as a general rule, they are extremely cutthroat in the dirt. A couple of types of Fusarium have been tried in the lab and in the nursery for their true capacity as natural control specialists for nematodes. Night and partners (1980) exhibited that a high extent *of H. schachtii* eggs were parasitized by *F. oxysporum* in sugar beet fields in California. Comparable segregates of *F. bullysporum* colonized over 70% of recently framed female eggs on the roots in sterile soil in nursery pots (Maurya *et al*., 2023 a). Fusarium species produce various poisons that irritate streptomyces, microbes, growths, and nematodes (Ciancio *et al*., 1988). Hallmann and Sikora (1994) detailed that the disconnects of *F. oxysporum*, decreased root knobs brought about by nematodes in tomatoes by 52-75%. Channel societies of endogenous plant-pathogenic *F. oxysporum* disconnects killed juvenile *M. incognita* inside 8 h (Hallmann and Sikora, 1994). The nematicidal impact of the way of life filtrate was likewise seen in *F. solani* on *M. namelessly* (Mani and Sethi, 1984). Heat-stable and pH-autonomous poisons are answerable for the nematode-killing impact. Apparently, the Fusarium species are not plant pathogenic, has high pathogenicity to nematode eggs or produce metabolites poisonous to nematodes, which can endure in regular soils. Such strains and their high limit in soil and rhizosphere can be successful natural control specialists (Maurya *et al*., 2023 b).

G. Pochonia Chalamydosporia:

Pochonia chlamydosporia (Goddard) (*Verticillium chlamydosporium*) was re-ported as a parasite of nematode eggs in 1974. Interestingly (Sreeja *et al*., 1996), *Verticillium chlamydosporium* was disconnected and recognized from dark pepper tainted with semi-endoparasitic nematodes. In an in vitro explore, the organism decreased the bring forth pace of RKN eggs by 41.4% in 5 days, recommend ing that it very well may be utilized for the administration of zest root knob nematodes. Because of the enormous populace, saprophytic properties, and diligence of *P. chlamydosporia* spores, just *Pochonia chlamydosporia* has shown successful control against the dark pepper-going after knob nematodes (Eapen *et al*., 2009). Natural soils have been demonstrated to be a superior substrate for the development of *P. chlamydosporia* than mineral soils (Kerry *et al*., 1993). The three-sided connection transport between the root knob nematode, *P. chlamydosporia*, and the host plant has been viewed as perplexing (Kerry, 2001).

H. Arthrobotrys Oligospora:

Arthrobotrys oligospora is a type of Arthrobotrys. The most broadly detached and far and wide nematode-catching organism in the climate the principal revealed nematode-catching parasite (Farrell *et al*., 2006; Jaffee, 2004; Wachira *et al*., 2009). Arthrobotrys (53 sp.), Dactyllina (28 sp.) and Drechslerella are the three principal genera of nematodes (14 sp.). Contagious action in the dirt outcomes in a lower number of nematodes, consequently limiting nematode killing (Jaffee *et al*., 1996). They incorporate around 200 systematically different types of organisms, which are all fit for benefiting from live nematodes (youthful, grown-up, and eggs) and involving them as supplements (Nordbring-Hertz *et al*., 2006). Three kinds of the nematode *Arthrobotrys oligospora* were detached from 60 sections of land of espresso and pepper crops.

Vesicular mycosis (VAM) The commitment of VAM in decreasing the unsafe effects of root attack of some plant parasitic nematodes is presently generally recognized. Four kinds of mycorrhizae with vesicles were additionally all around as powerful as phorate in controlling worm pervasions on dark pepper. Pre-inoculation of the urinary lot with VAM will assist with decreasing the seriousness of M. Undefined root contamination. *Glomus fasciculatum* had a decrease in the root knob record of 32.4%, while *Glomus etunicalum* had a lessening of 36%. In dark pepper, the most elevated development was kept as stem length, number of hubs, number of leaves present, and shoots and root weight in plants not just getting MFA (Koshy *et al*., 2003).

Augmentation of tunnelling nematodes and knob nematodes was reduced when AMF was utilized before nematode immunization, decreasing the root gesture ule file and the root sore list. This organism was more powerful in charge ling nematodes at lower nematode densities at higher densities and in have less nematodes than in defenseless has (Kerry and Jaffee, 1997). Nodular nematodes in huge cavities might get away from the parasitic assault and control viability might be restricted.

The blend of parasites with *Pasteuria penetrans* expanded the proficiency of lessening the quantity of *M. incognita* nematodes in tomatoes (De Leij, *et al*., 1992a).

5.3 Bacteria:

Have plant tissues, soil, nematodes, and their eggs and pimples all produce different nematode-pathogenic bacterial gatherings (Tian *et al.*, 2007). To oversee plant-parasitic nematode populaces under regular circumstances, they develop a com-plex web of collaborations between the climate, microbes, nematodes, and plants (Tian *et al.*, 2007; Rahanandeh *et al.*, 2012).

A. Bacillus Subtilis:

Bacillus subtilis (Ehrenberg) Cohn assists increment with establishing essentialness yet is poisonous to establish sicknesses and nematodes. *Bacillus subtilis* strain (RB.DL.28), a functioning nematicidal rhizobacterium confined from Vietnamese dark pepper roots, was demonstrated to be the most intense inhibitor of root-hitch nematode egg bring forth with 82% (Nguyen *et al.,* 2019).

Chitinases and proteases have been viewed as exceptionally applicable in repressing egg bring forth, and all the more as of late, regular thermostable synthetic substances have been demonstrated to be significant for killing J2 worms. Prophylac spasm utilization of *B. subtilis, P. fluorescens, T. viride* and AMF smothered the development of nematode states in soil and pepper roots, coming about in a sustainable soil climate with lower levels of contamination. *P. longum* treated with *B. subtilis* showed the best decrease in root hub record (Subhagan, 2008).

What's more, *Bacillus thuringiensis* Berliner (Bt) has nematicidal impacts in bug control and was likewise examined against a financially important plant parasitic nematode (El-Sherif *et al.*, 2007; Khan *et al.*, 2010). In his subsequent instar (J2) adolescent of *Meloidogyne javanica B. thuringiensis* culture (Carneiro *et al*., 1998). *C. elegans* populaces diminished by 80% after in vitro treatment with Bt (Mozgovaya *et al*., 2002).

B. Pasteuria Penetrans:

Pasteuria penetrans are Gram-positive, endospore-framing bacterial parasites of different spineless creatures that were first found by parasitizing Daphnia, a spe-cies of the variety Daphnia. *Pasteuria parasitizes* six types of plant parasitic nematodes (Mohan *et al*., 2012) and one types of bacterivorous nematode (Mohan *et al*., 2012). Pasteuria species it is one of the most encouraging bacterial biocontrol specialists for the overwhelming majority worm species since it can totally restrict nematode multiplication by going about as an ovarian parasite (Perrine-Walker and Le, 2021).

Dark pepper is a lasting plant answered to be a superb host for *P. penetrans* on *M. incognita* (Sosamma and Koshy, 1997). Under nursery conditions, *P. Penetrans* guideline of RKN in dark pepper diminished nematode expansion, root list, and expanded improvement and root mass productivity (Sosamma and Koshy, 1997). Pasteuria strains ended up being intended for *M. incognita* and upset its life cycle (Mhatre *et al*., 2020). Purification forestalled nematode fruitfulness by keeping tainted females from laying eggs or egg masses.

C. Pseudomonas Fluorescens:

The capacity of *Pseudomonas fluorescens* Migula to tie carbs and lectins to the root surface and in this manner contend with the host has been ascribed to potential biocontrol specialists against root-hitch nematodes (Oostendrop and Sikora, 1990). Different organic elements, for example, *Bacillus subtilis* (Bbv 57), *Pseudomonas fluorescens* (Pfbv 22), *Trichoderma viridi*, AM parasites, and biomechanical fertilizer, have been displayed to increment plant development as far as expanding leaf number and plant biomass known to can advance pepper signifi-cantly (Senthilkumar and Ananthan, 2018). FYM-rich *Pseudomonas fluorescens* is viewed as the best of all biocontrol specialists in diminishing nematode populations on dark pepper (Bina and Sarodee, 2019).

5.5 Endophytic Bacteria:

Endophytes one of the main adversary species regularly utilized in organic control are endophytes (Ryan *et al*., 2008). Like endoparasitic nematodes, they colonize plant tissues and are an astounding possibility for microorganism control (Hallmann *et al*., 2009). Endophyte is more successful when contrasted with synthetic control the movement to the plant's interior tissues where they distinguish microbes own (Ryan *et al*., 2008). Endophytic consortia (*Pseudomonas, Arthrobacter sp. Bacillus spp*.), reduced nematodes, *Radopholus similis*, and so on. *M. incognita* (Aravind *et al*., 2009). Detached endophytic microbes Tried for its organic control from the foundations of the dark pepper plant properties against root-hitch nematodes and their action against *Fusarium oxysporum* and *Meloidogyne incognita* (Wiratno *et al*., 2019). Nine endophytic microbes disengaged from pepper plants was protected and viable against *F. oxysporum* and *M. incognita*.

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