

Synergistic Disease Complexes of Plant Parasitic Nematodes and Soilborne Pathogens

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Abstract: -

This review examines the biotic and abiotic elements influencing the synergistic interactions between phytophagous worms and soilborne diseases, as well as the processes underpinning these interactions. Methods for managing and resolving nematode–pathogen complexes are examined and talked about.

Introduction

It has long been understood that the intricate interactions between the host, the pathogen, and the surrounding environmental factors determine how disease develops in farmed crops. There are additional chances for interactions with other microorganisms that share an ecological niche in the case of soilborne diseases. It has been shown that nematodes play a major part in the development of diseases brought on by soilborne pathogens in a variety of crops worldwide. Root-knot nematodes (Meloidogyne spp.) are frequently involved in these nematode-fungus disease complexes, but a number of other endoparasitic (Globodra

spp., Heterodera spp., Rotylenchulus spp., Pratylenchus and ectoparasitic spp.) (Xiphinema spp., Longidorus spp.) nematodes have also been linked to illnesses brought on by soilborne fungal pathogens. Although there have been reviews of nematode-fungus complexes before this review (i) addresses the mechanisms underlying synergistic interactions; (ii) identifies biotic and abiotic factors influencing their development; and (iii) suggests possible strategies for managing and nematode-soilborne resolving pathogen complexes. It has long been known that the intricate interactions between the host, the virus, and the surrounding environment

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influence how disease symptoms manifest rather than being exclusively caused by the infection. Furthermore, plants are rarely, if ever, impacted by a single potential disease in the wild. This is particularly true for soilborne pathogens, as they have a great deal of opportunity to interact with other microbes that share their biological niche. The causes of disease and the factors that contribute to its complex nature.

PPN-pathogen complexes are instances of how interactions between soil bacteria affect the development of disease. When two organisms interact synergistically, a disease complex is created. Positive synergistic interactions occur when a nematode-pathogen relationship causes more plant damage than the total of the pest and pathogen's individual damages (1 + 1 > 2). On the other hand, an interaction can be characterized as antagonistic IR (1 + 1 < 2) when a nematode and fungal partnership causes less plant harm than would be predicted from the total of the individual organisms. The relationship between nematodes and fungus can be characterized as neutral (1 + 1 = 2) when it is known that they interact and cause plant damage equal to the sum of the damage caused by the pest and the pathogen acting alone. The latter can be challenging to find since neutral connections can cause plant damage that is comparable to additive associations, in which the pathogen

and nematode are known to not interact, even if the former two relationships can be easily shown experimentally. Cotton wilt produced by Fusarium oxysporum f.sp. vasinfectum was severe when root-knot more worms (Meloidogyne spp.) were present. This was the first documented instance of a nematodefungus interaction. Field tests using ethylene dibromide or 1,3-dichloropropene to sterilize soil later produced more proof of the relationship between Fusarium spp. and cotton root-knot nematodes. The frequency of wilting cotton plants was considerably lower in areas where a soil sterilant was applied. It was believed that the compounds, which are thought to have minimal fungicidal effect, decreased pathogen infection indirectly by lowering the densities of the nematode populations they interact with.

Mechanisms underlying synergistic interactions

Utilization of nematode-induced wounds by soilborne pathogens

PPN have the ability to inflict different kinds of wounds on host plant roots during entry or feeding, contingent on particular life cycles. Ectoparasitic nematodes, such Tylenchorhynchus and Trichodonus species, for instance, leave behind tiny micropuncturetype lesions after feeding on the root epidermal cells. Endoparasitic nematodes, on the other hand, significantly disturb the roots of their



hosts. A migratory endoparasite, the rootlesion nematode Pratylenchus spp. makes its way intracellularly via the cortex of roots by using its stylet to tear through cell walls. Meloidogyne spp., Globodera spp., and Heterodera spp. are sedentary endoparasites with complex life cycles and highly specialized feeding methods. Vermiform juvenile nematodes (J2) choose penetration sites behind developing root tips and move to the vascular cylinder, where specialized "nurse cell systems" are started, either intracellularly (Globodera and Heterodera spp.) or intercellularly (Meloidogyne spp.). Nematode invasion sites and tracts have been dismissed. by several authors as having little bearing on the etiology of fungal infections. Nonetheless, some investigations unequivocally show that nematode damage contributes the to emergence and progression of diseases brought on by soilborne pathogens. The significance of mechanical injury by the root-lesion worm Pratylenchus brachyurus on the emergence of black shank symptoms (Phytophthora parasitica) in flue-cured tobacco (Nicotiana tabacum cv. Hicks) using a variety of techniques. Artificial root-wounding treatment resulted in noticeably worse black shank disease symptoms in the plants. Furthermore, compared to plants inoculated with the oomycete alone, plants that were either (i) inoculated with the nematode P. brachyurus

and the oomycete P. parasitica simultaneously, or (ii) introduced P. brachyurus one week before P. parasitica, also showed increased disease development. However, the fast onset of illness was not preferred by plants injected with nematodes two or three weeks prior to the introduction of P. parasitica. Another greenhouse experiment involved sectioning, staining, and analyzing root samples from plants treated with P. parasitica, P. brachyurus, or both. Close proximity to P. brachyurus feeding sites did not affect P. parasitica development; however, oomycete colonization was decreased in necrotic lesions brought on by the worm. This could provide some insight into why plants injected with P. parasitica two to three weeks prior to fungal inoculation exhibited no black-shank signs. The simultaneous introduction of P. parasitica and nematodes enabled the latter to take advantage of tiny gaps made in the roots by P. brachyurus's migratory activity. However, it doesn't appear feasible that the artificial wounding method used could replicate the kind of harm brought on by an invasion of PPN.

Modifications within the rhizosphere

Soilborne fungi and PPN are thought to be attracted to the release of plant root exudates. PPN may affect the release of root exudates in a variety of ways, which could change how soilborne pathogens react later on.



First, more root exudates that are appealing to fungal invaders may be produced as a result of the harm done to plant roots during PPN invasion. Second, it has been demonstrated that some potato cultivars respond to invasion by potato cyst nematodes by producing more lateral roots. Root exudate production may rise as a result of this increase in root surface area. Lastly, PPN infestation may change the chemical makeup of the exudates from the favoring fungal infections. The roots, processes involving root-knot nematodes are arguably the most well-known instances of this process. Changes in the rhizosphere have been highlighted by the growth of fungus, primarily R. solani, around the root-knot galls of numerous plants. Early observations of this phenomenon while researching the tomato M. incognita–R. solani combination. It was observed that when tomato roots afflicted with R to naught by the nematode-fungus conspiracy," M. incognita aged, they became more vulnerable to fungal infection by R. solani. They noticed that R. solani will gather on cellophane that was immediately opposite the galled areas of the roots by using the cellophane membrane. Conversely, ungalled regions only had a limited amount of mycelial cover. Golden & Van Gundy (1975) conducted more research on tomato and okra infested with M. incognita using semipermeable membranes (cellophane) in a subsequent article. Sclerotria were once more formed in

opposition to the galls of M. incognita when R. solani was introduced to the cellophane's exterior surfaces (using mycelial plugs). Microscopic analysis of the sclerotia revealed that they were loosely made, undifferentiated entities formed by uneven branching and interwinding. The scientists deduced from these investigations that the increased attraction of R. solani might be explained by metabolic leakage from M. incognita's galls.

Reduction of host resistance

The importance of nematode-fungus complexes in the development of crop species that exhibit resistance to economically significant pests and diseases is rarely, if ever, documented; however, several studies document the breakdown of resistance during concurrent infections. "It is frustrating to the plant breeder to see the fruits of his labor come

said. Generally, split-root techniques, as previously mentioned, have been used to test loss of resistance. Researchers have used this kind of methodology to ascertain whether the host plant's systemic chemical defense system malfunctions, leading to the loss of disease resistance brought on by nematode infestation. During split-root studies with M. incognita, Bowman & Bloom (1966) discovered that the tomato cultivars Rutgers and Homestead, which had previously been resistant to F.oxysporum f.sp. lycopersici, began to exhibit



signs of wilt. The ability of a nematodeinduced factor to pass through a resistant scion (a graft from a resistant tomato cultivar) and make it susceptible to F. oxysporum f.sp. lycopersici was confirmed by additional research employing root layering and grafting techniques. However, in tomato plants that were not infested with M. incognita, resistant scions could prevent infection by F. oxysporum f.sp. lycopersici. Vargas et al. (1996) found that the nematode Nacobbus aberrans reduced the resistance to Phytophthora capsici in chilli (Capsicum annuum), even when the oomycete and nematode were physically separated on split roots. Nematode induced loss of resistance to Fusarium udum in pigeonpea (Cajanus cajun) was linked to decreased levels of the iso flavanoid phytoalexin cajanol, albeit few studies have examined how this can happen. Resistance to the disease was conferred by the quick buildup of cajanol in some pigeonpea cultivars. Nevertheless, when F. udum, M. incognita, and M. javanica were infected together, the cajanol content was 62% lower and resistance was lost, and the incidence and severity of wilt disease were noticeably higher than in plants inoculated with F. udum alone. It is currently unknown how worm activity altered the plant, despite the fact that this study unequivocally demonstrates that nematode infection decreased a chemical defense

mechanism to fusarium wilt in pigeonpea. During nematode attack, either the plants' total metabolic rate decreased or the synthesis of iso-flavonoids underwent particular modifications. Some writers generally concur that polygenic resistance is less persistent than monogenic resistance. According to, plants with a single dominant gene for resistance are rarely impacted by nematode infestations, but plants with polygenic resistance to fungal infections are often observed to become vulnerable to fungal attack. M. incognita F. infestations disrupted resistance to oxysporum f.sp. lycopersici in tomato cultivars with polygenic resistance, but not in cultivars where resistance was expressed by a dominant single I-gene. When PPN and associated fungal diseases are present, transgenic plants with quantitative trait loci may be better equipped to provide long-lasting resistance. Nematode induced physiological changes that have no bearing on the gene or genes encoding resistance make resistant plants more susceptible to infections. For instance, PPN invasion may provide portals for soilborne diseases by breaking through a physical barrier that was previously impregnable and chosen for in a plant breeding program. Studies of disease complexes on several crop genotypes shown interactions have that between nematode and fungal species can differ significantly across plant species, cultivars,



and lines. As a result, while some studies have shown the opposite with identical combinations of nematode and fungal species, others have been unable to demonstrate resistance loss. Other abiotic variables, such temperature and soil type, have also been demonstrated to influence interactions and may have differed throughout research on particular disease complexes.

Factors affecting synergistic interactions

Numerous studies disease on complexes contradict one another, as is the case with almost all scientific study. There are results that demonstrate the specificity of particular illness complexes and the impact of biotic and abiotic variables on them, even though some of these discrepancies may be explained by experimental methodology and accuracy. The interaction between these organisms differs among different nematode RE MO(In) fact, Kimpinski & Willis (1981) species, populations, and fungal genotypes. Research on the V. dahliae-Pratylenchus complex of potatoes serves as an example of this. For instance, populations of P. penetrans, but not P. crenatus or P. scribneri, were found to exacerbate potato early death disease (V. dahliae). Furthermore, populations of P. neglectus collected from Ontario, Canada would interact synergistically with V. dahliae, according to greenhouse experiments conducted by Hafez et al. (1999). In contrast, populations of P. neglectus from Parma, Idaho

did not increase disease or yield loss any more than treatment with V. dahliae alone. Unique pieces for each population were found by restriction analysis of the ITS1 region on the rDNA gene from nematodes from the Canada and Idaho populations, suggesting diversity within this species. The ability of different nematode species, populations, and pathotypes to amplify V. dahliae wilt is probably connected to how well they parasitize potatoes. The work of Hafez et al. (1999), where beginning populations (Pi) were 5000 and 10,000 nematodes per 5000 cm3 soil, clearly shows this. The Canadian population's fecundity was roughly 50% higher than that of the Idaho population. Additionally, distinct physical environmental conditions may be preferred by different Pratylenchus species and pathotypes.

observed that P. penetrans and P. crenatus populations were affected differently by soil temperature and pH. According to Botseas & Rowe (1994), two pathotypes of V. dahliae vegetative compatibility group 4 (VCG 4) developed distinct interactions with P. penetrans, demonstrating that fungal genotype can also influence the potato early death complex. When inoculated separately, the two pathotypes of V. dahliae (VCG 4A and B) showed no differences in aggressiveness in greenhouse and outdoor microplot tests.



However, compared to plants inoculated with V. dahliae VCG 4B in the presence of P. penetrans, plants inoculated with V. dahliae VCG 4A and cultivated in soil infested with P. penetrans exhibited higher levels of disease severity, lower tuber yields, and earlier senescence.

Numerous studies have revealed that VCG 4A is the more aggressive of the two pathotypes on potatoes, despite Botseas & Rowe's (1994) inability to distinguish between V. dahliae VCG 4A and B. This is especially pertinent to the research on mint, where the most aggressive pathotype was earlier identified by Douhan & Johnson (2001) as VCG 2B. These kinds of particular interactions are probably relevant to other disease complexes with 12 or more anastomosis groups, as those involving R. solani.

Future perspectives

PPN Undoubtedly, and fungal infections have complicated synergistic interactions. The study discussed here emphasizes how important it is to comprehend unique illness complexes before choosing the best control strategies. Forecasting possible disease issues may be aided by sampling soils for known interacting organisms. The spatial distributions of plant diseases (Nilsson, 1996) and PPN (Heath et al., 2000) in crops are currently being determined through the development of applications integrating

remote sensing and digital image processing. The prediction of illness complexes is probably going to benefit greatly from further advancements in this kind of technology. Finding out if there are any trends in the spatial population densities of interacting creatures would also be intriguing. Given the specificity of some of the disease complexes listed, it is necessary to employ relevant diagnostic techniques in order to assess the suitability of management approaches. For instance, P. penetrans would develop a disease complex with V. dahliae VCG 4A rather than V. dahliae VCG 4B, according to the findings of Botseas & Rowe (1994). Dobinson et al. (2000) showed that molecular markers might be used to characterize VCG 4A and 4B. VCG 4A was able to be differentiated from 4B with a fair degree of success due to the lack of a **AGRICULTUR** subspecies-specific repetitive DNA sequence

subspecies-specific repetitive DNA sequence (E18) and differential restriction fragment length polymorphisms (RFLPs) in the nuclear rDNA and Trp1 loci. Furthermore, these authors assert that a PCR assay may be developed and that marker analysis may be used to detect V. dahliae VCG 4A from soil or plant tissues. Adopting contemporary molecular-based diagnostic methods would surely help many other complexes. It seems that managing illness complexes is more difficult than one might think. Controlling one of the interacting species chemically is the



most obvious way to stop the illness complex from happening. Even modest concentrations of nematodes or fungi can produce a disease complex of major relevance, hence it is essential to have prior understanding of the interaction in question. As a result, the issue of the interaction might not be resolved by eliminating one pathogen. In a survey of cotton producers' management decisions in Texas, USA, Wheeler et al. (2000) discovered that growers typically applied higher rates of the nematicide aldicarb (roughly 30-50% higher) in fields impacted by both T. basicola and M. incognita than in fields where the organisms were found alone. The authors claim that there was no justification for the producers' choices, despite the fact that these numbers imply that they were aware of the harmful consequences of this disease complex.

investigation into the creation of focused strategies for disease complexity. Furthermore, there is a growing push to limit the use of agrochemicals due to current public education and knowledge regarding their nontarget impacts. It is encouraging that several different approaches have been looked into for the treatment of illness complexes. Numerous research in plant breeding have focused on identifying the loci in soybeans that provide dual resistance against F. solani and H. glycines implicated in sudden death syndrome. Cultural methods such soil solarization and multiyear cropping regimes have had varying degrees of success in lowering V. dahliae and P. penetrans population densities. Last but not least, the application of the fungi Paecilomyces lilacinus and Verticillium chlamydosporium along with the vesicular arbuscular fungus Gigaspora margarita decreased the harmful effects of a disease complex on pigeonpea involving the sedentary endoparasite Heterodera cajani and the fungus F. udum. The most promising strategy for eliminating disease complexes including nematodes and fungi seems to be an integrated approach that targets both interacting organisms.

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