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Economic importance of Helicotylenchus nematode and its sustainable management strategies in Ethiopia

Sintayo H and Gichile H
Ethiopian Institute of Agricultural Research,
Chiro National Sorghum Research and Training Center, Chiro, Ethiopia
Corresponding author: hayilugr@gmail.com

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ABSTRACT

Helicotylenchus species, a type of spiral nematode are among the most destructive biotic stressors in the world's major agricultural growing regions. Cereals and horticulture crops are vulnerable to these plant parasite nematodes. It parasitizes a variety of host plants and has a considerable harm potential at relatively low population density. It is difficult to identify the signs of the harm that plant parasitic nematodes have caused. Their minuscule size further lessens the likelihood that they will be identified as the creatures causing any harm. While some nematodes function as different vectors, others predispose plants to other infections. With the exception of Antarctica, they are more widely dispersed over all continents with temperate and tropical temperatures. These plant parasites are thought to be responsible for crop yield losses of more than US$ 300 billion globally. According to estimates, these losses would amount to over 14% in developing nations and over 9% in rich nations. Compared to temperate locations, tropical regions experience far more damage from nematodes. This plant-parasitic nematode has a short life cycle, which is backed by several academics in literatures. In the right circumstances, the life cycle is said to be finished in about 32 days. The species is bisexual by nature and reproduces by amphimixis or cross-fertilization. The goal of integrated nematode management is to bring nematodes down to manageable numbers using a range of strategies, such as genetically resistant hosts, predators and parasites, naturally occurring environmental changes. Therefore, economic importace, theclassification, life cycle, damage symptoms, and management of the helicotylenchus nematode will be covered in this review paper, along with an updates on the relationship between helicotylenchus species and many important agricultural crops worldwide, especially in Ethiopia.

Keywords: Host plant, host resistance, helicotylenchus species and nematode managment

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Introduction

One of the most successful groups of invertebrates is the nematode, which can live freely in both fresh and salt water as well as the soil and feed parasitically on the roots of plants. Helicotylenchus nematodes areamong the most significant types of organisms reducing yield and costing field and horticultural crops in underdeveloped nations are plant-parasitic nematodes (Stirling and Pattison, 2008: Ravichandra, 2008; Abebe *et al*., 2015; Xia *et al*., 2022). Despite their little size, they are highly destructive when they act. According to Reddy (2008), the global average annual yield loss on major horticulture crops as a result of these worms' damage is estimated to be roughly 13.54%.

Additionally, the financial losses which surpassed an astounding $300 billion annually when all crops were taken into account (Sasser and Freckman, 1987; Ravichandra, 2008; Abebe *et al*., 2015). According to Crow (2012), spiral nematodes of the genus Helicotylenchus are one of the most common plant-parasitic nematodes connected to agricultural crops globally. As an example, plant parasitic nematodes have been found to cause losses of up to 70% on plantains and cooking bananas in Africa and ranked among the top ten economically significant genera of phytonematode (Ravichandra, 2008).

The damage caused by Helicotylenchus dihystera and H. multincintus to roots and plants, in conjunction with Meloidogyne spp., Pratylenchus coffeae, and Radopholus similis, results in a 31–50% reduction in crop yield (Speijer et al., 2001; Rotimi *et al*., 2004; Tripathi *et al*., 2015). Phytonematode population dynamics and seasonal changes linked to some crop plants have been documented (Nath et al., 1988; Adekunle, 2009; Sayed *et al*., 2014). The process of reproduction varies greatly amongst Helicotylenchus species (Stirling and Pattison, 2008: Murungi *et al*., 2014). Certain species have males and females that pair in order to reproduce sexually, such as Helicotylenchus muticinctus. Certain animals are hermaphrodites, meaning they can fertilize their own eggs without having to mate. When designing nematode control programs, it is essential to have a solid grasp of the interaction between worms and their hosts as well as the population dynamics of particular nematodes on plants. So, the major objectives of this paper will be to review the economic importace, the classification, life cycle, damage symptoms, and management of the helicotylenchus nematode, along with an updates on the recent insights on relationship between helicotylenchus species and many important agricultural crops worldwide, especially in Ethiopia.

Global Distribution of Helicotylenchus species

With the exception of Antarctica, temperate and tropical climates on every continent, numerous islands, and the entire United States are home to Helicotylenchus species. Numerous types of soil, such as heavy, sandy, and organic soils, are suitable for the growth of Helicotylenchus spp. significant quantities of spiral nematodes were also observed on Solanum lycopersicum, Vigna unguiculata, and Celocasia esculentus. Based on their frequency and abundance, Sawadogo *et al*. (2009) found a similar finding in which the genus Helicotylenchus was identified as one of the main nematode genera with high parasitic potential on V. unguiculata. Osei *et al*. (2012) had also observed that S. lycopersicum and a large population of Helicotylenchus spp. are related in Ghana. Daramola (2016) also shows that in the guinea savanna ecological zone, a large number of Helicotylenchus species were linked to bananas. The primary pests of banana and plantain, Helicotylenchus dihystera and Helicotylenchus multincinctus, have been found to cause a significant reduction in crop yield in Nigeria and worldwide (Nath et al., 1998; Sayed *et al*., 2014; Olaniyi, 2014). According to Subbotin *et al*. (2011), the genus Helicotylenchus is found around the world and is connected to the root systems of several plant groups (Nicol et al., 2002; Singh *et al*., 2013). However, because data from certain countries are unavailable, the actual losses may be larger.

Classification: ***Helicotylenchus*.**

The genus Helicotylenchus Steiner 1945 is considered one of the ten most important plant parasitic nematodes in the world (Sasser 1989; Xia *et al*., 2022). Spiral nematode, Helicotylenchus systematic position: - Order - Tylenchida, Sub order - Tylenchina , Super family - Tylenchoidea , Family – Hoplolaimidae, Sub family - Rotylenchoidinae and Genus – Helicotylenchus. Within the genus Helicotylenchus, more than 200 nominal species have been described worldwide (Divsalar et al., 2020). The genus Helicotylenchus is classified as semi-endoparasitic that may occur in large numbers, causing plant growth reduction (Yeate *et al*., 1993). A combination of morphological evaluation, morphometrics, and molecular phylogenetic inference should be used to accurately determine the species of an individual population (Subbotin *et al*. 2015).

Life cycle of Helicotylenchus

The process of reproduction varies greatly amongst Helicotylenchus species (Stirling and Pattison, 2008: Murungi *et al*., 2014). Certain species have males and females that pair in order to reproduce sexually, such as Helicotylenchus muticinctus. Some of them are hermaphrodites, meaning they can fertilize their own eggs without having to mate. Some species, such as Helicotylenchus pseudorobustus, solely have female offspring and reproduce asexually by parthenogenesis. They do not mate and individual females lay eggs in the earth. Before hatching, a first-stage juvenile develops inside each egg and molts into a second-stage juvenile (Stirling and Pattison, 2008). The second-stage juvenile needs to find a host plant and start feeding after hatching in order to continue developing. Typically, host root cortical cells are the food source for Helicotylenchus species. The worm consumes the contents of the cells by inserting its mouthspear, or stylet, into the cortical and epidermal cells. All Helicotylenchus species molt three more times after feeding to become juveniles in stages three and four before becoming adults. The detailed life cycle of Helicotylenchus is depicted (Fig 1). The main physical differences between the different juvenile life stages of Helicotylenchus spp. and adults are their body sizes and lack of a fully formed reproductive system. Most species lay their eggs in the earth, whereas Helicotylenchus places their eggs inside banana roots.

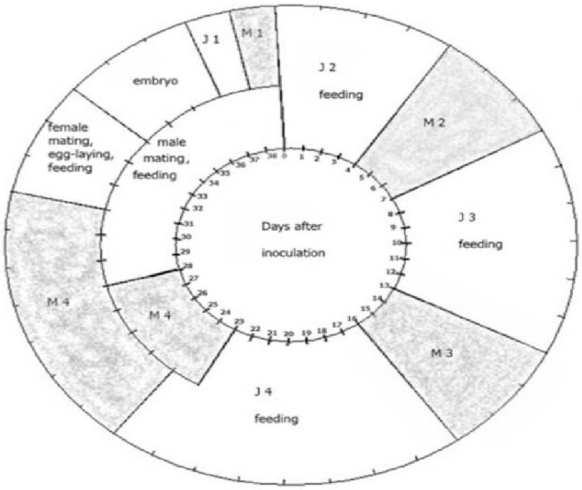

Fig 1. Schematic representation of the life cycle of Helicotylenchus-multicinctus (Karakas, 2007)

Symptoms caused by Helicotylenchus

The symptoms of *Helicotylenchus pseudorobustus* are more subtle than those of certain other nematodes such as root-knot or sting nematodes. The nematodes attack root cortex and produce necrotic lesions. Heavy infection by *Helicotylenchus* spp. can cause a reduction in the root system, leading to unhealthy plants. On turfgrasses, *Helicotylenchus paxilli* has been shown to reduce root length and cause thinning of turf. Generally the turf decline will occur in patches and is often accompanied by proliferation of weeds in the affected areas. *Helicotylenchus multicinctus* causes small necrotic lesions on roots, and with heavy infestation these lesions coalesce, leading to root necrosis and die-back of roots. Plant stunting and reduction in yield can result. Because these symptoms could be induced by other causes, a laboratory assay conducted by a qualified diagnostic lab is required for a positive diagnosis.Following Helicotylenchus infection, plants' root systems and outer layer of cortical tissue suffered damage, which further decreased the plants' capacity to absorb nutrients and water. For instance, species of Helicotylenchus connected to the Musaceae harmed the cortical tissue of roots and decreased their capacity to absorb nutrients and water (Riascos-Ortiz *et al*., 2020; Xia *et al*., 2022). H. microlobus infected Paspalum vaginatum causing brown lesions on their roots (Jagdale *et al*. 2020). H. multicinctus, H. dihystera and H. erythrinae have been found to be harmful to banana and plantain crops around the world (Riascos-Ortiz *et al*., 2020). Inoculating H. dihystera on Olive seedlings caused 78% reduction in weight, and the development of the lateral roots occurred retardation (Diab and El-Eraki, 1968; Xia *et al*., 2022). Some studies suggest that H. pseudorobustus feeding in the cortical parenchyma of corn and soybean roots and causing serious damage (Taylor, 1961, Luo, 2002). Symptoms of maize include lesions on roots, root pruning, yellowing, and above-ground plant stunting; these symptoms can be misdiagnosed as seedling blights and root rots, nutrient deficiencies, insect feeding, drought.

Fig 2. Symptoms caused by spiral Helicotylenchus nematodes (Tylka *et al*., 2011)

Economic importance of Helicotylenchus

Plant-parasitic nematodes have a huge impact on agriculture worldwide. Plant-parasitic nematodes damage nearly all crops (Sasser, 1980). Based on 37 life-sustaining crops, the global average estimated annual damage caused by nematodes is US$ 358.24 billion, or roughly 12.6% (9–15%) of overall crop production (Abd-Elgawad, 2014; Martin & Fleming, 2014). Furthermore, as further loss studies on crops with regional significance are taken into account, this figure will undoubtedly rise. Globally, the 17 types of plant-parasitic nematodes caused by this parasitic organism are estimated to have cost the rice crop alone US$ 35 billion (McCarter, 2009). It is estimated that species of the genus Meloidogyne, which causes root-knot nematodes, generate US$ 157 billion in losses worldwide (Abad et al., 2008). Given that crop losses in Africa have been reported to range from 30 to 100%, it is obvious that the 20 species of this genus that have been identified from Afica alone are threatening the agricultural sector on the continent (Murungi *et al*., 2014). Even though Helicotylenchus pseudorobustus parasitizes a large number of commercially significant plants, most of them are rarely regarded as serious pests. Helicotylenchus paxilli is especially prone to infesting coastal paspalum, a turfgrass utilized in tropical and subtropical regions of North America. Helicotylenchus paxilli is one of the most prevalent nematodes on this grass that requires nematicide treatment in Florida, United States of America. Although bananas are not a major commercial crop in Florida, Helicotylenchus multicinctus harms both ornamental banana plants grown in nurseries and landscapes as well as bananas grown for local fruit consumption. Helicotylenchus dihystera is another species that is widely distributed in Florida on a variety of crops, ornamentals, and other cultivated and non-cultivated plants. The harm caused by this nematode in Florida hasn't been evaluated, though.

According to Mandefro *et al*. 2009; Tessera *et al*.2009a; Yesuf *et al*.2009: Abebe *et al*.2015, few research have been done thus far on plant parasitic nematode-related issues in Ethiopia which have a significant negative influence on agricultural productivity. Additionally, there is little information available about Ethiopia's plant parasitic nematode management, economic significance, distribution, prevalence, and biodiversity. Few and irregular surveys have been carried out thus far, and the results have not been well communicated to stakeholders and policy makers. An expatriate researcher initiated survey and identification study in the 1970s, identifying certain nematode species linked with vegetable crops that belonged to the genera Helicotylenchus.Subsequently, a restricted surve y and identification attempt was conducted, conc entrating on various crops nationwide (Van den Berg & Mekete, 2010; Getaneh, 2011; Meressa *et al* ., 2011; Mekonnen *et al*., 2014; Getaneh *et al*., 2015) .Despite the little effort, some significant PPN species, such as Helicotylenchus, were identified and collected. In Ethiopia, data on PPN related to vegetables is more readily available than data on other crops.

Management of Helicotylenchus spp.

Because Helicotylenchus spp. have a wide host range, crop rotation and cover crops are exceedingly difficult to control. Helicotylenchus species react favorably to nematicides and bionematicides that are useful in controlling other nematodes because their bodies are left exposed in the soil. The application of pesticides, biological agents, host-plant resistance, and cultural techniques are among the management tactics that reduce the likelihood of damage from numerous nematode species. The majority of these tactics confront a number of difficulties; for instance, the usage of nematicides has drawn criticism due to its detrimental impact on the environment and public health. For the production of both high- and low-value crops, integrated management of nematodes is commonly employed (Perry & Tovar-Soto, 2012).

Cultural methods

Crop rotation, fallowing, flooding, antagonistic plants, soil additives, deep cultivation, and enhanced crop husbandry are examples of cultural control strategies for nematodes (Viaene *et al*., 2013). These approaches have a benefit over chemical control methods since they require less infrastructure and methodology, and they can be applied in resource-poor sub- Saharan African nations like Ethiopia where significant changes to farming practices are not necessary for adoption. A study was carried out to evaluate the effectiveness of dry fallowing in managing root-knot nematodes. More nematodes were reduced in a 9-month fallow than in those that were planted continuously or in a 3-month fallow. It is somewhat successful helpful techniques when combined with other pest management strategies, such as integrated pest management (IPM).Vegetable production has adopted cultural strategies such as crop rotation, fallowing, desiccation, and eliminating alternative hosts (Mandefro *et al*., 2009). It has also been demonstrated that natural flooding of Central Rift Valley vegetable farms for roughly three months lessens the damage caused by root-knot nematodes. M. incognita infestation on tomato was significantly decreased by applying chicken litter, 200 kg ha^{-1} of rapeseed cake, and a combination of 5 t ha^{-1} to 15 t ha^{-1} of poultry litter and 200 kg ha^{-1} of rapeseed cake (Shiferaw et al., 2014). Under a screenhouse trial, Ethiopian eggplant, Solanum aethiopicum, benefited from the suppression of nematodes by using both organic (poultry, cow dung, and household waste) and inorganic (NPK 15:15:15) fertilisers, which also led to increased growth (Abebe *et al*., 2015).

Host resistance

Since host resistance is affordable and safe for the environment once it is established, it is preferred to chemical control when managing pests. It is essential that genetic solutions to soilborne disease problems remain an option in the future, but this will only occur if growers use resistance in a way that does not encourage the development of resistancebreaking biotypes of the pathogen (Stirling and Pattison, 2008). To date, there aren't many researches on host resistance to PPN that have been done in Ethiopia. Under glasshouse circumstances, sixty tomato germplasms from the Melkasa Research Center were evaluated for M. incognita infection. The 60 tomato germplasms that were examined revealed varying levels of infection response. It was discovered that seven were resistant, eleven were somewhat resistant, twenty-eight were moderately susceptible, twelve were sensitive, and the final two were severely susceptible (Mandefro et al., 2000).Resistant lines were to be tested in the field under conditions of high nematode pressure; if successful, they were to be sent straight to the improvement program.

Biological control of plant-parasitic nematodes

Very limited attempts have been made with regard to biological control of PPN in Ethiopian agriculture. Biological control is free from residual and adverse environmental effects (Sumeet & Mukerji, 2000). BioNem WP has been developed as a commercial BioNematicide by Agro-Green. It contains the bacterium Bacillus firmus and has been reported to be effective against M. incognita, M. hapla, Heterodera spp., Tylenchulus semipenetrans, X. index and Ditylenchus dipsaci. BioNem WP was introduced to Ethiopia to be used against root-knot nematode in vegetable production. Terefe *et al.* (2009) tested this product under pot-house and laboratory conditions on tomato in Ethiopia and found that BioNem at a dose of 1, 2, 4 and 8 g pot−1 significantly reduced the number of galls, final nematode population and number of eggs per egg mass, and increased plant height, fresh shoot weight and dry shoot weight of plants compared with controls. Endophytic bacteria were isolated from coffee roots in Ethiopia and identified by Fatty Acid Methyl Ester-Gas Chromatography (Mekete et al., 2009). Bacillus pumilus and B. mycoides were most effective in reducing the number of galls and egg masses caused by M. incognita by 33 and 39%, respectively (Mekete et al., 2009). Soil samples were collected from different agricultural and non-agricultural fields to study the occurrence and identity of the natural fungal predators and parasites of root-knot nematodes. Only one unidentified fungus was found to have nematode-trapping activity, but the activity was slow compared to the well-studied genus Arythrobotrys (Mandefro *et al*., 2000).

Chemical methods

If handled irresponsibly, the majority of chemical nematicides can be dangerous to humans, pets, and other animals due to their relative toxicity. Because they are poisonous, most nematicides pose a concern to the environment. Negative environmental events and/or circumstances may prevent all nematodes from working as intended. However, a new generation of pesticides with low mammalian toxicity and relatively specific modes of action is now being produced by the agrochemical industry. From the perspective of nematode and soilborne disease management, a key requirement is that chemicals are developed that can be used in IPM programs to target specific soilborne pathogens (Stirling and Pattison, 2008). Nematicides are well known to be effective, but due to their expensive cost of application and significant toxicity to people, relatively few experiments have been conducted in Ethiopia. Chemical nematodes were applied to the banana corm in order to suppress the burrowing nematode Radopholus similis.

Integrated nematode management

Integrated nematode management is approach to reduce nematode to tolerable levels through a variety of techniques including predators and parasites, genetically resistant hosts, natural environmental modifications and when necessary and appropriate chemical nematicides (Hasan *et al*., 2021; Abd-Elgawad and Askary, 2018). Basically, decisions to implement nematode management programmes are based on the perceived value of the potential crop loss and the cost of the management procedure and it involves determining an economic threshold. Management procedures should usually be implemented when the marginal revenue derived from the management input is equal to or excess the marginal cost. The design development and implementation of integrated nematode management systems for plant protection requires extensive interaction of nematologists with scientists in complementary disciplines (Sikora et al., 2005). Currently, plant-parasitic nematode exclusion, population reduction and host tolerance or resistance approaches areusing as pillar componentsof integrated nematode management.

Conclusions

It was concluded that spiral nematodes of the genus Helicotylenchus are among the most ubiquitous plant-parasitic nematodes worldwide. They are root parasites of a wide variety of plants, and certain species can cause serious damage to their hosts. It is difficult to identify the signs of the harm that plant parasitic nematodes have caused. This is due to their microscopic size further lessens the likelihood that they will be identified as the creatures causing any harm. With the exception of Antarctica, they are more widely dispersed over all continents with temperate and tropical temperatures. However, compared to temperate locations, tropical regions experience far more damage from plant parasitic nematodes. These plant parasites are thought to be responsible for crop yield losses of more than US$ three hundreds of billion globally. Plant-parasitic nematode has a short life cycle, which is backed by several academics in literatures.

Few researches have been done thus far on plant parasitic nematode related issues in the world as well as in Ethiopia which have a significant negative influence on agricultural productivity. Additionally, there is little information available about Ethiopia's plant parasitic nematode management, economic significance, distribution, prevalence, and biodiversity. This is due to the existence of very limited number of nematologists across the globe and Ethiopia is not exceptional for this critical issue. Furthermore, there have only been a small number of sporadic surveys conducted thus far, and stakeholders and policy makers have not received enough communication of the findings. In order to effectively manage nematodes, populations must be brought down to the level of the economic threshold. The goal of nematode management is to bring nematodes down to manageable numbers using a range of strategies and to achieve this goal the collaborative efforts are needed from plant breeders, plant pathologist and nematologists in order develop improved nematode resistant cultivar based on commodity improvement program. Eventually,at present, only a small percentage of plant-parasitic nematodes are successful cultured. So, for the future, a mass culture of plant-parasitic nematodes is a key to pathogenicity studies and many other biological studies.

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