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A Review on Biology and Management of *Radopholus similis*

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Abstract
The burrowing nematode (*Radopholus similis*) is an amphimictic species characterized by accentuated sexual dimorphism. Burrowing nematode has migratory endoparasitic habits and it develops and reproduces inside plant tissues of host roots. Fertilization is normally assumed to be bisexual, since females recovered from populations with males usually have sperm in their spermatheca, but reproduction by parthenogenesis does take place. The life cycle of the pathogen is completed in about 21 days at 25°C, and each female lays an average of four to five eggs each day for 2 weeks. This nematode burrows in the cortex of the root, destroying them and causing the formation of cavities then after eggs lay inside the cracks. *R. similis* of major economic importance and interactions with other pathogens enhance crop damage and yield loss. Phytosanitary measures are of prime importance in reducing the negative impact of plant-parasitic nematodes before they introduce. But once burrowing nematodes have become established in a field, the only option left is to try reducing their preplant density and further spread by the use of combination of different management methods such as crop rotation, cover crops, fallowing, removal of infested material, organic amendments, soil solarisation, hot water treatment, biological, host resistance and chemical methods. Generally knowing the biology of *R. similis* and its different management strategies contribute more to the reduction of the burrowing nematode and thus, sustainable banana production.
Key words: *Radopholus similis,* amphimictic, parthenogenesis, sustainable, management

Introduction

Banana (*Musa* sp.) is a major staple food, supplying up to 25% of the carbohydrates for approximately 70 million people in Africa's humid forest and mid-altitude regions. World *Musa* production is currently about 97 million tones annually. Hence, bananas are important for food security in the humid tropics and provide income to the farmers. Many pests and diseases have significantly affected *Musa* cultivation. Black sigatoka, bacterial wilts, viruses and nematodes cause significant crop losses worldwide (Carlier *et al*., 2000; De Waele, 2000; Thwaites *et al*., 2000). Although various species of nematodes infest banana roots with adverse consequences, the migratory endoparasite *Radopholus similis* is considered the most important (Gowen *et al*. 2005). The disease caused by this nematode is variously known as *Radopholus* root rot, blackhead, toppling disease or decline. The burrowing nematode has a wide geographical distribution in banana growing regions because this nematode was spread with infected banana rhizomes from Southeast Asia (Myanmar, Thailand, and Indonesia) to new banana growing areas in the world. It present in glasshouses in temperate areas (O'Bannon, 1977) and also occur in Africa including Ethiopia (Gebrehiwot & Seifu, 2015). *R. similis* has also been recovered from 365 plants (Holdeman, 1986). Its primary hosts are banana, black pepper, citrus, and foliage ornamentals belonging to the Araceae (*Philodendron, Anthurium*), the Marantaceae (*Calathea*), and the Zingiberaceae (ginger). Other hosts include betel nut palm, coconut, coffee, parlor palm, sugarcane, tea, and turmeric. The symptoms of infected banana plants grow poorly, have fewer and smaller leaves, show premature defoliation, and have smaller fruits. Often entire banana plants topple over. At first, primary banana roots show browning and cavities in the cortex, followed by deep cracks on the root surface. The burrowing nematode, *Radopholus similis* (Cobb 1893) Thorne 1949 is one of the major constraints to the productivity of banana wherever the crop is grown (Gowen and Quénéhérvé, 1990), with losses due to nematodes estimated at about 20% worldwide (Sasser and Freckman, 1987). Locally however, losses of 40% or greater can frequently occur, particularly in areas prone to tropical storms. Therefore, knowing the biology is helpful for effective and economical nematode pest management programme requires the integration of a range of methods, adjusted to local conditions and continually monitored. Thus, the objective of this paper is to review on the biology and different management methods of *Radopholus similis*.

Literature Review

Biology of *Radopholus Similis*

Radopholus similis (Cobb) Thorne is generally considered to be an amphimictic species (Loos, 1962), and both males and females have been described in the literature (Sher, 1968; Van Weerdt, 1960). This species has migratory endoparasitic habits, which is the feeding behavior of the species in the group, in that they feed on host tissue but do not set up a permanent feeding site and can move out to infect a new host. *Radopholus similis* (burrowing nematode) develops and reproduces inside plant tissues of host roots or it spends its life in the root cortex. Although in adverse conditions the nematodes may emerge from the roots. It is reported to take up to 5 years to die out in soil if no banana crops are grown during this period, presumably because of alternative weed hosts. It normally reproduces sexually, but if the female has not mated for some time it can reproduce as a hermaphrodite; in this species, mature males do not penetrate intact roots and do not feed. Reproduction (Fertilization) is normally assumed to be bisexual, since females recovered from populations with males usually have sperm in their spermatheca, but reproduction by parthenogenesis (Males are present, but female can produce eggs without fertilization) does take place. A population can be initiated from a single egg without the presence of any males. Temperature-range for reproduction of *Radopholus similis* fluctuating between 24°C and 32°C, but optimum reproduction occurs at around 30°C. It does not reproduce below 16-17°C or above 33°C. The whole life-cycle takes place inside the roots and completed in about 21 days at 25°C, and each female lays an average of four to five eggs each day for 2 weeks. Generations succeed one another as long as conditions remain favourable for development. The rate of increase of the population may then range from 1-10 in 45 days. All larval stages and adult females are infective and capable of penetrating roots at any point, but, entry is usually by the root tip or in the region of root hair production and takes less than 24 hours. The burrowing nematode enters feeder roots and moves in the cortical parenchyma, feeding on nearby cells or burrows in the cortex of the root (Blake, 1966), destroying them, and causing the formation of cavities. As the nematodes continue to feed, the cavities enlarge and coalesce, forming long tunnels. Three to 4 weeks from infection the lesions (necrosis) develop one or more deep cracks and inside the cracks the female lays eggs. Necrosis of root and corm tissues is accelerated by other pathogens such as fungi and bacteria, among which, *Fusarium* and *Sclerotium* invade nematode-infected roots much more readily and further increase their rotting and destruction.

Management of *Radopholus Similis*

Prevention

Phytosanitary measures are of prime importance in reducing the negative impact of plant-parasitic nematodes. Some migratory endoparasitic species are regulated as a quarantine pest, i.e., a "pest of potential economic importance to the area endangered thereby and not yet present there, or present but not widely distributed and being officially controlled" (Holdeman, 1986). Leukél (1948) arranged a list of plant-parasitic nematodes most frequently regulated in international trade. Out of the 15 regulated species on his list, 8 species are migratory endoparasitic nematodes: *A. besseyi*, *D. dipsaci*, *R. similis*, *D. destructor*, *A. fragariae*, *B. xylophilus*, *A. tritici*, and *B. cocophilus*. *R. Similis* can be readily transported in soil on shoes and tools. Therefore, it can be controlled before introducing in to a field by cleaning equipments before being used on uninfested fields, minimizing movement of animals from infested to uninfested fields and by using well decomposed manure in to field to kill any nematode present.

Post Introduction Control

Once migratory endoparasitic nematodes have become established in a field, the only option left is to try reducing their preplant density and further spread through cultural, physical, biological and chemical methods.

Cultural Methods

Crop Rotation: Crop rotation with non-hosts can be effective for *R. similis*. Plants useful for rotation are brassicas (canola and mustards), *Crotalaria spectabilis* (crotolaria) and Sudan grass (Jackson, 2003). These can be ploughed into the field where the chemicals released from the decaying plant matter acts as a nematicide.

Cover Crops: The planting of selected cover crops, such as *Panicum maximum* var. trichoglume (green panic) or a mixture of this and *Macroptilium atropurpureum* (siratro) has been shown to suppress populations of burrowing nematodes and is recommended for the fallow between banana crops (Jackson, 2003).

Site Selection and Land Preparation: Land where bananas are to be planted should be kept free of crops susceptible to the burrowing nematode for at least one year. Crops known or suspected to be hosts for burrowing nematodes include: *Abelmoschus manihot* (bele or aibika); *Cajanus cajan* (pigeon pea); *Colocasia esculenta* (taro); *Dioscorea alata* (yam); *Ipomoea batatas* (sweet potato); *Piper methysticum* (kava); *Saccharum edule* (duruka or pit pit); *S. officinarum* (sugar cane); *Sorghum sudanese* (Sudan grass); *Vigna unguiculata* subspecies *unguiculata* (cowpea); *Zea mays* (maize) and *Zingiber officinale* (ginger) (Jackson, 2003).

Flooding: Only a few nematode species survive short periods of flooding. Six-seven weeks of complete flooding can be as effective as 10-12 months of fallow in reducing nematode populations. However, this method is often not practicable as flooding requires the land to be leveled and a permanent water supply.

Fallowing: Fallow fields kept weed free for 1 – 2 years with non-host plants, such as *Chromolaena odorata* (Asteracea) can also dramatically reduce the number of nematodes. When land is no longer to be used for banana production the old banana mats should be killed and the stumps removed so that nematodes do not continue to feed and reproduce.

Removal of Infested Material and Management of Weeds: The sanitation of contaminated banana fields and discolored tissues from banana sets reduce *R. similis.* The presence of the burrowing nematode was more consistently found within three families, the Euphorbiaceae, Poaceae and Solanaceae. *Caladium bicolor*, *Commelina diffusa*, *Echinochloa colona* and *Phenax sonneratii* weed species are better hosts of *R. similis* (Quénéhérvé *et al*., 2006). They can be reduced by the use of no-tillage cultural practices that favour less suitable weed hosts (e.g. *Ipomea* spp.) in old banana fields. The control of weeds before replanting with banana in vitro-plants appears essential to limit the reinfection by the burrowing nematode *R. similis.* To maximize the benefits of this nematode management technique, strict weed control on the rotation crop and/or a regular weeding during the fallow period is required (Quénéhérvé *et al*., 2006).

Planting of Nematode Free Planting Material: The distribution of these genomic groups all over the world appears to be linked to historical contingencies of planting material spread. Reducing nematode populations in the soil before planting and the use of cleansed or nematode-free planting material propagated through *in vitro* techniques (tissue culture) are of primary importance in the control of *R. similis*. This type of control strategy allowed banana producers to delay the application of nematicides for 1 or 2 years after planting (Quénéhérvé, 1993).

Organic Amendments: Mulching and organic amendments in some banana production systems may not always have a direct effect on *R. similis*, but lead to reduced damage by the nematode (Goyal *et al*, 2005). Mulched mats had a lower soil temperature compared with non mulched/bare mats, which may have slowed *R. similis* reproduction and feeding activity and reduced root damage. Incorporating chitin-containing materials into the soil, such as crushed shells of crabs and prawns, can reduce nematode levels (Jackson, 2003). There are microorganisms in the soil that feed on chitin and chitin-containing nematode eggs and nematodes. Increasing the chitin levels in the soil increases the numbers of these fungi. Once the crushed shells are used up, the fungi begin to attack the nematodes.

Physical Methods of *R. Similis* Management

Soil Solarisation: For small fields, covering them for 6 – 8 weeks with plastic after tilling and watering raises the soil temperature and sterilizes it. If chicken manure or brassica residues are incorporated before sterilization, this shortens the time necessary to one month.

Hot Water Treatment: Submerge trimmed suckers for 20-25 minutes in water at 53-54°C. Specially constructed treatment tanks heated with bottled gas may be used (Jackson, 2003). Strict control of temperature and time is essential and careful supervision by agriculture staff is recommended. Under-treating may not kill the nematodes and over-treating may kill the plants. After treatment, spread the suckers on a clean surface to dry and then plant as soon as possible. *R. similis* has been successfully managed by dipping suckers in hot water at 53–55°C for 20 min (Bridge, 1975). A hot water dip (50^{o}C, 10 min) has been successfully used to control burrowing nematodes in anthuriums (Holtzmann *et al*., 1967; Higaki *et al*., 1994). However, hot water treatments are labour intensive and require careful monitoring (temperature and timing of exposure is critical) to be efficient and to limit the negative effects on the plants.

Host Resistant Method

Plant resistance to nematodes has increased in importance as control strategies during the past decades. In nematology, resistance is defined as the ability of a host to prevent multiplication of the nematode (Costa *et al*., 2007 and Wharton *et al.*, 1988). Bananas resistant to *R. similis* such as 'Goldfinger (FHIA-01)' have been developed. Breeding for resistance to *R. similis* is ongoing in various parts of the world. A major drawback to breeding for resistance has been the sterility of the most edible cultivars, and limited genetic variability. However, genetic engineering and other biotechnology-based approaches to improvement are viable alternative methods.

Biological Methods of *R. Similis* Management

Biological control of plant parasitic nematodes in banana showed great potential of integrated nematode management for use under field conditions. However, it is advisable to perform local tests to study the necessary adaptations according to the different agro-ecosystems. The use of mutualistic endophytes such as *Fusarium oxysporum*, species of *Trichoderma* or *Glomus* to biologically enhance tissue cultured banana plantlets is considered an important alternative for improving management of *R. similis* and increasing yields (Pocasangre *et al*. 2000; Niere *et al*. 2001; Vu *et al*. 2006). Several studies demonstrated that tissue culture banana inoculated with non-pathogenic isolates of *F. oxysporum* growing endophytically were effective in reducing densities of the burrowing nematode, *R. similis* on banana under glasshouse and field conditions. *Paecilomyces lilacinus* strain 251 is a commercially available fungal pathogen of nematode eggs. This fungus also can parasitize females of sedentary nematodes and their reproductive structures (Holland *et al*. 1999; Siddiqui *et al*., 2000; Khan *et al*. 2006). It was used to control *R. similis* (Mendoza *et al*., 2007)**.** *Bacillus firmus* is the biological agent in a bionematicide registered in Israel under the trade name Bionem_WP (Keren Zur, 2000). In addition, in vitro bioassays demonstrated that BioNem_ WP in a range of 0.5 to 2.5 g per kg soil provided effective control of *R. similis* (Mendoza *et al*., 2008). *R. similis* was controlled substantially in single and combined applications of *F. oxysporum* with *P. lilacinus* or *B. firmus*. The combination of *F. oxysporum* and *P. lilacinus* caused a 68.5% reduction in nematode density whereas the individual applications reduced the density by 27.8% and 54.8% over the controls, respectively. Combined application of *F. oxysporum* and *B. firmus* was the most effective treatment in controlling *R. similis* on banana (86.2%), followed by *B. firmus* alone (63.7%). Biological control of *R. similis* in banana can therefore be enhanced via combined applications of antagonists with different modes of action that target different stages in the infection process. It is being employed more often in integrated pest management programmes.

Chemical Nematicides

In recent years a number of nonvolatile organophosphate and oxime carbamate nematicides have been evaluated for using on bananas. Of these fenamiphos (Nemacur), ethroprophos (Mocap), and isazophos (Miral) are widely used in commercial plantations in major banana exporting countries (Jackson, 2003). These can be an option to control migratory endoparasitic nematodes that spend a part of their life cycle in the soil. *R. similis* have been control by Nematicides like phorate or phenamiphos. These nematicides are generally available in granular formulations and should be used according to the specific recommendations of the manufacturers as given on the labels. Normal doses are in the region of 1.5- 2.5 g active ingredient per plant or 25 g/m^2. Application should be done seven days prior to planting. *R. similis* on banana were also controlled by injection of abamactin in to the pseudostem as well as preplant application. Generally Nematicides are effective in controlling nematodes and easy to use. But they are expensive and repeated use of them on a large scale may result in many environmental problems, mainly due to the high toxicity of these products (Lacher *et al*., 1997).

Integrated Disease Management

A successful nematode management strategy ideally will involve a combination of individual components that together are applicable, appropriate, and economical.

REFERENCES

Bridge, J. 1975. Hot water treatment to control plant parasitic nematodes of tropical crops. *Med. Fac. Landbouww. Rijksuniv. Gent* 40:249–59

Blake, C. D. 1966. The histological changes in banana roots caused by *Radopholus similis* and *Helicotylenchus multicinctus*. *Nematologica*, 12 : 129-137.

Carlier, J, Fouré, E, Gauhl, F, Jones, D. R, LePoivre, P, Mourichon, X, Pasberg-Gauhl, C, Romero, R. A. 2000. Black leaf streak. In: Jones DR (ed) Diseases of Banana, Abaca and Enset. *CAB International*, 544 p.

Costa, J. C, Lilley, C. J, Urwin P. E. 2007. *Caenorhabditis elegans* as a model for plant-parasitic nematodes. *Nematology* 9:3–16

De Waele, D. 2000. Root knot nematodes. *In:* Jones DR (ed) Diseases of Banana, Abaca and Enset. *CAB International*, pp. 544.

Gebrehiwot Nega and Seifu Fetena, 2015. Root Necrosis Assessment of Plant Parasitic Nematodes of Banana (*Musa* spp) at Arba Minch, Ethiopia. Journal of Biology, Agriculture and Healthcare. Vol.5, No.15, 2015.

Gowen, S, Quénéhérvé, P. 1990. Nematode parasites of banana, plantains and abaca. *In*: Luc M, Sikora RA, Bridge J (eds) Plant parasitic nematodes in subtropical and tropical agriculture, *CAB International*, pp 431-460.

Gowen, S. R, Quénéhérvé, P, Fogain R. 2005. Nematode Parasites of Bananas and Plantains. *In:* Luc M, Sikora RA, Goyal K, Walton LJ, Tunnacliffe A. 2005. LEA proteins prevent protein aggregation due to water stress. *Biochem., J.* 388 (1):151–57

Higaki, T., Lichty, J. S., Moniz, D. 1994. Anthurium Culture in Hawaii. Research Extension Series 152. College of Tropical Agriculture and Human Resources, University of Hawaii, Honolulu, Hawaii.

Holdeman, Q. L. 1986. The burrowing nematode *Radopholus similis sensu lato*. Sacramento, CA: Nematology Publ., Calif. Dep. Food Agric., Div. of Plant Ind. 52 pp.

Holland, R. J, Williams, K. L, Khan, A. 1999. Infection of *Meloidogyne javanica* by *Paecilomyces lilacinus. Nematology* 1:131–139

Holtzmann, O. V., Higaki, T., Matayoshi, S. 1967. Control of *Radopholus similis* in anthurium by hot-water treatment (Abstr.). *Phytopathology* 57, 1006.

Huette, R. N. and Golden, A. M. 1991. NATHAN AUGUSTUS COBB: The Father of Nematology in the United States. *Annu. Rev. Phytopathol*. 29:15-26

Jackson, G. V. H, Ruabete, T. K and Wright, J. G. 2003. Burrowing and Lesion Nematodes of Banana. *Plant Protection Service*. New Caledonia.

Keren-Zur, M, Antonov, J, Bercovitz, A, Feldman, K, Husid, A, Kenan, G, Markov, N, Rebhun, M .2000. *Bacillus firmus* formulations for the safe control of root-knot nematodes. *Proceeding of Brighton crop protection conference on pests and diseases*, Vol 2A, pp 47–52

Khan, A, Williams, K. L, Nevalainen, H. K. M. 2006. Control of plant-parasitic nematodes by *Paecilomyces lilacinus* and *Monacrosporium lysipagum* in pot trials. *BioControl* 51:643–658

Lacher, T. E., Mortensen, S. R., Johnson, K. A, Kendall, R. J. 1997. Environmental aspects of pesticide use on banana plantations. *Pestic*. Outlook 12, 24–28.

Leukél, R.W. 1948. *Dilophospora* and nematode disease in wheat in South Carolina. *Plant Dis. Rep.* 32:291–92

Mendoza, A. R, Kiewnick, S, Sikora, R. A. 2008. In vitro activity of *Bacillus firmus* against the burrowing nematodes *Radopholus similis*, the root knot nematode *Meloidogyne incognita* and the stem nematode *Ditylenchus dipsaci*. *Biocontrol Sci Technol* 18:377-389

Mendoza, A. R, Sikora R. A, Kiewnick S. 2007. Influence of *Paecilomyces lilacinus* strain 251 on biological control of the burrowing nematode *Radopholus similis* in banana. *Nematropica* 37:203–213

Niere, B, Sikora R. A, Speijer, P. R. 2001. Mutualistic endophytic fungi role in biocontrol and safety of application. In: Sikora RA (ed) Integrated control of soil pests. IOBC/ WPRS Bulletin 24, pp 117–120

O'Bannon, J. H. 1977. Worldwide dissemination of *Radopholus similis* and its importance in crop production. *Journal of Nematology* 9, 16-25.

Orton Williams, K. J., Siddiqi, M.R. 1973. CIH Descriptions of Plant-parasitic Nematodes Set 2, No. 27.

Pocasangre, L. E, Sikora, R. A, Vilich, V, Schuster, R. P. 2000. Survey of banana endophytic fungi from Central America and screening for biological control of *Radopholus similis*. Acta Hortic 531:283–289

Quénéhervé, P. 1993. Nematode management in banana agroecosystems: comments and outlook from the Cote d'Ivoire experience. Crop Prot. 12, 164–172.

Quénéhervé, P., Chabrier, C., Auwerkerken, A., Topart, P., Martiny, B., Marie-Luce, S. 2006. Status of weeds as reservoirs of plant parasitic nematodes in banana fields in Martinique. Crop Prot. 25, 860–867.

Sarah, J. l., Pinochet, J. and Stanton, J. 1996. The Burrowing Nematode of Bananas, *Radopholus Similis* Cobb, 1913. International Network for the Improvement of Banana and Plantain, *Parc Scientifique Agropolis II*. FRANCE

Sasser, J. N, Freckman, D. W. 1987. A world perspective on nematology: the role of the Society. *In*: Veech JA, Dickson DW (eds) Vistas on Nematology. *Society of Nematologists*, USA. pp7-14.

Siddiqui, I. A, Qureshi, S. A, Sultana V, Ehteshamul-Haque, S, Ghaffar, A. 2000. Biological control of rot-root knot disease complex of tomato. *Plant Soil* 227:163–169

Thwaites, R, Eden-Green S. J, Black, R. 2000. Diseases caused by bacteria. *In*: Jones DR (ed) Diseases of Banana, Abaca and Enset. *CAB International*, pp. 544.

Vu, T, Hauschild R, Sikora R. A. 2006. *Fusarium oxysporum* endophytes induced systemic resistance against *Radopholus similis* on banana. *Nematology* 8:847–852

Wharton, D. A, Preston C. M, Barrett J, Perry R. N. 1988. Changes in cuticular permeability associated with recovery from an hydrobiosis in the plant parasitic nematode, *Ditylenchus dipsaci*. *Parasitology* 97:317–30

Loos, C. A. 1962. Studies on the life history and habits of the burrowing nematode, *Radopholus similis*, the cause of black head on banana. Proc. Helminthol. Soc. Wash. 29:43-52.

Sher, S. A. 1968. Revision of the genus *Radopholus* Thorne, 1949 (Nematoda: Tylenchoidea). Pxoc. Helminthol. Soc. Wash. 35:219-237.

Van Weerdt, L. G. 1960. Studies on the biology of *Radopholus similis* (Cobb 1893) Thorne *1949.* Nematologica 5:45-51.