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Yield losses by Phytonematodes: challenges and opportunities with special reference to Egypt

Mahfouz M. M. Abd-Elgawad

Phytopathology Department, National Research Center, El-Tahrir St., Dokki 12622, Giza, Egypt

Abstract

Plant-parasitic nematodes (PPN) constitute a major constraint to agriculture. Estimates of their crop-loss are important for establishing research, extension, and budget priority. Regulatory policy action, pesticide impact assessment, resource allocation, and program prioritization are usually contingent upon such crop loss data. Recent questionnaire results of important PPN genera and estimates of crop losses in Egypt due to PPN are presented herein. Crop losses due to the nematodes on 80 crops, 15 of which are 'life sustaining', were estimated at L.E. 15.85 (= $2.30) billion annually based on 2011-2012 Egyptian production figures and prices. Crop loss estimates of vegetables, fruits, and field crops demonstrated staggering figures and therefore nematode problems warrant considerably more effort and support than they are currently receiving. Current challenging nematode issues include reduced number of effective nematicides available and limitation in their use due to environmental issues, increased adoption of intensive agriculture, climate change, occurrence of resistance-breaking PPN pathotypes on economically important crops, and potential introduction of quarantine-nematodes. Therefore, basic and applied nematological research should be more oriented to provide better management of plant-parasitic nematodes in an economically and environmentally beneficial manner.

Key words: Crop production, nematode damage and management, yield loss, Egypt.

Introduction

Common obstacles hindering perfect estimates of crop losses caused by plant-parasitic nematodes (PPN) have recently been highlighted **(Abd-Elgawad and Askary, 2014).** Information requirements for crop-loss assessment purposes must include estimates of crop distribution and value, pest distribution and average infestation level, and finally a damage function relating average infestation and crop yield. All these estimates are susceptible to error, and interaction effects among biological components should be considered **(Koenning *et al.*, 1999).** Yet, studies on the impact of phytonematodes on agriculture are essential because they can let people know how serious nematode problems can be. Such studies are considered the basis for nematode-management options. In Egypt, such information can also develop farmers' awareness of PPN damage and consequently adopt adequate control measures to avoid yield losses and ensure high quality of organic grown crops. Strategies solely based on cultural and tillage practices, are frequently not sufficient in controlling the nematodes due to nematode abundance and their broad host spectrum in Egypt **(Abd-Elgawad, 2008).** Moreover, reliable crop loss estimates are important for establishing research, extension, and budget priority **(McSorley *et al.*, 1987).** Pest-specific crop-loss information is needed by government agencies; corporations involved with crop protection and production, and university systems for descriptive and predictive purposes **(Noling, 1987).** Regulatory policy action, pesticide impact assessment, resource allocation, and program prioritization are usually contingent upon crop loss data. Therefore, one should not be discouraged by some cautious tones and limitations in establishing such estimates. Admittedly, it is essential that the full spectrum of crop production limitations is considered appropriately, including the often overlooked phytonematode constraints **(Nicol *et al.*, 2011);** to maximize agriculture output.

On a global scale, the distribution of nematode species varies greatly while the economic impact of their genera differs **(e.g., Evans *et al.*, 1993; Luc *et al.*, 2005).** Worldwide economic impact of PPN on agriculture was reported **(McSorley *et al.*, 1987; Sasser, 1988; Koenning *et al.*, 1999; Nicol *et al.*, 2011; Abd-Elgawad and Askary, 2014)** but information is scanty on large-scale nematode losses in Egypt. Our goal here is to present the most important PPN genera and their losses in Egypt. Their current challenges and our ability to cope with them are discussed.

Material and Methods

Assessment of important PPN in Egyptian vegetables, fruits, and field crops. Crops included those in tables (1-3). Ten Ph. D. Egyptian nematologists were asked to rank the five most damaging genera of plant parasitic nematodes occurring in Egypt. Based on the number of first, second, third, fourth and fifth place votes, a weighted index was calculated by giving first place votes a score of 5; second place votes a score of 4; third place votes a score of 3; fourth place votes a score of 2; and fifth place votes a score of 1 **(Sasser, 1988).**

Assessment of their yield losses. Over 70 selected papers, chapters, M. Sc./Ph. D. theses, and books on PPN in Egypt representing different authors, localities, periodicals, years, and crops were thoroughly reviewed to document important phytonematode genera and assess yield losses due to nematodes. Other criteria used to assess such losses comprised Egyptian nematologist and grower interviews, previous reports and visual assessment based on foliage growth (necrotic, chlorotic, stunted, and wilted plants), root symptoms, and educated guess to expert opinions according to **Anwar and McKenry (2012).** The number of nematologists and growers interviewed was variable and ranged from 4-12 for each crop. Nematologists and growers were selected for their experience on specific crops under all degrees of agrochemical inputs, management intensity and productivity. Such interviews included condition of the crop, quantitative and qualitative yield losses based on market value, and life span of the crop. Estimates were reported first as percentage of yield losses then converted to their corresponding monetary losses. The latest Egyptian agricultural statistical tables of 2011-2012 showing areas (in Feddan which equals 4200 m^2), yield (Ton/Feddan), and production (Ton) for each cultivated crop were obtained from Egyptian Ministry of Agriculture & Land reclamation **(Anonymous, 2012).** Based on the Egyptian annual crop production from these data, losses in quantity and value are reproduced after assessment of yield losses. Current challenging PPN issues and their possible solutions were addressed **(Abd-Elgawad and Askary, 2014).**

Results

The questionnaire of this study could nominate fourteen genera as the most damaging phytonematodes in Egypt. These genera, with the total weighted votes for each nematode genus received is given in parentheses, were reported to be *Meloidogyne* (50), *Pratylenchus* (28), *Rotylenchulus* (24), *Tylenchulus* (22), *Trichodorus & Paratrichodorus* (5), *Heterodera* (5), *Tylenchorhynchus* (4), *Helicotylenchus* (3), *Hoplolaimus* (2), *Aphelenchoide*s (2), *Hirschmanniella* (2), *Ditylenchus* (1), *Xiphinema* (1), and *Longidorus* (1).

Annual losses due to nematodes on 37 vegetables (Table 1), 25 field crops (Table 2), and 18 tree fruits (Table 3) were estimated at L.E. 5.12, 8.05, and 2.68 billion, respectively, based on 2011-2012 Egyptian production figures and prices on wholesaling basis; not retail. Average estimates of their corresponding annual yield losses are 11.35, 8.76, and 10.28%. So, crop losses due to nematodes on all the 80 Egyptian crops, 15 of which are life sustaining crops according to **Wittwer (1981),** were estimated at L.E.15.85 (= $2.3) billion annually. The life sustaining crops, include banana, barley, chickpea, corn, field bean, peanut, pigeon pea, potato, rice, sorghum, soybean, sugar beet, sugar cane, sweet potato, and wheat, that stand between man and starvation, suffered 9% as an average yield loss. Damage estimates for non-food plants including ornamentals, turf, and forest trees were not included. Therefore, the total nematode damage may exceed these figures. Also, the increase in commodity prices since 2011 may inflate this estimate further. In addition, the temporal change in value of the dollar relative to Egyptian currency should be considered. Eventually, estimated overall average annual loss on the Egyptian major vegetable, field, and fruit crops due to damage by PPN, equaled 10.13%. is less than that (12.3%) of previous average estimate for world's major crops **(Sasser and Freckman, 1987).** This is probably due to significant contributions made to nematology during the past years. Yet, the above-mentioned estimates demonstrated staggering figures and therefore nematode problems warrant considerably more effort and support than they are currently receiving.

Table (1): Summary of estimated annual yield losses in vegetables due to damage by plant parasitic nematodes in Egypt*.

Varieties	Loss (%)	Actual production (metric tons)	Price (L.E./ton)	Actual loss (metric tons)	Loss (Million L.E.)
Tomato	12%	8571050	1500	1168779.5	1753.17
Squash	20%	559598	1000	139899.5	139.9
Green bean	7%	251279	3000	18913.44	56.74
Dry bean	7%	69486	5000	5230.13	26.15
Green cowpea	10%	24277	3000	2697.44	8.09
Dry cowpea	10%	12950	5000	1438.89	7.19
Green pea	12%	180631	4000	24631.5	98.53
Dry pea	12%	124	6000	16.91	0.10
Cabbage	9%	638227	500	63121.35	31.56
Cauliflower	5%	171088	500	9004.63	4.50
Eggplant	20%	1193642	1000	298410.5	298.41
Pepper	22%	650554	2000	183489.59	366.98
Okra	13%	97108	3500	14510.39	50.79
Jew's mallow	6%	80316	1000	5126.55	5.13
Spinach	10%	39413	2500	4379.22	10.95
Mallow	8%	2161	1000	187.91	0.19
Artichokes	10%	387704	1500	43078.22	64.62
Taro	6%	118759	2000	7580.36	15.16
Radish	10%	12000	800	1333.33	1.07
Turnip	8%	32779	500	2850.35	1.43
Lettuce	12%	93661	2000	12771.96	25.54
Carrot	13%	179291	2000	26790.61	53.58
Parsley	8%	88487	1000	7694.52	7.69
Arugula	7%	52281	1000	3935.13	3.94
Egyptian leek	10%	31223	1000	34692.22	34.69
Sweet Potato	7%	319427	750	24042.89	18.03
Strawberry	12%	242297	2000	33040.5	66.08
Beet	10%	3518	2000	390.89	0.78
Pumpkin	17%	1256	1200	257.25	308.7
Watermelon	14%	1874710	1200	305185.35	366.22
Cucumber	15%	587612	1500	103696.24	155.54
Armenian cucumber	15%	50568	1400	8923.76	12.49
Cantaloupe	15%	854204	1500	150741.88	226.11
Melon	15%	89927	1400	15869.47	22.22
Shahad	15%	62716	1600	11067.53	17.71
Potato	8%	4758040	2000	413742.61	827.49
water melon pulp seeds	10%	67274	4500	7474.89	33.64

*Based on 2011-2012 total Egyptian production figures and prices on wholesaling basis; not retail.

Table (2): Summary of estimated annual yield losses in field crops due to damage by plant parasitic nematodes in Egypt*.

Varieties	Loss (%)	Actual production (metric tons)	Price (L.E./ton)	Actual loss (metric tons)	Loss (Million L.E.)
Corn	10%	7205541.6	2750	800615.73	2201.69
Rice	9%	5896577	2000	583177.95	1166.36
Sorghum	4%	750894.34	2500	31287.26	78.22
Soybean	8%	25939	3500	2255.57	7.89
Peanut	20%	205393.13	8000	51348.28	410.79
Sesame	12%	31270.92	6000	4264.22	25.59
Common Sunflower	20%	19948	2000	4987	9.97
Sunflower	20%	19987	1700	4996.75	8.49
Onion	5%	126595	1500	6662.89	9.99
Wheat	7%	8795483.1	2800	662025.61	1853.67
Barley	2%	108495.24	2000	2214.19	4.43
Faba bean (dry)	7%	140712.88	6000	10591.29	63.55
Faba bean (green)	7%	52430	2500	3946.34	9.87
Lentil	10%	718.08	8000	79.79	0.64
Chickpea	5%	3106.2	8000	163.48	1.31
Lupine	5%	1551.15	6000	81.64	0.49
Fenugreek	3%	5281.62	8000	163.35	1.31
Sugar beet	12%	9126058	350	1244462.5	435.56
Sugar cane	14%	13475000	300	2193604.7	658.08
Berseem clover (cut)	9%	39855255	200	3941728.5	788.35
Berseem clover (seed)	9%	31393.25	3000	3104.83	9.31
Flax (fiber)	7%	51742	10000	3894.56	38.94
Flax (seed)	7%	5724.484	8000	430.88	3.45
Garlic	2%	309155	10000	6309.29	63.09
Cotton	5%	635000	6000	33421.05	200.53

*Based on 2011-2012 total Egyptian production figures and prices on wholesaling basis; not retail.

Table (3): Summary of estimated annual yield losses in production of fruits due to damage by plant parasitic nematodes in Egypt*.

Varieties	Loss (%)	Actual production (metric tons)	Price (L.E./ton)	Actual loss (metric tons)	Loss (Million L.E.)
Oranges	10%	2577720	1000	286413.33	286.41
Citrus	10%	1152965	1000	128107.22	128.11
Grape	15%	1320801	1000	233082.52	233.08
Mango	5%	598084	5000	31478.11	157.39
Banana	17%	1054243	4000	215929.29	863.72
Fig	10%	165483	4000	18387	73.55
Prickly Pear	7%	27290	1000	2054.09	2.05
Guava	8%	339354	1500	29509.04	44.26
Pomegranate	10%	64574	2500	7174.89	17.94
Apricot	8%	96643	8000	8403.74	67.23
Pear	7%	48817	8000	3674.4	29.4
Apple	12%	455817	3000	62156.86	186.5
Peach	20%	332487	1500	83121.75	124.68
Plum	6%	12666	7500	808.47	6.06
Olive	10%	459650	2500	51072	127.68
Almond	10%	18222	20000	2024.67	40.49
Papaya	12%	6000	2000	818.18	1.64
Date-palm	8%	1113270	3000	96806.09	290.42

*Based on 2011-2012 total Egyptian production figures and prices on wholesaling basis; not retail.

Discussion

The present questionnaire addressed 14 phytonematode genera in Egypt as the most economically important nematodes. These genera comprise 162 worldwide species which fulfilled one or more of the criteria to be considered to present a phytosanitary risk according to **Singh *et al.* (2013).** Other genera found in Egypt; include *Aphelenchus*, *Anguina*, *Merlinius*, *Paratylenchus, Dolichodorus*, *Mesocriconema* and ***Fergusobia* (Ibrahim, 2007; Kella and Bekhiet, 2011);** did not get a vote. Although PPN of economic importance can be grouped into relatively restricted specialized groups, others previously viewed as benign or non-damaging, are becoming pests as cropping patterns change **(Nicol, 2002; Nicol *et al.*, 2011),** while new species are continually being described. A comprehensive list of main hosts and yield loss estimates are recently provided **(Singh *et al.*, 2013)** with an extensive bibliography for each of 250 phytonematode species, from 43 genera including those voted for in the present questionnaire, considered to present a phytosanitary risk.

Compared to other worldwide survey **(Sasser and Freckman, 1987),** *Meloidogyne* and *Pratylenchus* are still first but *Rotylenchulus* and *Tylenchulus* are relatively high on the current list. In Europe, however, *Heterodera* (161), *Globodera* (156), *Meloidogyne* (100), *Ditylenchus* (93), *Pratylenchus* (88), *Aphelenchoides* (26), *Xiphinema* (26), *Longidorus* (17) and *Tylenchulus* (8) were recorded to be most damaging to plants (Sasser, 1988). In a recent worldwide questionnaire, Jones *et al*. (2013) reported that the top 10 PPN genera/species were composed of: 1) *Meloidogyne*; 2) *Heterodera* and *Globodera*; 3) *Pratylenchus*; 4) *Radopholus similis*; 5) *Ditylenchus dipsaci*; 6) *Bursaphelenchus xylophilus*; 7) *Rotylenchulus reniformis*; 8) *Xiphinema index*; 9) *Nacobbus aberrans*; and 10) *Aphelenchoides besseyi*. Their order, based on scientific and economic importance, varies from those listed in the current survey probably because of difference in regions, climate, and prevailing crops. **Yet, Jones *et al.* (2013)** bestowed honorable mention to some important nematodes missed out in their questionnaire. They included *Helicotylenchus* spp. **(Subbotin *et al.*, 2011)** and the ectoparasitic *Trichodorus* spp., the vector of Tobacco rattle virus (Decraemer and Geraert, 2006) which are recognized herein with low poll ratings.

The overall average annual loss on the 80 Egyptian crops (Tables 1-3) due to damage by PPN is less than that of previous average estimate **(Sasser and Freckman, 1987)** for world's major crops (i.e. 10.13% vs. 12.3%). Although Egypt is a developing country, the losses may probably be due to significant contributions made to nematology during the past years in general. Yet, the above-mentioned estimates demonstrated relatively high losses and therefore nematode problems warrant considerably more effort and support than they are currently receiving.

Staggering were the estimates as reported by **Sasser and Freckman (1987)** or herein (Tables 1-3) for the high nematode-losses, further unexpected bad effects have been occurring, in a way that may aggravate such losses in Egypt. Such factors include reduced number of effective nematicides available and limitation in their use due to environmental issues, increased adoption of intensive agriculture, climate change, occurrence of resistance-breaking PPN pathotypes on economically important crops, and potential introduction of quarantine-nematodes especially with plant propagation materials. Similar factors may be considered worldwide **(Abd- Elgawad and Askary, 2014).** Therefore, research and management of plant-parasitic nematodes should be carried out in an economically and environmentally beneficial manner; briefly as follows:

1. Safe and Tactful use of applicable nematicides

Because most phytoparasitic nematodes spend their lives confined to the soil or within plant roots, delivery of a chemical nematicide to the immediate surroundings of a nematode is difficult. The outer surface of nematodes is a poor biochemical target and is impermeable to many organic molecules. Delivery of a toxic compound by an oral route is nearly impossible because most phytoparasitic species ingest material only when feeding on plant roots. Consequently, synthetic nematicides have tended to be broad-spectrum toxicants possessing high volatility or other properties promoting migration through the soil **(Chitwood, 2003).** Therefore, several chemical nematicides have been withdrawn from the market due to their serious threats to natural biological control processes, wildlife, groundwater contamination, resource depletion, and human health and safety. Furthermore, the resulting record of less-than-perfect environmental or human health safety has resulted in the widespread deregistration of several agronomically important chemical nematicides (e.g., ethylene dibromide and dibromochloropropane). More recently, the most important remaining fumigant nematicide, methyl bromide, has been banned because of concerns about atmospheric ozone depletion as well. In addition to their health hazards, many chemical pesticides are expensive, or have been withdrawn from use which has led to increased interest in organic methods for crop and pest management for many crop production systems. In other words, growing dissatisfaction with such chemicals required environmentally friendly pathogen control approaches. The future of nematicides for the control of nematodes will depend on the formulation of new compounds that are effective and environmentally safe. The development of other application technology, e.g. treatment by seed coating or chemicals applied through chemigation as well as development of systemic nematicides is urgently needed.

2. Intensive agriculture system

This system uses high levels of complementary inputs, e.g. fertilizers and pesticides to achieve maximum yields at the lowest possible cost from the same cultivated area. Indeed, the list of negative effects of intensive farming seems to be getting longer: soil degradation, salination of irrigated areas, over-extraction and pollution of groundwater, resistance to pesticides including nematicides, erosion of biodiversity, etc. **(http:// www.euractiv.com/ cap/ intensive-farming-ecologically-s-linksdossier -506029).** In Florida, intensive citriculture system suppressed entomopathogenic nematodes and consequently had the potential to exacerbate herbivory by insect pests **(Campos-Herrera *et al.*, 2013).**

3. Climate change

The most likely consequences of climate change are shifts in the geographical distribution of plant host and pathogen and altered crop losses, caused in part by changes in the efficacy of control strategies **(Coakley *et al.*,**

1999). Such a change does not exclude the threat of the emergence of new pests, including nematodes **(Nicol *et al.*, 2011). Carter *et al.* (1996)** predicted the increase of the root-knot nematodes (RKNs) as climate change because of additional pathogen generations per year in a warmer climate. This is especially important since most nematode life processes have thermic optima that determine the ideal geographic ranges of nematodes **(Luc *et al.*, 2005). Boag *et al.* (1991)** used data from soil samples collected during the European PPN Survey to assess the possible impacts of climate warming on the geographical range of virus-vector nematodes. Initial analyses of nematode presence-absence data suggested a close association between mean July soil temperature and nematode distribution. Based on this result, the authors predicted that climate change could result in increased nematode and virus problems in northern Europe; they estimated that a 10 ^{0}C warming would allow the nematode species in study to migrate northward by 160 to 200 km **(Neilson and Boag, 1996).** Although nematodes migrate very slowly, humans are credited with efficiently disseminating them. Nematode spread into new regions could put a wide range of crops at risk; additionally, introduction of new crops into a region could also expose them to infestation by nematode species already present. Changes in precipitation could influence nematode distribution on a large scale, although previous findings had suggested that soil moisture would not affect nematode distribution in most agricultural soils in northern Europe **(Boag *et al.*, 1991; Neilson and Boag, 1996; Coakley *et al.*, 1999)**. Yet, in an alternative example, the rice root knot nematode, *Meloidogyne graminicola*, can be maintained under damaging levels through good water management. However, with reduced availability of water following climatic changes and/or competition for urban use, reduced quality of water management, or the introduction of water saving mechanisms such as direct wet seeding is favoring the development of high populations of *M. graminicola*, drastically raising its damage. Also, *Radopholus similis* occurs only below ~1,400 m altitude in the East African Highlands where it is a principal pest of banana and plantain, a regional key starch staple for over 20 million people. A small raise in temperature would result in *R. similis*, which is cold-sensitive, infecting millions more bananas grown at higher altitudes **(De Waele and Elsen 2007, as in Nicol *et al.*, 2011). So**, programs to prevent nematode spread into new regions should be initiated and precisely applied **(e.g. Sikora *et al.*, 2005; Abd-Elgawad and McSorley, 2009).**

4. Lag in nematode-genetic manipulation

Nematode control through genetic resistance is still insufficient although an extensive list of major annual and perennial crops carrying resistance to root-knot, cyst, and other PPN was recently reported **(Molinari, 2011).** Plant cultivars with high-standard agricultural traits of tomato, tobacco, cotton, peanut resistant to *Meloidogyne* spp., of potato resistant to *Globodera* spp., and soybean resistant to *Heterodera* spp. are commercially available for growers **(Starr and Roberts, 2004).**

While some crops benefit from resistance, many lack identified resistant germplasm **(McCarter, 2008).** Furthermore, resistance breaking through selection of virulent nematode populations (e.g. soy parasites) or selection for non-susceptible species (e.g. potato parasites) can occur, lessening the trait's value **(Starr *et al.*, 2002).** Root-knot and cyst nematodes, and perhaps other species, have the capacity to develop new strains and races when cultivars resistant to these forms are planted too frequently **(Sasser and Freckman, 1987).** For example, five of nine populations of *Meloidogyne* spp. from Greece, identified as *M. javanica* (4 populations) and *Meloidogyne incognita* (one population) using either isozyme phenotypes or the sequence characterized amplified region-polymerase chain reaction (SCAR-PCR) technique, were virulent against the *Mi* resistance gene as assayed by pot experiments in controlled conditions. These populations could reproduce on tomato cultivars containing that gene **(Tzortzakakis *et al.*, 2005).** Also, hypersensitive resistance (HR) to the common root-knot nematode species was clearly observed in infested roots of tetraploid potato clones that have been tested previously by UMR APBV-Potato team **(Berthou *et al.*, 2003 and Kouassi *et al.*, 2005),** but such HR observations were not so distinct in the histopathological changes induced by Egyptian *M. incognita* population probably because the Egyptian nematode population is more virulent **(Eddaoudi *et al.*, 1997)** and/or other stressing environmental factors have accounted for such variations since some nematode-second stage juveniles (J_2) were found active even after 10 days of inoculation **(Abd-Elgawad *et al.*, 2012).** Moreover, despite the above-mentioned progress in molecular nematology, no transgenic approaches to resistance have reached commercialization and nematode control lags behind transgenic control of insects, viruses, and fungi. This lack of improved technology reaching the grower has been detrimental to nematology as a discipline and has coincided with static-to-declining numbers of trained applied nematologists, particularly in the United States (McCarter, 2008). On the other hand, genetic basis of resistance and virulence along with interactions leading to incompatible/compatible responses of the plants to nematodes and the role of some important hormones in plants and genetic variability of nematode populations were recently reviewed **(Molinari, 2012).** Race-non-specific (horizontal) resistance should be targeted as opposed to gene-for-gene recognition system including HR **(Keane, 2012).**

5. Quarantine problems

Quarantine and certification programs are important in limiting the spread of PPN but the programs cause indirect costs in addition to direct loss. For example, *M. chitwoodi* and *M. fallax* are increasingly regulated as they can be spread through seed potatoes and potato tubers infested by PCN from Europe. As is widely accepted, quarantine cannot be feasibly carried out to all units of transferable plants, pots, soil and cuttings. Comprehensive precautions should be implemented for complete protection against a species as yet not found in a country **(Salama and**

Abd-Elgawad, 2003). Complete certainty of pest absence can be assured only if every unit in the lot is inspected. Unfortunately, testing every unit is sometimes neither economical nor practical. So, it is usually necessary to sample a portion of the units in the lot, and to accept or reject the entire lot based on the results. The inspector must assume some risk and set limits defining freedom from infestation, e.g., less than 1% of units infested, or less than 5 units infested, since it is a choice between objectives and available fund. Also, effect of sample size on the probability of detecting PPN species in a polyspecific nematode population and comparison of observed with expected rates of failure to detect this nematode by soil sampling in several locations were reported **(Abd-Elgawad and McSorley, 2009).**

Despite great efforts exerted on quarantine, striking examples of faulty quarantine regulations have led to the spontaneous introduction of nematode pests. *B. xylophilus*, associated with pine wilt disease but depends on bark beetles (*Monochamus* spp.) to spread from tree to tree, is native to North America and is thought to have been carried to Japan at the beginning of the twentieth century on timber exports **(Nicol *et al.*, 2011).** In Japan, it is causing massive mortality of native pine trees. In 1999, *B. xylophilus* was found in Europe for the first time, in Portugal. Quarantine nematologists were already researching the identity of this species in order to be able to distinguish it from the many species of *Bursaphelenchus* that inhabit wood. Unfortunately, there is a variation in characters between species in the *Bursaphelenchus* group, which makes morphological identification particularly difficult, so biomolecular tools, e.g. sequencing, species-specific primers and probes, are highly recommended **(OEPP/EPPO, 2009a).** Likewise, molecular and reliable protocols for quarantine species such as *G. rostochiensis* and *G. pallida* **(OEPP/EPPO, 2009b),** *M. chitwoodi*, *M. fallax* **(OEPP/EPPO, 2009c),** and *Xiphinema americanum* sensu lato **(OEPP/EPPO, 2009d)** were established while others are in progress. Generally, the cost of such protocols might vary from one country to another. For example, the double labeled TaqMan probe type might cost approximately $ 200 in USA, $ 600 in Brazil, and $450 in Spain, in the same company, and also, it is possible to have different price/quantities and qualities depending on the company selected; it is conceivable that, hence, the rest of the reagents used for these protocols (master mix, plate, film…etc) might change as well, although the function and use of these products are equivalent. Admittedly, in the countries where such technologies are currently under development and equipment not certainly easily available, as in Egypt, an extra implementation, with more costs, will be required for performing the same protocols. A comparative of these costs by countries or continents may give a very good idea of which are the potential and the limitations in including these molecular analysis. Moreover, such analyses require materials that sometimes are not considered in the initial budget, and at the end it significantly increases the final cost. It is important to highlight again that costs may also differ with other companies selected for the reagents or material, such as Applied Biosystem, Qiagen **(http://www.qiagen.com/)**

and IDT Technologies **(http://eu.idtdna.com).** Yet, at any rate, strict conduction of such protocols will prevent the introduction and spread of quarantine species in new areas/states; thereby saving millions of dollars in annual crop losses **(Handoo *et al.*, 2013)**. **Holgado and Magnusson (2012)** addressed the current status and perspectives of quarantine nematodes in the light of European legislation. They stressed the need to have actualized statistic data to provide information on problems emanating from particular sources, areas or suppliers, to determine priorities for targeting inspections and monitoring consignments with high risk to the agricultural industry in their countries and to perform a Pest Risk Analysis (PRA). Such data are urgently needed for decision-makers in Egypt too.

6. Confusion in identification of some PPN species and races

The names of regulated PPN need to be as firmly established as possible. This requires awareness of the fact that some species might be subject to many taxonomic changes, and that there may exist many synonyms in the legislation of some countries; this needs to be recognized to avoid confusion and allow for the correct phytosanitary action to be taken. Examples of this controversy are *Radopholus citrophilus* and *R. similis*, which are both listed in European legislation. *R. similis* was thought to consist of different pathotypes but **Huettel *et al.* (1984)** concluded that the banana race and the citrus race were two distinct species; the name *R. similis* was restricted to the banana race, and the citrus race was described as *R. citrophilus*. **Later, Kaplan *et al.*, (1997)** synonymized *R. citrophilus* with *R. similis*; **Valette *et al.*, (1998)** proposed *R. citrophilus* as a junior synonym of *R. similis*, although Siddiqi (2000) proposed it as a subspecies of *R. similis*, and **Elbadri *et al.* (2002),** using molecular techniques, demonstrated marked intraspecific variation in various isolates of *R. similis*. This continuing taxonomic uncertainty has caused confusion for quarantine officers and specialists involved in PRA work, due to the uncertainty on the actual host lists of *R. similis* **(Holgado and Magnusson, 2012).** More recently, *M. enterolobii* and *M. mayaguensis* were considered separate species, but their recent synonymization meant that when distribution, host range and other information published under both names were consolidated, the apparent risk increased substantially. Therefore, information published under species synonyms also needs to be considered when assessing phytosanitary importance **(Singh *et al.*, 2013).** On the other hand, splitting of a species (e.g. the new species *Ditylenchus gigas* and *D. weischeri*, previously considered as part of *D. dipsaci* species complex **(Chizhov *et al.*, 2010; Vovlas *et al.*, 2011)** demonstrated that the distributions and phytosanitary importance of closely related or cryptic species and races could be assessed more precisely with more specific identification methods. Admittedly, uncertainties concerning the validity of nematode species will lead to practical problems related to quarantine measures and nematode management as well as highlight the importance of research into taxonomy and specific identification methods.

7. Discrepancy in nematode technological progress among countries

Addressing recent nematological issues will pose additional challenges to tropical and subtropical nematology since there has been discrepancy in nematode technological progress between the North and the South countries **(Luc *et al.*, 2005).** Moreover, the increased application of molecular diagnostics may widen the knowledge gap between nematologists working in developed and developing countries. The study of interactions between nematodes and other pathogens in disease complexes provide opportunities for multidisciplinary research with scientists from other disciplines but remain fairly underexploited. Contrary to developed countries, difficulties in recognizing emerging nematode threats in developing countries, like Egypt, prevent the timely implementation of management strategies, thus increasing yield losses. For example, in USA, the immediate implementation of a federal quarantine on the pale cyst nematode, *Globodera pallida*, as a serious pest helped prevent the spread of this species in the United States; thereby saving millions of dollars in annual crop losses **(Handoo *et al.*, 2013).** This is especially important since over-population occurs predominantly in developing, mostly tropical and subtropical, countries where the majority of hungry people live.

8. Inaction or shift in PPN management

Even in the developed countries, forgotten nematode problems can reappear all of a sudden as rotation sequences are altered or new cultivars introduced, as has been seen with new outbreaks of PCN and sugarbeet stem nematode *D. dipsaci* **(Luc *et al.*, 2005).** A problem new to a particular country could arise through the introduction and subsequent spread of a known nematode parasite from another temperate country. It is, therefore, the case in temperate countries that surveys are designed to determine the distribution of known nematodes causing known damage. In contrast, in the subtropical and tropical areas, new problems are being, and have yet to be, discovered involving new nematode species and even genera, or species not recorded as harmful to a crop. Examples are the 'legume Voltaic chlorosis' of leguminous crops, discovered in Burkina Faso, associated with a new species, *Aphasmatylenchus straturatus*, and a genus not previously known to be a harmful parasite **(Germani and Luc, 1982).** In Egypt, *A. besseyi* causing white tip leaf disease on rice was detected (Amin, 2001) and most recently aerial shoot galls on camphor trees induced by the plant parasitic nematode, *Fergusobia* spp., and the dipterous insect, *Fergusonina* spp. were reported in several Egyptian governorates during winter, spring, summer and autumn seasons **(Kella and Bekhiet, 2011).**

9. Lack of economically-oriented PPN research

We believe that more economically-oriented research work should be followed. **McCarter (2008)** proved this case by figures. Nearly half of the total (48%)

yield loss caused by nematodes derives from just two crops, rice **(Bridge *et al.*, 2005) and maize (McDonald and Nicol, 2005),** which dominate because of their overall predominance in world agriculture. Twenty-eight percent of the total loss derives from rice in China and maize in the US alone. Despite the impact of rice and maize on the estimated total yield loss, few molecular nematologists focus their research on these crops and the associated nematode pathogens. While 29 species of nematodes parasitize rice, studies of disease distribution and yield loss in rice have been limited **(Bridge *et al.*, 2005),** and international agricultural research centers have employed a minimal number of nematologists **(Luc *et al.*, 2005).** Similar situations might be found in Egypt if not even worse. Therefore, basic and applied nematological research should be more oriented in Egypt to improve management tactics and strategy of phytonematodes in a more economically and environmentally useful array.

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References

Abd-Elgawad, M.M.M. (2008). The current status of phytonematode management in Egypt with special reference to applicable nematicides. Egyptian Journal of Agronematology 6: 33-46.

Abd-Elgawad, M.M.M. and McSorley, R. (2009). Movement of citrus nematode-infested material onto virgin land: detection, current status and solutions with cost-benefit analysis for Egypt. Egyptian Journal of Agronematology 7(1):35-48.

Abd-Elgawad, M.M.M., Kerlan, M., Molinari, S., Abd-El-Kareem, F., Kabeil, S.S.A., Mohamed, M.M., and El-Nagdi, W.A. (2012). Histopathological changes and enzymatic activities induced by *Meloidogyne incognita* on resistant and susceptible potato. eSci Journal of Plant Pathology 1: 62-72.

Abd-Elgawad, M.M.M. and Askary, T.H. (2014). Impact of phytonematodes on agriculture economy. In: Askary, T.H. and Martinelli, P.R.P. (eds), *Biocontrol Agents of Phytonematodes*. CAB International, Wallingford, UK: In press.

Amin, A.W. (2001). First record of *Aphelenchoides besseyi* Christie, 1942 (Nematoda: Aphelenchoididae) in Egypt causing white tip leaf disease on rice. Opuscula Zoologica (Budapest) 33: 3-6.

Anonymous (2012). *Area, productivity and production of Vegetable Crops for total seasons of year 2012.* Egyptian Economic Affairs Sector, Ministry of Agriculture and Land Reclamation, Giza, Egypt (in Arabic).

Anwar, S.A. and McKenry, M.V. (2012). Incidence and population density of plant-parasitic nematodes infecting vegetable crops and associated yield losses in Punjab, Pakistan. Pakistan Journal of Zoology 44: 327-333.

Berthou, F., Kouassi, A., Bossis, M., Dante, J.P., Eddaoudi, M., Ferji, Z., Pelle, R., Taghzouti, M., Ellisseche, D., Mugniery, D. (2003). Enhancing the resistance of the potato to tropical and mediterranean root-knot nematodes by using ex-*Solanum sparsipilum* germplasm. Euphytica 132: 57-65.

Boag, B., Crawford, J.W. and Neilson, R. (1991). The effect of potential climatic changes on the geographical distribution of the plant-parasitic nematodes *Xiphinema* and *Longidorus* in Europe. Nematologica 37: 312-23.

Bridge, J., Plowright, R.A., Peng, D. (2005). Nematode parasites of rice. In: Luc, M., Sikora, R.A., and Bridge, J. (Eds). *Plant Parasitic Nematodes in Subtropical and Tropical Agriculture,* 2nd edn. CAB International, Wallingford, UK, pp. 87-130.

Campos-Herrera, R., Pathak, E., El-Borai, F.E., Schumann, A., Abd-Elgawad, M.M.M., and Duncan, L.W. (2013). New citriculture system suppresses native and augmented entomopathogenic nematodes. Biological Control 66: 183-194.

Carter, T.R., Nurro, M. and Torkko, S. (1996). Global climate change and agriculture in the North. Agricultural and Food Science in Finland 5: 223-385.

Chitwood, D.J. (2003). Nematicides. In: Plimmer, J.R. (Ed). *Encyclopedia of Agrochemicals, Vol. 3.* John Wiley & Sons, New York, USA, pp.1104-1115.

Chizhov, V.N., Borisov, B.A. and Subbotin, S.A. (2010). A new stem nematode, *Ditylenchus weischeri* sp. n. (Nematoda: Tylenchida), a parasite of *Cirsium arvense* (L.) Scop. in the Central Region of the Non-Chernozem Zone of Russia. Russian Journal of Nematology 18: 95-102.

Coakley, S.M., Scherm, H., Chakraborty, S. (1999). Climate change and plant disease Management. *Annual Review of phytopathology* 37: 399-426.

Decraemer, W. and Geraert, E. (2006). Ectoparasitic nematodes. In: Perry, R.N. and Moens, M. (eds). *Plant Nematology*. CAB International, Wallingford, UK, pp. 153–184.

Decraemer, W. and Hunt, D.J. (2006). Structure and classification. In: Perry, R.N. and Moens, M. (eds). *Plant Nematology*. CAB International, UK, Wallingford, Oxfordshire, pp. 3–32.

De Waele, D. and Elsen, A. (2007). Challenges in Tropical Plant Nematology. Annual Review of Phytopathology 45: 457-485.

Eddaoudi, M., Ammati, M. and Rammah, A. (1997). Identification of resistance breaking populations of *Meloidogyne* on tomatoes and their effects on a new source of resistance. Fundamental and Applied Nematology 20: 285-289.

Elbadri, G.A.A., De Ley, P., Waeyenberge, L., Vierstraete, A., Moens, M. and Vanfleteren, J. (2002). Intraspecific variation in *Radopholus similis* isolates assessed with restriction fragment length polymorphism and DNA sequencing of the internal transcribed spacer region of the ribosomal RNA cistron. International Journal of Parasitology 32(2): 199-205.

Evans, K., Trudgill, D.J. and Webster, J.M. (1993). *Plant Parasitic Nematodes in Temperate Agriculture*. CAB International, Wallingford, UK.

Germani, G. and Luc, M. (1982). Etudes sur la chlorose voltaïque des légumineuses due au Nématode *Aphasmatylenchus straturatus* Germani. 1 & 2. *Revue de Nématologie* 5, 139-146 and 161-168.

Handoo, Z.A., Mowery, J.D. and Chitwood, D.J. (2013). The history of the USDA nematode collection and its database: valuable resources for taxonomic research and identification. Proceedings of the 10th Int. Nematological Symposium, Russian Society of Nematologists, Golitsyno – Bolshie Vyazemy/ Moscow, 1-5 July, 2013, pp. 110-113.

Holgado, R. and Magnusson, C. (2012). Quarantine Nematodes-European Legislation: current status and perspectives. http://www.izbis.com/ aktuelnosti2012/ nematoda/Nematode1.pdf

Huettel, R.N., Dickson, D.W. and Kaplan, D.T. (1984). *Radopholus citrophilus* n. sp. (Nematoda), a sibling species of *Radopholus similis*. Proceedings of the Helminthological Society of Washington 51: 32-35.

Ibrahim, I.K.A. (2007) Diseases and pests of field crops and the control methods in Egypt (In Arabic). Monshaat Al-Maaref Publisher, Al-Raml Station, Alexandria, Egypt. P. 320.

Jones, J.T., Haegeman, A., Danchin, E.G.J., Gaur, H.S., Helder, J., Jones, M.G.K., Kikuchi, T., Manzanilla-López, R., Palomares-Rius, J.E., Wesemael, W.M.L. and Perry, R.N. (2013). Review: Top 10 plant-parasitic nematodes in molecular plant pathology. Molecular Plant Pathology DOI: 10.1111/mpp.12057.

Kaplan, D.T., Vanderspool, M.C. and Opperman, C.H. (1997). Sequence tag site and host range assays demonstrate that *Radopholus similis* and *R. citrophilus* are not reproductively isolated. Journal of Nematology 29: 421-429.

Keane, P.J. (2012). Horizontal or generalized resistance to pathogens in plants. In: Cumagun, C.J. (ed.). *Plant Pathology*. InTech, Rijeka, Croatia, pp. 327-362.

Kella, A.M. and Bekhiet, M.A. (2011). Aerial nematode galls on camphor trees induced by the relationship between *fergusobia* nematode and *fergusonina* insect. Egyptian Journal of Agronematology 10(2):170-176.

Koenning, S.R., Overstreet, C., Noling, J.W., Donald, P.A., Becker, J.O. and Fortnum, B.A. (1999). Survey of crop losses in response to phytoparasitic nematodes in the united states for 1994. Journal of Nematology 31(4S): 587-618.

Kouassi, A.B., Kerlan, M.C., Sobczac, M., Dantec, J.P., Rouaux, C., Ellisseche, D. and Mugniery, D. (2005). Genetics and phenotypic characterization of the hypersensitive resistance of *Solanum sparsipilum* to *Meloidogyne incognita*. Nematology 7(2): 213-225.

Luc, M., Bridge, J. and Sikora, R.A. (2005). Reflections on nematology in sub-tropical and tropical agriculture. In: Luc, M., Sikora, R.A. and Bridge, J. (Eds). *Plant Parasitic Nematodes in Sub-tropical and Tropical Agriculture***.** CAB International, Wallingford, UK, pp. 1-10.

McCarter, J.P. (2008). Molecular approaches toward resistance to plant-parasitic nematodes. In: Berg, R.H. and Taylor, C.G. (Eds). *Cell Biology of Plant Nematode Parasitism-Plant Cell Monographs*. Springer-Verlag Press, Berlin, Germany, pp. 239-267.

McDonald, A.H. and Nicol, J.M. (2005). Nematode parasites of cereals. In: Luc, M., Sikora, R.A. and Bridge, J. (Eds). *Plant Parasitic Nematodes in Sub-tropical and Tropical Agriculture***.** CAB International, Wallingford, UK, pp. 131-191.

McSorley, R., Arnett, J.D., Bost, S.C., Carter, W.W., Hafez, S., Johnson, A.W., Kirkpatrick, T., Nyczepir, A.P., Radewald, J.D., Robinson, A.F. and Schmitt, D.P. (1987). Bibliography of estimated crop losses in the United States due to plant parasitic nematodes. Annals of Applied Nematology 1: 6-12.

Molinari, S. (2011). Natural genetic and induced plant resistance, as a control strategy to plant-parasitic nematodes alternative to pesticides. Plant Cell Reports 30: 311-323.

Molinari, S. (2012). Resistance and virulence in plant-nematode interactions. In: Boeri, F. and Chung, J.A. (eds). *Nematodes*. Nova Science Publisher, Inc., New York, USA, pp. 59-82.

Neilson, R. and Boag, B. (1996). The predicted impact of possible climatic change on virus-vector nematodes in Great Britain. European Journal of Plant Pathology 102:193–99.

Nicol, J.M. (2002). Important nematode pests. In: Curtis, B.C., Rajaram, S. and Gómez, M. (eds). *Bread wheat improvement and production.* FAO Plant Production and Protection Series 2002, p 567.

Nicol, J.M., Turner, S.J., Coyne, D.L., den Nijs, L., Hockland, S. and Tahna Maafi, Z. (2011). Current nematode threats to world agriculture. In: Jones, J., Gheysen, G. and Fenoll, C. (Eds) *Genomics and molecular genetics of plant-nematode interactions*. Springer, Dordrecht, The Netherlands, pp. 21-43.

Noling, J.W. (1987). Partitioning crop losses. In: Veech, J.A. and Dickson, D.W. (Eds). *Vistas on nematology*. Hyattsville, MD: Society of Nematologists, pp. 64-74.

OEPP/EPPO (2009a). EPPO standards PM7/4(2) diagnostics. *Bursaphelenchus xylophilus*. *Bull OEPP/EPPO Bull* 39:344-353.

OEPP/EPPO (2009b). EPPO standards PM7/40(2) diagnostics. *Globodera rostochiensis* and *G. pallida*. *Bull OEPP/EPPO Bull* 39:354-368.

OEPP/EPPO (2009c). EPPO standards PM7/41(2) diagnostics. *Meloidogyne chitwoodi* and *Meloidogyne fallax*. *Bull OEPP/EPPO Bull* 39:5-17.

OEPP/EPPO (2009d). EPPO standards PM7/95(1) diagnostics. *Xiphinema americanum sensu lato*. *Bull OEPP/EPPO Bull* 39:382-392.

Salama, H.S. and Abd-Elgawad, M.M.M. (2003). Quarantine problems: an analytical approach with special reference to palm weevils and phytonematodes. *Archives of Phytopathology and Plant Protection* 36, 41-46.

Sasser, J.N. (1988). A perspective on nematode problems worldwide. In: Saxena, M.C., Sikora, R.A. and Srivastava, J.P. (Eds) *Proceedings of a workshop held at Larnaca, Cyprus, 1-5 March, 1987.* ICARDA, Aleppo, Syria. pp. 1-12.

Sasser, J.N. and Freckman, D.W. (1987). A world perspective on nematology: the role of the society. In: Veech, J.A. and Dickson, D.W. (Eds) *Vistas on nematology*. Society of Nematologists Inc., Hyattsville, Maryland, USA, pp. 7–14.

Siddiqi, M.R. (2000). *Tylenchida: Parasites of Plants and Insects, 2nd edn*. CAB International, Wallingford, UK, pp. 336–380.

Sikora R.A., Bridge J. and Starr J.L. (2005). Management practices: an overview of integrated nematode management technologies. In: Luc M., Sikora R.A. and Bridge J. (Eds). *Plant Parasitic Nematodes in Subtropical and Tropical Agriculture*, 2nd edn. CAB International, Wallingford, UK, pp. 793-825.

Singh, S.K., Hodda, M. and Ash, G.J. (2013). Plant-parasitic nematodes of potential phytosanitary importance, their main hosts and reported yield losses. *Bulletin OEPP/EPPO Bulletin* 43 (2): 334–374.

Starr, J.L. and Roberts, P.A. (2004). Resistance to plant-parasitic nematodes. In: Chen, Z.X., Chen, S.Y. and Dickson, D.W. (Eds). *Nematology, Advances and Perspectives, Vol. 2.*. CAB International, Wallingford, UK, pp. 879-907.

Starr, J.L., Cook, R., and Bridge, J. (2002). *Plant resistance to parasitic nematodes*. CAB International, Wallingford, UK.

Subbotin, S.A., Inserra, R.N., Marais, M., Mullin, P., Powers, T.O., Roberts, P.A., Van den Berg, E., Yeates, G.W. and Baldwin, J.G. (2011). Diversity and phylogenetic relationships within the spiral nematodes of *Helicotylenchus* Steiner, 1945 (Tylenchida: Hoplolaimidae) as inferred from analysis of the D2-D3 expansion segments of 28S rRNA gene sequences. Nematology 13: 333–345.

Tzortzakakis, E.A., Adam, M.A.M., Blok, V.C., Paraskevopoulos, C. and Bourtzis, K. (2005). Occurrence of resistance-breaking populations of root-knot nematodes on tomato in Greece. European Journal of Plant Pathology 113:101-105.

Valette, C., Mounport, o., Nicole, M., arah, J.-L. and Baujard, P. (1998). Scanning electron mieroscopy study of two African populalions of *Radopholus similis* (Nematoda: Pratylenchidae) and proposal of *R. citrophilus* as junior synonym of *R. similis.* Fundamental and Applied Nematology 21: 139-146.

Vovlas, N., Troccoli, A., Palomares-Rius, J.E., De Luca, F., Liébanas, G., Landa, B.B. *et al.* (2011). *Ditylenchus gigas* n. sp. parasitizing broad bean: a new stem nematode singled out from the *Ditylenchus dipsaci* species complex using a polyphasic approach with molecular phylogeny. Plant Pathology 60: 762–775.

Wittwer, S.H. (1981). The 20 crops that stand between man and starvation. Farm Chemicals 144: 17-28.

الملخص العربي

الفقد المحصولي بنيماتودا النبات: التحديات والفرص مع إشارة خاصة إلى مصر

محفوظ محمد مصطفى عبد الجواد

قسم أمراض النبات – المركز القومي للبحوث – الدقي ١٢٦٢٢ – القاهرة – مصر.

تشكل النيماتودا المتطفلة على النبات عائقا رئيسا للزراعة. يعتبر تقدير الخسائر التي تسببها لكل محصول ذات أهمية في توجيه البحوث والإرشاد الزراعي، ووضع الأولوية في ميزانية إدارته. عادة ما تكون العمليات الزراعية للمحصول، وتقييم أثر المبيدات، وتخصيص الموارد، وتحديد أولويات البرنامج الزراعي معتمدة علي مثل هذه البيانات الخاصة بكمية الفقد المحصولي نتيجة الإصابة النيماتودية. تم في هذا البحث عرض نتائج استبيان لتحديد أهم أجناس النيماتودا المتطفلة على النبات وتقدير الخسائر الناتجة عنها في ثمانين محصولاً في مصر منها ١٥ محصولاً رئيسيًّا لاستدامة الحياة. قدرت هذه الخسائر بنحو ١٥,٨٥ مليار جنيه مصري (= ٢,٣٠ مليار دولار أمريكي) سنويًّا على أساس محصلة الإنتاج المصري والأسعار السائدة في ٢٠١١–٢٠١٢. أظهرت تقديرات خسائر محاصيل الخضر والفاكهة والمحاصيل الحقلية أرقامًا مذهلة، وبالتالي فالمشاكل النيماتودية تستدعي بذل جهد ودعم – لمكافحتها – أكثر مما هو موجود حاليًّا. تشمل القضايا الراهنة المتعلقة بهذه المكافحة مناحي عديدة أهمها تناقص عدد المبيدات النيماتودية الفعالة المتاحة والحد المستمر من استخدامها بسبب القضايا البيئية، وزيادة الاعتماد على نظم الزراعة المكثفة، وتغير المناخ بطريقة تؤدي لزيادة انتشار النيماتودا، ونشوء سلالات نيماتودية قادرة على كسر مقاومة الأصناف النباتية ذات الأهمية الاقتصادية، واحتمال دخول هذه النيماتودا إلى بعض البلاد رغم تدابير الحجر الزراعي. لذلك، ينبغي توجيه البحوث الأساسية والتطبيقية في مجال نيماتودا النبات لتوفير قدر أكبر من الفائدة الاقتصادية والبيئية.