International Journal of Sciences: Basic and Applied Research (IJSBAR)

ISSN 2307-4531
(Print & Online)

http://gssrr.org/index.php?journal=JournalOfBasicAndApplied

Limitations to Peri-urban Vegetable Farming in Ghana: An Overview of Root Knot Nematodes Contribution

Joseph Adomako[a*], Kingsley Osei[b], Frederick Kankam[c], Yaw Danso[d]

[a,b,d] *CSIR-Crops Research Institute, Plant Health Division, Post Office Box, 3785, Kumasi, Ghana*

[c] *University for Development Studies, Faculty of Agriculture, Department of Agronomy, Tamale, Ghana*

[a] *Email:joeadomako@gmail.com*

Abstract

Root knot nematodes represent important pathogens affecting global crop production due to their wide host range. The attack of root knot nematode on various vegetable crops leads to delayed maturity, reduced yields and quality of crop produce, high costs of production and therefore loss of income. However, their damage in most cases is overlooked and goes unnoticed by majority of farmers because the damage presents symptoms of drought and nutrient stress conditions. The limited knowledge among farmers about the problems associated with root knot nematodes and the inadequate management measures for curtailing the menace presents a major hindrance for vegetable crops protection. Management strategies should be applied in line with integrated pest management (IPM) practices to enhance adoption by farmers. Also, vegetable producers should be educated on the effects of root-knot nematodes.

Key words: *Meloidogyne* spp; Nematologist; Nematicides; Pest management; Plant parasitic nematodes.

1. Introduction

Agriculture forms the back bone of Ghana's economy contributing about a third of the Gross Domestic Product (GDP) [1]. Peri-urban farming is an age long activity practiced by several households' in the country. Vegetables are an important component of the daily diets of several households in the country and one of the main crops cultivated by peri-urban farmers.

---

* Corresponding author.

Peri-urban farmers according to [2] contributes up to 80% of all fresh vegetables. The common vegetables produced include cabbage, carrot, green pepper, spring onions and lettuce. The availability of these vegetables serve as a cheap source of vitamins and other essential elements for human health and well-being. Apart from meeting the dietary needs of consumers, it is an important source of income to the farmer and raw material for industrial processors. These farms, usually backyard gardens or open-space farms [3] are located around the outskirts of several towns and cities [4]. In Ghana, peri-urban vegetable farming is mainly practiced under rain fed conditions situated on upland and inland valley swamps. Continuous cultivation annually is the common feature of peri-urban farming in Ghana. It is estimated that 70% of the farmers cultivate their plots for between 10-20 years [5]. The continuous and intensive use of farmlands leads to the build-up of pests and diseases which constraints production. Root-knot nematodes among other factors represent one of such constraint in vegetable production. It is associated with the production of several vegetable crops in the country. And these includes but not limited to vegetable crops such as tomato, okra, cabbage, lettuce and carrots [6, 7]. Activities of root knot nematodes goes unnoticed by majority of farmers [8,9]. This is because their damage presents a typical drought and nutrient stress symptoms, often misdiagnosed [10]. The limited knowledge in diagnosing damage of root knot nematodes limits the ability to identify suitable management practices. This contributes to the pests' economic importance. According to [11], a global crop loss of about US$ 118 billion can be attributed to plant nematodes. In support, several works in the country [12, 13, 14, 15] have reported the limited knowledge of farmers on the damage caused by root knot nematodes. This hinders farmers' appreciation and adoption of various management strategy developed and packaged to combat the pest. Also the limited literature and number of Nematologist limits effective education and dissemination of appropriate information on this pest. These challenges present a major hindrance in the fight against root knot nematode to ensure vegetable security and sustainable income for farmers. This review article assesses the general impact of root knot nematodes on crop production, their symptoms and management options. Suggestions intended to help reduce plant nematodes menace in peri-urban vegetable farms have also been provided.

1.2 Economic Importance of Root-knot Nematodes

Root-knot nematodes belong to the genus *Meloidogyne.* It is an economically important obligate plant parasite with over 5500 plant hosts [16]. The genus *Meloidogyne* includes approximately 100 described species but only four *viz M. incognita, M. javanica, M. arenaria* and *M. hapla* are the most widely distributed that cause's serious economic damage. Of these *M. incognita, M. arenaria* and *M. javanica* highly dominates in the tropics and subtropics [17]. Meloidogyne *hapla* is found mostly in the cooler regions of the world, although Wong and Mai [18] reported higher temperatures could favour their invasion into other ecological zones. In Ghana, several authors [13, 19, 20, 21, 22, 23, 24] have reported on the incidence of *Meloidogyne* genera on several crops and weeds. However, [25] confirmed *M. incognita, M. arenaria and M. javanica* the dominant species based on molecular identification.

Notwithstanding the fact that root-knot nematodes are cosmopolitan, data on their economic impact is minimal. This could be attributed to the fact that their damage are less obvious compared to other pests and diseases. Root-knot nematodes have been associated with yield losses ranging between 20 and 33% [31] in crop production. In Ghana, [25] and [26] linked the frequent failure in vegetable production to root-knot nematodes attack. Apart from the direct reduction in crop yield due to disruption in the host plant physiology, they also reduce product qualities (e.g. carrots) which are of great economic and social importance. Severe infections lead to damage and death of a large number of plants resulting in economic loss to farmers. In view of this, [27] reported that *Meloidogyne* spp. causes an estimated annual loss of $157 billion globally. [28] however believes that many crop producing regions in Africa, have no comprehensive assessment that focuses specifically on the economic impact of *Meloidogyne* spp. Root-knot nematodes also interact with other plant pathogens predisposing them to other infections. [29] demonstrated the breakdown of resistance to *F. oxysporum lycopersici* in the presence of *M. incognita*. The damage of this pest predisposes crops to other pathogens through the leaching of nutrients into the rhizosphere soil which favours the growth of bacteria and fungi [30, 31]. Again, [32] reported that root-knot nematodes attack elicits leaf browning, suppression in plant growth, fruit yield and photosynthetic pigments. The extent of damage caused is however related to the density of initial nematode infestation in the soil. Several authors [33, 34, 35, 36] have reported on the negative effects of root-knot nematodes density on growth and yield of crops. According to [37] reduction in the growth and yield of crops are directly influenced by pre-plant density of the nematodes in the soil. Also, there is an observed relationship between increased nematodes populations and death of crop before maturity [38]. The increment in pre-plant density of nematodes can be influenced by the continuous utilization of fields and use of susceptible crops, a characteristic feature in peri-urban vegetable production.

1.3 Life History and Symptoms induced by root knot nematodes

Root-knot nematodes, *Meloidogyne* species are sedentary endoparasitic, whose life cycle is dependent on the feeding sites. It consists of a simple life cycle comprising of the egg, four larval stages and adult stage. Female nematodes lay their eggs in a gelatinous matrix of up to 500 eggs forming an egg mass. The second juvenile stage of root-knot nematode is the most important, because they hatch from the egg and identify a suitable host through the aid of sensory substances released from roots and has effect on plant roots. Host finding or migration in soil occurs in water films surrounding soil particles and root surfaces. The root knot nematode releases enzymes to soften plant cell walls and uses the spear to create entry point into the suitable host. The root knot nematode juvenile then moves into the root and migrates between cells until it reaches its final and permanent feeding site. After establishing a feeding site, the juveniles develop into adults within the roots. Under suitable environmental conditions and adequate food supply, most of the adults develops into females and remain sedentary within the roots. They develop into a pear or globose shape and use its spear to obtain food from the giant cells which is essential for establishing host parasitic relationship. However, under reduced food supply and unfavourable environmental conditions, males are produced and migrate from the roots.

The rapid rate of reproduction and development on good hosts, leads to several generations of the pests during a single cropping season. Their feeding activity on affected roots affects water and nutrient translocation by the root system leading to severe crop damage. Root-knot nematodes infested fields show retarded plant growth, lack of vigour, leaf chlorosis, patchy growth, failure to respond accordingly to fertilizers and wilting under moisture stress as above-ground symptoms due to damaged or malfunctioning root system. Plants affected by root-knot nematode usually exhibits varying root galling shapes shown as below ground symptoms. The galls produced may be small or large, terminal or sub-terminal. However, the type of galling may differ between crops and symptom severity increases with the age of the crop. In severe infestations, heavily galled roots may rot and the size of the root system markedly reduced. In crops such as carrots, symptoms may appear as forked shape or reduced length.

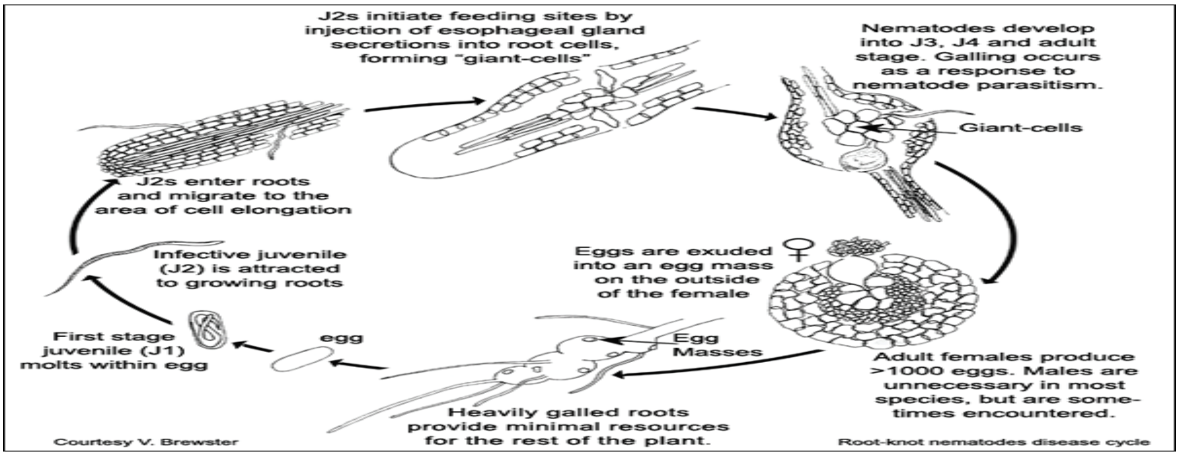

Figure 1: Basic life cycle of root-knot nematode (*Meloidogyne* spp. Courtesy of G. Abawi and V. Brewster)

Figure 2: Symptom of Root knot nematodes infection on carrot

Figure 3: Root knot nematode induced galls on okra roots

1.4 Farmers knowledge of root knot nematodes damage

Soil inhabiting nematodes are considered as hidden enemy to the farmer. This is due to the difficulty in noticing their presence without trained personnel. Before their presence and damage threshold is established, it has to go through a series of process. The close association of parasitic nematodes damage to other factors makes their activities unnoticed. Divergent view exists on farmers' knowledge of root knot nematodes damage. In a survey involving 240 okra farmers, across two agro ecologies, [13] observed 84% of respondent did not manage root knot nematodes infection, an indication of the limited knowledge of the pest among farmers. Similarly, [14] observed 92% of farmers interviewed had no knowledge about the menace caused by root feeding nematodes. Similarly, [53] reported that only 18.5% of 120 maize farmers in Uganda had any knowledge on the impact of phytonemtodes. Conversely, [12] reported 30% of 120 tomato farmers interviewed had knowledge about the root pest. However, it was observed that 95% of the total farmers interviewed applied fungicides and insecticides but not nematicides. This confirms the limited information available to these farmers in nematodes management.

1.5 Root knot nematodes management options available to peri urban vegetable farmers

Root-knot nematodes will continue to pose serious threat with intensification of cropping systems in response to the increasing demand for vegetables coupled with limited land space for peri urban vegetable production. Strategies for root-knot nematodes management are generally designed to reduce population levels below damaging thresholds since eradication is a challenge under field conditions. Since young and tender seedlings of various crops are very much vulnerable to attack compared to older plants, management strategy should be targeted at the early stages of the crop and should aimed at protecting the seedlings. Several management measures are being employed to reduce the population of plant parasitic nematodes fields. The widely reported and adopted strategies are cultural, chemical and use of resistant or tolerant varieties of food crops.

1.5.1 Cultural management strategy

This strategy represents the most economical and easily available means of managing nematodes in vegetable farm. This includes options such as land and crop rotation, intercropping and fallowing. However, the limited space available and the increased demand for vegetables production hinders adoption of such strategies in Ghana. Also the adoption of such management strategies may be limited due to the wide host range of root-knot nematodes. Again, the difficulty in selecting a rotational crop with acceptable returns and similar labour requirements hinders crop rotation. Various tillage practices have been used to successfully manage these pests. Deep ploughing has been identified as an effective means of managing nematodes [39, 40], however, such tillage measure may be detrimental to soil quality and therefore sustainable crop production Inter-cropping with antagonistic plants like the African marigold (*Tagetes* spp.) has been used to reduce soil population of many soil nematodes including root-knot nematodes. The application of locally available organic materials such as poultry manure, cocoa pod husk, neem seed and leaf powder, moringa leaf, and sunn hemp residues [6, 52, 42, 41] have been used to reduced nematodes population. These materials releases toxic substances against nematodes and encourage soil microbial antagonists [43]. Apart from suppressing root-knot nematodes, the incorporation of organic materials as soil amendments also improves soil structure and encourages soil biological activities [44].

1.5.2 Chemical management strategy

Chemical control involves the application of inorganic formulations to interfere with activities of *Meloidogyne* spp. in infested soils. Nematicides are usually the most effective and quick method of managing high levels of *Meloidogyne* spp. under field conditions. They are known to reduce nematodes populations but may not completely eliminate the infection [45, 46]. Treatment of nursery bed with carbofuran (Furadan 3G) and aldicarb (Temik 10G) have been found to be successful in producing nematode free seedlings of many transplanted crops [43]. In Ghana, [26] and [54] observed decreased root-knot nematodes population after nematicide application. However, the use of nematicides is unpopular due to their toxicity to humans, residual effects in the food chain, and their contribution to environmental pollution.. These negative effects have led to their withdrawal from global and local market making them readily unavailable and expensive to small scale vegetable farmers. Also pesticides with nematicidal properties available to farmers require high doses, making them cost- ineffective. Continous application of such nematicidal pesticides leads to the development of resistance in target nematode species [47].

1.5.3 Resistant varieties

The use of resistant varieties in managing *Meloidogyne* spp. depends on target species since resistance is species specific. Several vegetable crops with resistance genes against various *Meloidogyne* spp. [48] have been developed. Tomato varieties conferring resistance to *M. incognita* (due to the *Mi-1* gene) have been developed. Some tomato genotypes with resistance to *Meloidogyne* have been reported in Ghana [25, 49, 50]. Farmers are to obtain and use resistant cultivars to reduce the cost of production. Resistant genotypes also protect the environment against pollution from chemical residues associated with nematicides.

1.6 Conclusion and recommendation

The continuous use of fields for peri-urban vegetable production has the potential to increase the population and outbreak of root-knot nematodes. Despite this threat, nematodes are mostly neglected and hardly considered in crop production and protection programmes. To adequately address this challenge, more resources needs to be channeled into research. It should aimed at surveying fields to assess and understand root-knot nematodes species identity, genetic diversity, population structure, parasitism mechanisms and the overall threat they pose [51]. Again training institutions such as the CSIR College of Science and Technology should be fully resourced with state of the art laboratories and equipment to train more professional and extension agents to bridge the knowledge gap. Farmers are encouraged to contact agricultural facilities such as the CSIR-Crops Research Institute, Kumasi where several technologies have been developed to manage parasitic nematodes. Outreaches such as the plant clinics should be carried out to educate farmers on the limiting factors of root-knot nematodes on vegetable crop production. To effectively manage these pests, management strategies should be applied in concert with integrated pest management (IPM) practices to improve adoption by farmers. With the phasing out of various effective nematicides, the search for effective and environmental friendly management methods should be pursued.

References

[1]. Ghana Statistical Services (GSS). Revised gross domestic product 2011. Accra, 2012.

[2]. O. Coffie, T. Larbi, G. Danso, S.K. Kufogbe, M. Henseler, T. Schuetz, and N. Obiri-Opareh. A narrative on peri-urban agriculture in Accra metropolis, 2005.

[3]. A.I. Adeoti, O. Coffie and O.I. Oladele. Gender Analysis of the Contribution of Urban Agriculture to Sustainable Livelihoods in Accra, Ghana. Journal of Sustainable Agriculture, 36(2), 236-248, 2012.

[4]. L.J.A. Mougeot, Urban agriculture: definition, presence, potentials and risks. In. Growing cities, growing food: urban agriculture on the policy agenda. In Bakker, N.; Dubbeling, M.; Gündel, S.; Sabel-Koschella, U.; de Zeeuw, H., (Ed.) 1-42. Deutsche StiftungfürInternationaleEntwicklung (DSE). Feldafing, Germany: ZentralstellefürErnährung und Landwirtschaft, 2000.

[5]. P. Drechsel and S. Dongus. Dynamics and sustainability of urban agriculture; examples from sub-Saharan Africa. Sustainability Science 5(1): 69-78, 2010.

[6]. Y. Danso, K. Osei, J. Adomako, J.S Asante and B. Abugri. The Impact of Organic Soil Amendments on Population Densities of Plant Parasitic Nematodes and Okra Yield. Journal of Agriculture and Ecology Research International. 6(3): 1-6, 2016.

[7]. J. Adomako and C.K. Kwoseh. Effect of castor bean (Ricinuscommunis) aqueous extracts on the performance of root knot nematodes (Meloidogynespp.) on tomato (Solanum lycopersicum). Journal of Science and Technology. 33(1). 1-11, 2013.

[8]. E.M. Onkendia, G.M. Kariukib, M. Maraisc and L.N. Molelekia. The threat of root-knot nematodes (Meloidogyne spp.) in Africa: a review. Plant Pathology. Doi: 10.1111/ppa.12202, 2010.

[9]. B. Zarina. Studies on plant parasitic nematodes of ornamental and vegetable plants with special reference to root-knot nematode. PhD Thesis (Nematology), University of Karachi, Pakistan, 1996.

[10]. J.M. Nicole, S.J.Turner, D.L.Coyne, L. Nijs, S. den Hockland and Z. TahnaMaafi. Key Nematodes Threatening Major Agricultural Crops of Importance Worldwide. In. J. Jones et al. (eds.), Genomics and Molecular Genetics of Plant-Nematode Interactions.,DOI 10.1007/978-94-007-0434-3_2, © Springer Science+Business Media B.V, 2011.

[11]. H.J. Atkinson, C.J. Lilley and P.E. Urwin. Strategies for transgenic nematode control in developed and developing world crops. Food biotechnology-plant Biotechnology, 23: 251-256, 2012.

[12]. F. Manneh, C.K. Kwoseh and J.L, Starr. Production Practices and Pest and Disease Problems of

Tomato Farmers in Ashanti Region of Ghana. Journal of Agriculture and Ecology Research International 6(3): 1-9, 2016.

[13]. Y. Danso and C. Kwoseh. Some Okra Production Decisions and Farmers' Awareness of Meloidogyne species Infection in Two Agro-ecologies, Ghana. American Journal of Experimental Agriculture, 11(5): 1-6, 2016.

[14]. K. Osei, R.K. Bam and J.S Asante. Rice production practices and farmers' perception of the white tip nematode (Aphelenchoides besseyi Christie) in Ghana. Journal of Applied Biosciences 47: 3264–3269, 2011.

[15]. K. Osei, R. T. Awuah, M. A. Tabil, and J. S. Asante. Prevalence and farmers' perceptions of parasitic nematodes in yam rhizosphere soils from some yam producing areas of Ghana. Agricultural and Food Science Journal of Ghana 3:217-226, 2004.

[16]. N.A. Mitkowski and G.S. Abawi. Root-knot nematodes. The Plant Health Instructor. DOI: 10.1094/PHII-2003-0917-01, 2003.

[17]. Horticulture Australia Limited. Management of root knot nematode in vegetable crops. Internet: www.tia.tas.edu.au, 2014.

[18]. T.K, Wong and W.F Mai. Effect of temperature on growth, development and reproduction of Meloidogyne hapla in lettuce. Journal of Nematology. 5:139-142, 1973.

[19]. J. Adomako, K. Osei, Y. Danso J.S. Asante, B. Abugri and F. Kankam. Response of five cowpea varieties to some phytonematodes under field conditions. International Journal of Plant & Soil Science 12(4): 1-5, 2016.

[20]. K. Osei, J.Y. Asibuo, A. Agyeman,, P. Osei-Bonsu, Y. Danso and J. Adomako. Reactions of some confectionery groundnut accessions to plant parasitic nematodes infection. Agrosearch (2013) volume 13(2):1-11, 2013.

[21]. O.B. Hemeng. Root-knot nematodes (Meloidogyne incognita) as serious pests of yam (Dioscorea spp.), Ghana Journal of Agricultural Science. 11: 131-13, 1978.

[22]. P.G. Addoh. The root-knot nematode problem in Ghana: host and non-host plants of Meloidogyne spp. Ghana Journal of Agricultural. Science. 3:3-12, 1970.

[23]. F.C. Peacock. The effect of crop rotation on root-knot nenatodes in the Gold Coast. Emp. expo Agric. 25:99-107, 1957.

[24]. E.E, Edwards. The root-knot eelworms on weeds and cultivated plants in the Gold Coast. Helminth. 27, 181-184, 1953.

[25]. B.K. Kwara, C.K. Kwoseh, J.L.Starr. Effectiveness of root-knot nematode (Meloidogyne species) resistant tomato (Solanum lycopersicum L.) and pepper (Capsicum species) cultivars in Ghana. Nematropica 44:130-136, 2014.

[26]. O.B. Hemeng. Efficacy of selected nematicides for control of root-knot nematodes. Pp. 52-56 in Proceedings of Research Planning Conference on Meloidogynespp. Nov. 16-20, 1981, IITA, Ibadan-Nigeria, 1981.

[27]. P. Abad, J. Gouzy, M.J. Aury, P. Castagnone-Sereno, et al. Genome sequence of the metazoan plant-parasitic nematode Meloidogyne incognita. Nature Biotechnology 26, 909-915, 2008.

[28]. D.L. Coyne, A. Tchabi, H. Baimey, N. Labuschagne, I. Rotifa. Distribution and prevalence of nematodes (Scutellonema bradys and Meloidogyne spp.) on marketed yam (Dioscorea spp.) in West Africa. Field Crops Research 96, 142-150, 2006.

[29]. G. Sidhu and J.M. Webster. Genetics of resistance in the tomato root-knot nematode-wilt-fungus complex. Journal of Heredity 65:153–156, 1974.

[30]. J.N. Sasser. Root-knot nematodes. A global menace to crop production. Plant Diseases Research, 64: 36-41, 1989.

[31]. N.T. Powell. Interactions between nematodes and fungi disease complexes. **Annual Review of Phytopathology** 9:253-274, 1971.

[32]. M.R. Khan. Nematology in developing countries; India-IMP,Region VIII. In:C. C. Carter, and J. N. Sasser, Eds. An advanced treatise on Meloidogyne Vol.1: Biology and control. Co-Publication of department of Plant Pathology North Carolina State University and the USAID, Raleigh, North Carolina, USA: Pp 379-398, 1994.

[33]. F. Kankam and J. Adomako. Influence of Inoculum Levels of Root Knot Nematodes (Meloidogynespp.) on Tomato (Solanum lycopersicumL.). Asian Journal of Agriculture and Food Science 2 (2). 171-178, 2014.

[34]. M.A. Hussain, T. Mukhtar and M.Z. Kayani. Assessment of the damage caused by Meloidogyne incognita on okra. Journal of Animal and Plant Sciences, 21, 857-861. 2011.

[35]. S.A. Anwar, A. Zia, M. Hussain and Kamran, M. Host suitability of selected plants to Meloidogyne incognita in the Punjab, Pakistan. International Journal of Nematology, 17:144-150, 2007.

[36]. C.S. Huang and J.M Charchar. Preplanting inoculum densities of root-knot nematode related to carrot yield in greenhouse. Plant Disease **66**, 1064–1066, 1982

[37]. R.A. Sikora and P.R. Fernandez. Nematode parasites of vegetables. In: M.Luc, R. Sikora, J. Bridge

(eds.). CAB. Plant Parasitic Nematodes in Subtropical and Tropical Agriculture, 2nd edition. Institute de Investigaciones de Sandidad. 2005.

[38]. S.K. Singh and R. K. Khurma. Susceptibility of six tomato cultivars to the root-knot nematode Meloidogyne incognita. The South Pacific Journal of Natural Sciences 13: 73-77, 2007.

[39]. F. Kankam and Adomako, J. Effect of tillage practices on root knot nematodes (Meloidogyne spp.) associated with maize (Zea mays). Asian Journal of Agriculture and Food Science. 2(3). 207-210, 2014.

[40]. M.A. Siddiqui and M.M. Alam. Integrated management of plant parasitic nematodes with oil cakes / nematicides and ploughing. Pakistan Journal of Nematology 17: 129-136, 1999.

[41]. E.N.K. Sowley, F. Kankam, and J. Adomako. Management of root-knot nematode (Meloidogyne spp.) on sweet pepper (Capsicum annuum L.) with moringa (Moringa oleifera Lam.) leaf powder. Archives of Phytopathology and Plant Protection, DOI: 10.1080/03235408.2013.848710. 2013.

[42]. F. Kankam, and J. Adomako**.** Efficacy of Neem Seed Powder on Root Knot Nematodes (Meloidogynespp.) Infecting Bambara Groundnut (Vigna subterranea). Asian Journal of Agriculture and Food Science 2 (2). 116-170. 2014.

[43]. M.R. Khan, R.K. Jain, T.M. Ghule, S. Pal,. Root-knot Nematodes in India; A comprehensive monograph. All India Coordinated Research Project on Plant Parasitic Nematodes with Integrated approach for their Control. Indian Agricultural Research Institute, New Delhi. pp 78, 2014

[44]. N. Nagaraju, N. Karemegam and B. Kadalmani. Eco-friendly management of root-knot nematode, Meloidogyne incognita using organic amendments on tomato. International Journal of Research Pharmacological Science, 1: 530-532, 2010.

[45]. H.C.I. Sirias. Root-knot nematodes and coffee in Nicaragua: management systems, species identification and genetic diversity, Plant Breeding. Swedish University of Agricultural Sciences. PhD thesis, 2011.

[46]. P. Strajnar and S. Širca. The effect of some insecticides, natural compounds and tomato cv. Venezia with Mi gene on the nematode Meloidogyne ethiopica (Nematoda) reproduction. Acta Agriculturae Slovenica 97, 5-10, 2011.

[47]. M.S. Blouin, C.A. Yowell, C.H Courtney and J.B. Dame. Host movement and the genetic structure of populations of parasitic nematodes. Genetics, 141, 1007-14, 1995.

[48].P.M. Norshie, T.H. Been, C.H. Schomaker. Estimation of partial resistance in potato genotypes against Meloidogyne chitwoodi. Nematology 13, 447-489, 2011.

[49]. F. Jaiteh, C. Kwoseh, C., and R. Akroma. Evaluation of tomato genotypes for resistance to root-knot nematodes. African Crop Science Journal, Vol. 20, Issue Supplement s1, pp. 41 – 49, 2012.

[50]. Y. Danso, R. Akromah and K. Osei. Molecular marker screening of tomato, (solanum lycopersicum L.) Germplasm for root-knot nematodes (Meloidogyne species) resistance. African Journal of Biotechnology Vol. 10(9), pp. 1511-1515, 2011.

[51]. M. Fargette, K. Berthier, M. Richaud, V. Lollier, P. Franck, A. Hernandez and R. Frutos. Crosses prior to parthenogenesis explain the current genetic diversity of tropical plant-parasitic Meloidogyne species (Nematoda: Tylenchida). Infection, Genetics and Evolution 10, 807-814, 2010.

[52]. K. Osei, E. Otoo, Y. Danso, J. Adomako, A. Agyeman, J. Sackey Asante. Organic soil amendments in nematode management in yam production. Nematropica. 43(1) 78-82, 2013.

[53]. F. Kagoda, J. Derera, P. Tongoona and D.L. Coyne. Awareness of plant-parasitic nematodes, and preferred maize varieties, among smallholder farmers in East and Southern Uganda: implications for assessing nematode resistance breeding needs in African maize. International Journal of Pest Management, 56, (3) 217-222. 2010.

[54]. K. Osei, S.A. Ennin, Y. Danso, E. Owusu Danquah and J. Adomako. Management of plant parasitic nematodes with fulan in mechanized yam production. African Journal of Plant Science 9(9), 346-351, 2015.