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Assessment of Nematode Distribution and Yield Losses in Vegetable Crops of Western Uttar Pradesh in India

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Abstract: ***Plant-parasitic nematode population densities were determined from 412 root and soil samples collected from vegetable growing areas of Western Uttar Pradesh province of India. The most abundant plant-parasitic nematodes detected, in order of decreasing frequency of infestation (percentage of samples), were Meloidogyne incognita (82.16%), M. javanica (68.42), Rotylenchulus reniformis (43.98%), Xiphinema basiri (23.45%), Hoplolaimus indicus (21.99%), Tylenchorhynchus nudus (16.60%), Pratylenchus zeae (15.77%), Heterodera avenae (7.88%), Aglenchus costatus (7.47%), Tylenchorhynchus mashoodi (6.64%), Aphelenchus avenae (5.39%), Discolaimus (4.15%), Boleodorus similis (3.32%), and Tylenchus (2.07%). Yield losses associated with nematode presence were quantified on 17 vegetable crops during 2012 to 2015. Based on our visual field observations and grower responses the average percentage of production losses due to nematode was 23.70% for 17 vegetable crops in Western UP, which ranged from 4% for bitter gourd to 43% for egg plants. Maximum yield loss of 43% was observed in eggplant followed by 40% in tomato, 38% in okra, 35% in bottle gourd and 32% in potato. Bitter gourd and cabbage were found to have insignificant yield losses of only 4% and 6% respectively.***

Keywords: Plant-parasitic nematodes, distribution, vegetables, yield losses, Uttar Pradesh

1. Introduction

Vegetables are important component in nutritional security, economic viability and fit well into the predominant intensive cropping systems prevailing in different parts of India. More than 60 kinds of vegetables are grown in India in tropical, subtropical and temperate agro-climates. During 2013-2014, India produced 162.19 million tonnes of vegetables and vegetable export from our country was worth Rs. 5462.93 crores. This production is still insufficient for second most populous country in the world where India shares 17.5% of global population. The land area of India is about 2.4 per cent of the total surface area of the world but we share only about 1%, in global market of horticultural products. The agricultural production in India is greatly hampered by the parasitism and predation of different pathogen and pests. Among them plant-parasitic nematodes present a formidable pest problem for different crops including vegetables, fruits, field crops, ornamentals and common weeds (Saxena & Singh, 1997; Anes & Gupta, 2014; Ngele & Kalu, 2015). Most species attack and feed on plant roots and underground plant parts. Nematodes not only suppress the plant growth but also interfere in the nodulation, nitrogen fixation and adversely affect the overall yield (Rehman *et al.*, 2012).

Root-knot nematodes, *Meloidogyne* spp. have become a major pest of almost all types of crops, impacting both quantity and quality of marketable yields in the Western Region of Uttar Pradesh. These nematodes reduce the plants ability to extract available soil water and nutrients, the result being lack of vigor and yield loss (Trudgill, 1992).

Several workers have attempted to assess crop losses caused by plant parasitic nematodes and their distribution in India. Van Berkum and Seshadri (1970) were the first to have calculated monetary losses to crops caused by nematode parasites in India. They estimated annual losses of $10 million on wheat due to 'ear cockle disease' caused by *Anguina tritici*, $ 3 million on coffee due to *Pratylenchus coffeae* and $ 8 million due to "Molya disease" caused by *Heterodera avenae* in Rajasthan province alone. Plant-parasitic nematodes cause estimated annual crop losses of $8 billion in the United States and $78 billion worldwide (Barker *et al.*, 1998). Damage caused by plant- parasitic nematodes on 24 vegetable crops in the USA was estimated to be 11% by Feldmesser *et al.*, in 1971.

The objective of this study was to quantify and document of relative occurrence, distribution, density and prevalence of different nematode populations and the yield losses they cause in associated crops cultivated in Western part of Uttar Pradesh, India.

2. Materials and Methods

2.1 Selection of Sites for Survey

A Survey was carried out to take the root and soil samples from crop fields of 118 localities of 5 districts of Western Uttar Pradesh of India at geographic location of 28.364°N 79.415°E and elevation of 268 meters. The climate of Uttar Pradesh is primarily defined as humid subtropical with dry winter and tropical monsoon suitable for different vegetable and cash crops. Seventeen vegetable crops including carrot, chilies, coriander, crucifers (cabbage and mustard), cucurbits (bitter gourd, cucumber, pumpkin, sponge gourd, melon and bottle gourd), eggplant, okra, pea, potato, spinach, and tomato from commercial fields located throughout Western UP were sampled during 2012 to 2015. Presence of nematodes in vegetable roots and soil was determined at the time of harvesting of each crop. A total of 412 root and soil samples were collected over a three year of period.

2.2 Sampling Methodology

Ten root and soil cores were randomly collected for each crop by walking in a zigzag pattern across each field with a tube of 2.5 cm diameter inserted to a depth of 18-20 cm. Soil cores were combined to represent each sampled field. Samples were packed into plastic bags, placed in a cooler for transport and then stored at 4°C until processed in the lab. Roots were separated from soil and carefully washed under tap water to remove adhering soil particles and then towel dried.

2.3 Nematode Extraction

Nematodes were extracted by following the method of McSorely (1987) from a fresh root composite sub sample of 25g by placing them in a mist chamber for 5 days. Isolated nematodes were heat killed at 60-65°C and then fixed in 4% formalin and placed in viols. Prior to counting, solution containing nematodes were agitated thoroughly and 3 ml suspension poured to a counting dish. Nematodes were counted using a stereo binocular microscope. Selected specimens for each of the recorded species were processed for dehydration by Seinhorst's (1959) rapid glycerin method and mounted on glass slides in anhydrous glycerin. Plant-parasitic nematodes were identified on the basis of morphology of adults and juveniles to genus and species using a high magnification binocular compound microscope.

2.4 Assessment of yield losses

The criteria used to assess yield loss comprised grower interviews, visual assessment based on foliage growth (necrotic, chlorotic, stunted, and wilted plants), root symptoms and educated guess to expert opinions. The number of growers interviewed was variable and ranged from 5-15 for each crop. The interview of growers included condition of the crop, quantitative and qualitative yield losses based on market value and life span of the crop. Estimates reported in this study are expressed as percentage of yield loss. All data collected were subjected to analyze statistically by using Software GraphPad Prism (version 5.0), USA.

3. Results and Discussion

3.1 Nematode survey

Fourteen species of plant-parasitic nematodes were found associated with 17 vegetable crops grown in the different field crops of Western UP (Table 1). The nematode genera found were *Meloidogyne incognita, M. javanica, Rotylenchulus reniformis, Xiphinema basiri, Hoplolaimus indicus, Tylenchorhynchus nudus, Pratylenchus zeae, Heterodera avenae, Aglenchus costatus, Tylenchorhynchus mashoodi, Aphelenchus avenae, Discolaimus, Boleodorus similis, and Tylenchus.* Five species *M. incognita, Rotylenchulus reniformis, Xiphinema basiri, Pratylenchus zeae, Heterodera avenae,* were found in all the samples, however, their frequency and density was highly variable from field to field and within the same locality. Frequency of these nematode species ranged from 82.16% to 2.07%. The two potentially damaging nematode genera identified were *Meloidogyne* and *Rotylenchulus.*

Root-knot nematode was found to infest the roots and soil of all the vegetable crops. This nematode induces severe root galling of variable size and numbers on roots of vegetables, such roots had arrested root systems with few feeder roots (personal visual observations). The most common nematode species found in this study were *M. incognita, M. javanica* and, *Rotylenchulus reniformis* which were found at the relative percent occurrence (RPO) of 82.16%, 68.42% and 43.98% respectively. Average population density of *M. incognita* was 310 individuals per 100cm^3 and 1510 per gram of soil and root, respectively, whereas the number of *Rotylenchulus reniformis* found in the root and soil were 1000 per g and 432 per cm^3, respectively (Table 1).

The migratory ectoparasitic nematodes including sting nematode, *B. longicaudatus,* spiral nematode, *H. dihystera*., lance nematode, *H. columbus,* needle nematode, *L. africanus,* stubby root nematode, *P. minor,* stunt nematode, *T. clarus* and dagger nematode, *X. indicus* have been found to be damaging nematode pests of many vegetable crops as they cause destruction of epidermis during feeding. (Cooke, 1989; McKenry *et al*., 2001)

Table 1: Relative Percent Occurrence (RPO) and Relative Density (RD) of different nematode genera in Western UP, India

S. No	Nematode species	RPO (%)	RD (%)	Nematode population densities	
				100 cm^3 of soil	Per g of root
1	*Meloidogyne incognita*	82.16	46.85	310 ± 75	1510 ± 200
2	*M. javanica*	68.42	23.12	215 ± 50	800 ± 100
3	*Rotylenchulus reniformis*	43.98	15.48	432±50	1000±20
4	*Xiphinema basiri*	23.45	4.98	12 ± 4	4±2
5	*Hoplolaimus indicus*	21.99	9.44	94±2	12±1
6	*Tylenchorhynchus nudus*	16.60	3.17	622±12	424±42
7	*Pratylenchus zeae*	15.77	5.07	322±78	212±54
8	*Heterodera avenae*	7.88	1.80	112±2	34±4
9	*Aglenchus costatus*	7.47	2.10	46±6	8±2
10	*Tylenchorhynchus mashoodi*	6.64	1.10	76±2	14±4
11	*Aglenchus avenae*	5.39	4.47	22±1	-
12	*Discolaimus*	4.15	0.80	12±4	8±2
13	*Boleodorus similis*	3.32	1.29	23±12	-
14	*Tylenchus*	2.07	1.29	95±10	-

Plant-parasitic-nematodes found associated with vegetable crops can be classified as epidermal, cortical, and vascular feeders. Epidermal feeders include *Hoplolaimus indicus, Tylenchorhynchus* spp., *H. indicus, Xiphinema basiri and Pratylenchus* zeae. These nematode species feed at or close to root tips where they arrest root elongation and disrupt the site of plant growth factors. Root hairs, a single cell extension of the epidermis, enlarge plant surface area and improve efficiency in absorbing water while also providing sites for *Rhizobium* invasion in legumes. Invasion by ectoparasitic nematodes reduces the ability of the epidermis to absorb water by pruning root hairs, by reducing rooting depth and numbers of branched roots (Anwar and Van Gundy, 1989, Endo, 1975**)**. Cortical feeders including *H. indicus*, *H. galeatus* and *Pratylenchus* sp, are migratory endoparasites. Carneiro *et al.*, (2002) reported that feeding activities result in cellular necrosis which interferes with radial transport of water and solutes and leakage of stored photosynthetic products. Vascular feeders in these studies included two species of root-knot nematode, *M. incognita* and *M. javanica*, which become sedentary endoparasites. This group of nematodes damages their hosts by redirecting large amounts of energy and nutrients from normal activities into development of the nematodes and their special feeding sites (Anwar, 1995; McClure, 1977). The altered tissues at feeding sites also disrupt the vascular system hampering the upward transport of water and dissolved nutrients by xylem and translocation of photosynthates to other regions of the plant by phloem (Hajera *et al*., 2009). Roots severely galled by root-knot nematodes can predispose plants to root rots leading to a shorter life span of the crop. These galled tissues become succulent, poorly protected from invasion, and rich in nutrients. The result is a nutrient-rich food source which fungi can rapidly colonize (Abawi and Chen, 1998). Root-knot nematode damage results in poor growth, decline in quality and yield of the crop and reduced resistance to other stresses like drought and disease. *Meloidogyne incognita* has often been reported as a damaging nematode pest of vegetable crops including recent work by these authors (Anwar and McKenry, 2010). A high level of root-knot nematode damage can lead to total crop loss. Gautam *et al*., 2014 found the Root-knot nematode infection with an overall incidence of 54.54% in five district of Chhattisgarh. Nematode damaged roots do not utilize water or fertilizers as effectively, leading to additional losses for the grower (Trudgill and Phillips, 1997). In smaller commercial and backyard settings of the Uttar Pradesh plants are often invaded by several different nematode genera and simultaneously cause damage at all three regions of a root: the epidermis, cortex and vessels. Such plants exhibit retarded growth, chlorotic leaves, delayed flower and fruit formation, susceptibility to fungal/bacterial/viral attack plus significant growth and yield reductions (Trudgill, 1992).

3.2 Assessment of Yield Losses

Based on our visual field observations and grower responses the average percentage of production losses due to nematode was 23.70% for 17 vegetable crops in western UP, which ranged from 4% for bitter gourd to 43% for egg plants (Table 2). Each of the seventeen commercially important vegetable crops planted in the western UP suffered greater losses due to nematode damage individually as well as on an average of 23.70% of all seventeen studied crops.

Multiple nematode associations appear to be causing synergistic increases in yield loss. Nematode damage experienced within relatively small-sized farms on very different soils following various cropping histories could be a major source of the greater nematode damage in the Punjab. Reliable crop loss estimates are important for establishing research, extension and budget priorities (Dunn, 1984).

Table 2: Percent yield losses in different vegetables by nematodes associated with crops in the Western UP, India

Name of the vegetable crop		**(%)Yield losses**		**Nematode invading tissue root**	
Common	Scientific Name		Epidermal	Cortical	Vascular
Bitter gourd	*Momordica charantia*	4	*Hoplolaimus indicus* *Tylenchorhynchus* spp		*Meloidogyne incognita*
Carrot	*Daucus carota*	25	*H. indicus*		*M. incognita*
Eggplant	*Solanum melongena*	43		*Pratylenchus* spp	*M. incognita*
Cucumber	*Cucumis sativus*	25	*Xiphinema basiri* *Paratylenchus* zeae	*Pratylenchus* spp.	*Meloidogyne* spp
Okra	*Hibiscus esculentum*	38	*H. indicus*	*Pratylenchus* spp.	*Meloidogyne* spp
Potato	*Solanum tuberosum*	32	*Tylenchorhynchus* spp.	*Heterodera avenae*	*Meloidogyne* spp
Pumpkin	*Cucurbita argyrosperma*	27	*Tylenchorhynchus* spp		*M. incognita*
Sponge gourd	*Luffa cylindrica*	15	*Hoplolaimus indicus*		*M. incognita*
Tomato	*Lycopersicum esculentum*	40			*M. incognita*
Watermelon	*Citrullus lanatus*	12	*Tylenchorhynchus* spp		*M. incognita*
Bottle gourd	*Lagenaria siceraria*	35	*Tylenchorhynchus* spp		*Meloidogyne* spp
Chilies	*Capsicum annuum*	20	*H. indicus*		*M. incognita*
			P.zeae		
Pea	*Pisum sativum*	20	*P. zeae*		*M. javanica*
	Coriandrum sativum	25	*H. indicus*	*Pratylenchus* spp	*M. incognita*
			P. zeae		
Cabbage	*Brassica oleracea*	6	*H. indicus*	*Pratylenchus* spp	*M. incognita*
			P. zeae		
Beet	*Beta vulgaris*	12	*H. indicus*		*M. javanica*
Bean	*Phaseolus vulgaris*	27	*H. indicus*		*M. incognita*

Specific estimates of vegetable crop losses due to *M. incognita* and *M. javanica* have ranged from 17 to 20% for eggplant, *Solanum melongena*, 18 to 33% for melon, *Cucumis melo*, 24 to 38% for tomato, *Lycopersicon esculentum*, and 25% for potatoes, *S. tuberosum* (Kathy, 2000). Ten genera of plant- parasitic nematodes other than root-knot have also been reported associated with vegetable crops, including *Rotylenchulus sps., Xiphinema sps, Hoplolaimus sps, Tylenchorhynchus sps, Pratylenchus sps, Heterodera sps, Aglenchus sps, Aphelenchus sps, Discolaimus sps, Boleodorus sps.,* Singh (1999). During a preliminary survey, several vegetable crops including bitter gourd, cabbage, carrot, chilies, cowpea, cucumber, eggplant, lettuce, melon, mustard, okra, potato, pumpkin, sponge gourd, squash and tomato were found to be infected with root-knot nematodes and other plant-parasitic nematode species (Anwar *et al.,* 2007). Nevertheless, the information on the losses inflicted by these nematodes on vegetable crops is not available in India.

Crop losses due to plant parasitic nematodes are estimated to be about 12.3% in developed nations and 14.6% in the developing countries (Sasser and Freckman, 1987). However, these early estimates of nematode damage to vegetables appear underestimated when evaluating vegetable crops in third world countries. Data from the US indicate 4.5% damage for 28 vegetable crops (McSorley *et al.*, 1987) but the estimates are 12% in India (Sehgal and Gaur, 1999). We observed 23.70% loss on 17 vegetable crops commercially grown in the Western UP. These are 80% and 46% higher compared to that of USA, and India, respectively. Each of the 13 commercially important vegetable crops planted in the Western UP suffered greater losses due to nematode damage individually as well as on an average (21%) of all 13 compared to that of planted in USA (6.23%). In vegetable production areas of developing nations like India the experience is 43% (Bhatti and Jain, 1977; Reddy, 1980, 1985) or in Sudan the estimate is 70% (Yasin, 1974) yield loss in the tomato crop due to root knot nematode.

These finding support the present work, as here also various parasitic as well as soil nematodes had been noticed affecting the plant growth of vegetable crops. Paruthi & Gupta (1985) also studied the pathogenecity of *M. javanica* on bottle gourd. Later on Netscher & Sikora (1990) investigated different species of root-knot nematode and found moderate occurrence of *M. arenaria* and severe infestation of *M. javanica* in bottle gourd crops whereas in sponge gourd, both, *M. incognita* and *M. javanica* rank highest with moderate infection of *M. javanica*.

The dominance of *M. incognita* (53.37%) in northern Uttar Pradesh including Bareilly region had also been reported by Khan *et al*., (1994). Khan & Khan (1996) reported the distribution of root-knot nematode species and race infesting vegetable crops in eastern Uttar Pradesh as 69.9% of *Meloidogyne incognita* infection.

Prior to the present work Jain (1992) and Jagpal (1997) had surveyed the nematode infestation of many other vegetables belonging to Family Solanaceae, cruciferae and Cucurbitaceae of different regions of Rohilkhand Division and reported mainly heavy infection of *M. incognita*. Jagpal (1997) has reported upto 92.33% occurrence of *M. incognita* on tomato, eggplant and okra, whereas, in the current study it ranged 82.16% to 88.33% on bottle gourd and sponge gourd respectively.

The present study provides important information to extension specialists, who can be used to create awareness among growers, it should alert the plant scientists to consider nematodes major damaging pests of crops and start searching for resistant cultivars as an option in plant-parasitic nematode management.

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