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Nematode Population Dynamics in Arid Salinated Soil under Cotton (*Gossypium hirsutum* L.) Cultivation in Uzbekistan

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ABSTRACT

The effect of seasonal change on the nematode distribution and trophic groups was investigated in a field study under cotton (*Gossypium hirsutum* cv. 'Namangan') cultivation. The total number of nematodes, trophic groups, and nematode species were different between study months in the soil, root and shoot of cotton. The change in soil temperature and moisture from April to September may be related to changes in the nematode population. Among the six trophic groups, the percentage of bacterivores in the total nematode population was 14.2%, predators 3.7%, omnivores 7.4%, fungivores 45.4%, non-parasitic plant feeders 23.6% and plant parasites 5.2% in May. During the growth season, 76 species of nematodes (from a total of 5628) were isolated from the root, shoot and soil. The highest diversity of nematodes occurred in May and the dominant genera were *Heterocephalobus* and *Aphelenchus*. Soil water availability and organic matter content positively affected the nematode population and diversity under cotton cultivation.

Keywords: arid soil, cotton, nematodes, seasonal change

INTRODUCTION

Salinization of soils and groundwater is a serious land-degradation problem in arid and semi-arid regions (Keren 2000). Indiscriminate flood irrigation with poor drainage facilities, deep plowing of marginal and naturally saline soils, overexploitation of groundwater, recycling of drainage outflows for irrigation and monocropping of high water consumptive crops (e.g. cotton) are the major factors accelerating secondary soil salinization in regions of Uzbekistan (Egamberdiyeva *et al*. 2007).

Soil biological properties are one of the most important components to evaluate the functional stability of agro-ecosystems in response to environmental degradation. They are very sensitive to environmental changes and can be used as indicators to evaluate the effect of soil degradation on agro-ecosystems (Bardgett 2005). Soil nematodes can be a tool for understanding biological mechanisms in soil because of their central role in the soil food web and link to ecological processes (Neher 2010).

Ecological factors such as seasonal change, soil physico-chemical properties, soil nutrients, moisture and temperature may influence soil nutrient content and ultimately the nematode composition (Mendoza *et al.* 2008).

Studies concerning the occurrence, distribution and diversity of nematodes have been carried out in different grasslands (Shi *et al*. 2008), desert ecosystems (Pen-Mouratov and Steinberger 2005), Antarctic dry valleys (Treonis and Wall 2005) and in normal soil conditions under various crop plants (Ettema 1998). However, little information is available on the distribution and diversity of soil nematode communities in salinated arid soils.

Therefore, the aim of this study was to evaluate the effect of seasonal change on the nematode distribution and trophic groups under cotton cultivation.

MATERIALS AND METHODS

Description of the study area and soil sampling

The study area was a conventionally tilled (0-40 cm depth) irrigated cotton (*Gossypium hirsutum* cv. 'Namangan') field affected by salinity in Sirdarya province of Uzbekistan. According to the WRB-FAO (2006) classification, the soil of the selected field was identified as Calcisol (silt loam seirozem) and was formed from loess, eluvial and proluvial parent materials. The soil was cropped with cotton monoculture for the last 50-60 years under flood irrigation without proper drainage facilities using a natural flow system. Urea, superphosphate and muriate of potash were applied at 150 to 300 kg ha^{-1} yr^{-1} as fertilizers.

On average, the soil contained 43 ± 9 g sand kg^{-1}, 708 ± 12 g silt kg^{-1}, and 250 ± 13 g clay kg^{-1}, had a cation exchange capacity of 23.6 ± 1 $cmol_+$ kg^{-1}, with 4.41% exchangeable Na and an Na absorption ratio of 0.32. The main chemical soil properties are: organic matter 0.79%; Ct 2.39%; Nt 0.07%; CO_3^{2-}-C 1.59%, Ca^{2+} 54.3 g kg^{-1}; Mg^{2+} 26.1 g kg^{-1}; K^+ 6.7 g kg^{-1}; P 1.2 g kg^{-1}; Cl^- 0.1 g kg^{-1}; Na^+ 0.8 g kg^{-1}; pH 8.0. The high concentration of Ca^{2+}, K^+ and Na^+ is associated with CO_3^{2-} and Cl^- reflecting the dominance of carbonate and chloride in saline soil.

The climate of the area is continental with a yearly average rainfall of 200 ± 36 mm and more than 90% of the total rain falling between October and May. The average minimum monthly air temperature is 0°C in January, the maximum of 37°C in July and the soil temperature ranges between -2 and 35°C. The average highest relative humidity is slightly more than 80% in January and the minimum is less than 45% in June (Egamberdieva *et al.* 2010). The combination of high temperatures and low rainfall under continental climate makes irrigation essential for crop production.

Soil samples were collected from subplots (1 m^2) under cotton cultivation in April, May, June, July, August and September 2009. Nematodes were extracted from 100 g soil sample (fresh weight) by a modified cotton–wool filter method (Liang *et al.* 2009) and from root and shoot (fresh weight) by the Coolen and De Herde (1972) method. The nematodes were expressed as the number of individuals. The trophic groups of soil nematodes characterized by feeding habits and life-history characters were assigned to: (1) bacterivores, (2) predators, (3) omnivores, (4) fungivores, (5) non parasitic plant feeders and (6) plant parasites (Yeates *et al*. 1993). Nematodes from each sample were identified to the genus level using an inverted compound microscope. All data were subjected to analysis of variance using Microsoft Excel 2007 package and standard error were calculated.

Received: 19 August, 2012. Accepted: 5 November, 2012.

Research Note

Table 1 Mean relative abundance of nematodes at different seasons during the study period.

Trophic groups	Host	April	May	June	July	August	September
Bacterivores	shoot	0	0	0	0	0	0
	root	0	4 (13 ± 2.3)	2 (4 ± 1.3)	0	0	2 (2)
	soil	15[a] (118 ± 10.4)[b]	19 (116 ± 6.6)	15 (67 ± 9.9)	10 (34 ± 3.8)	6 (20 ± 5.7)	11 (27 ± 4.9)
Predators	shoot	0	0	0	0	0	0
	root	0	0	0	0	0	0
	soil	7 (33 ± 6.6)	7 (31 ± 4.3)	2 (4 ± 0.5)	3 (8 ± 2.0)	0	3 (5 ± 0.5)
Omnivores	shoot	0	5 (3 ± 0.5)	0	0	0	0
	root	0	1 (3 ± 0.5)	0	0	0	0
	soil	1 (58 ± 11.0)	0 (61 ± 12.1)	1 (12 ± 0.5)	1 (7 ± 0.5)	1 (4 ± 0.5)	1 (7 ± 0.5)
Fungivores	shoot	0	7 (37 ± 7)	9 (32 ± 0.5)	3 (9 ± 0.5)	0	2 (2)
	root	0	17 (195 ± 16.7)	7 (29 ± 1.1)	8 (31 ± 3.7)	2 (3 ± 0.5)	3 (7 ± 1.2)
	soil	16 (174 ± 13.4)	22 (371 ± 36.3)	16 (112 ± 1.7)	14 (123 ± 11.5)	14 (56 ± 5.7)	18 (94 ± 5.7)
Non parasitic plant feeders	shoot	0	4 (30 ± 5.7)	3 (6 ± 0.5)	1 (3 ± 0.5)	0	2 (3 ± 0.5)
	root	0	5 (129 ± 8.0)	6 (42 ± 6.4)	2 (2)	0	3 (6 ± 0.3)
	soil	8 (188 ± 10.4)	12 (193 ± 8.5)	10 (125 ± 7.0)	8 (63 ± 14.0)	4 (17 ± 7.0)	6 (31 ± 10.0)
Phyto-parasites	shoot	0	1 (1)	2 (3 ± 0.5)	0	0	2 (2)
	root	0	4 (563 ± 8.6)	4 (649 ± 9.5)	1 (554 ± 77.6)	2 (421 ± 92.5)	1 (522 ± 81.7)
	soil	4 (23 ± 0.5)	7 (43 ± 0.5)	7 (44 ± 10.0)	3 (41 ± 15.3)	3 (8 ± 2.5)	1 (2)

[a] number of genera, [b] number of individuals (100 g soil, 10 g fresh root and shoot)

Table 2 Mean relative abundance (%) of soil nematode taxa at different seasons during the study period.

Months	Samples			Air temp. (°C)	Soil temp. (°C)	Moisture
	Shoot	Root	Soil			
Aprel	0	0	51 (594 ± 3.2)	24.5^0	22.2^0	4.8
May	17[a] (71 ± 1.4)[b]	31 (903 ± 3.5)	67 (817 ± 8.7)	32.0^0	24.8^0	5.0
June	14 (41 ± 2.8)	19 (724 ± 1.8)	51 (364 ± 0.4)	36.9^0	21.3^0	4.9
July	4 (12 ± 2.5)	11 (587 ± 1.4)	39 (276 ± 1.9)	37.5^0	29.5^0	3.9
August	0	4 (424 ± 2.5)	28 (105 ± 0.4)	39.0^0	29.7^0	3.4
September	6 (7 ± 0.4)	9 (537 ± 0.4)	40 (166 ± 2.5)	28.0^0	21.9^0	5.1

[a] number of genera, [b] number of individuals (100 g soil, 10 g fresh root and shoot)

RESULTS

The total number of nematodes was different between study months in soil, shoot and root of cotton (**Table 1**). The maximum number of nematodes in soil, shoot and root reached maximum values in May (816 ± 68.3, 71 ± 13.2 and 903 ± 36.1, respectively) (**Table 1**). Moreover, the maximum number of nematodes (ranging between 424 and 903 individuals) was observed in cotton roots. No nematodes were found in cotton shoots during April and August samples and were generally lower than in other months.

In May, the percentage of bacterivores in the total nematode population was 14.2%, predators 3.7%, omnivores 7.4%, fungivores 45.4%, non-parasitic plant feeders 23.6% and plant parasites 5.2%.

The percentage of bacterivores in the total nematode population ranged from 12.1 to 19.8%, with a lower percentage in July (12.1%) and a higher percentage of the total population in April (19.8%) and August (19.0%). Throughout the seasonal sampling, fungivores represented 53.3 and 56.6% of the total nematode population for August and September, respectively.

The percentage of plant parasites was maximum in August (99.2%) and unchanged in July and September (94.3 and 97.2%, respectively). The number of non-plant parasitic nematodes was lower in August and September, varying between 16 and 18%. The predators were found in the soil to be the least dominant trophic group, with 5.5, 3.7, 1 and 2.8% of the total extracted nematode population for April, May, June and July, respectively.

During the growth season, 76 species of nematodes (from a total of 5628) were isolated from the root, shoot and soil. 4 species belonging to the genera *Enoplida* (total 31, 0.6%), *Monhisterida* – 1 species (total 8, 0.01%), *Arealaimida* – 1 (total 5, 0.09%), *Dorylaimida* – 21 (total 315, 6%), *Rhabditida* – 26 (total 1425, 25.3%), and *Tylenchida* – 23 (total 3844, 68%) (**Table 2**).

Among bacteriovores, dominant genera were identified as *Acrobeles*, *Cephalobus*, *Diphtherophora*, *Eumonhystera*, *Eudorylaimoides*, *Heterocephalobus*, *Dorylaimellus*, *Tylocephalus* and *Tylenchus*. The group of predators included *Discolaimus*, *Longidorus*, *Mesodorylaimus* and *Nygolaimus*. The non-parasitic nematodes found included *Aphelenchus* and *Aphelenchoides*. The dominant genera such as *M. incognita*, *Ditylenchus dipsaci*, *Boleodorus thylactus*, *Neotylenchus abulbosus*, *Helicotylenchus multicinctus*, *Criconemella* sp., *Pratylenchus pratensis* were found among parasitic phytonematodes. Among fungivores, *Aprutides*, *Ditylenchus*, *Nothotylenchus*, *Tylencholaimus* occurred in each of the seasons and among omnivores, *Chromadora*, *Labronema* and *Prodorylaimus*.

A higher diversity of nematodes occurred in May, dominated by *Heterocephalobus* and *Aphelenchus*. When air and soil temperature reached 29 and 39°C, respectively in August, the number and diversity of nematodes decreased. *Heterocephalobus filiformus*, *Eucephalobus cornis*, *Cephalobus persegnis*, *Ditylenchus dipsac* and *Aphelenchus avenae* were dominant in those months.

DISCUSSION

Nematodes in an agro-ecosystem are potential bio-indicators due to their diversity and their relationships with soil processes (Yeates *et al.* 1999). We observed that the nematode community was affected mainly by seasonal changes in the patchiness of soil moisture availability and soil temperature. Similar results were observed by Cadet *et al.* (2003) and Tong *et al.* (2010) who showed the existence of a complex interaction between soil moisture and temperature that may influence nematode trophic groups, density and abundance.

According to Neher and Blair (1997), the change in moisture and temperature may prevent nematodes from persisting in the soil. Among the trophic groups, plant parasites were the most numerous, followed by fungivores, non-parasitic plant feeders, bacteriovores and omnivores, while predators were the least abundant trophic group. This is in agreement with data referring to Spanish Mediterranean grasslands (Urzelai *et al.* 2000) and a semi-arid zone in West-Africa (Pate *et al.* 2000), in which predators represented a small proportion of the community. Bacterivorus and fungivorus had a good contribution to overall density, a feature commonly shared by nematode communities from dry soils (Griffiths *et al.* 1995). The high abundance of fungal and bacterial feeding nematodes could also be attributed to colonization of cotton roots by large numbers of bacteria and fungi (Feng *et al.* 2003; Koening and Barker 2004).

Karuri *et al.* (2010) also found that bacterial, fungal feeding and parasitic nematodes were the most abundant trophic groups across provinces of Kenya.

Soil temperature also effects the nematode population and diversity (Bakonyi and Nagy 2000). In our observation, a higher favourable temperature resulted in an increase in the number and diversity of soil nematodes. This was also reported by Stamou *et al.* (2005) for Mediterranean soil nematodes, where the effect of temperature on the nematode community appeared to be much more pronounced in dry than in wet plots. The most important finding from the analysis of trophic structure was a gradual increase in plant parasites in the roots of cotton in all months, while an exact opposite trend was revealed in the case of bacteriovores, omnivores and predators. The studied soil had been cropped to cotton monoculture for the last 50-60 years under flood irrigation without proper drainage facilities using a natural flow system. According Wasilewska (1997), the high abundance of phytoparasites and especially the strong dominance of a few species among them occurred in long-term monocultures and was related to environmental degradation. In our observation, nematode richness (number of genera) was lower in April and August than in May and June. According to Tsiafouli *et al.* (2007), more nematode genera were found as organic management increased.

The higher diversity of nematodes occurred in May and the dominant genera were *Heterocephalobus* and *Aphelenchus*. That is in agreement with the findings of Liang *et al.* (2005) and Zolda (2006), who observed the most dominant nematode genera to be *Aphelenchus* and *Acrobeloides* under various agricultural practices and crops. In our study the dominant genera such as *M. incognita, Ditylenchus dipsaci*, *Boleodorus thylactus*, *Neotylenchus abulbosus*, *Helicotylenchus*, *Criconemella* sp., and *Pratylenchus* were found among parasitic phytonematodes. *Helicotylenchus* was also found in high abundance by Yeates *et al*. (1999) in asparagus cultivation where mineral fertilizers were applied. Similar results were found by Vestergård (2004) in which the number of *Helicotylenchus* was stimulated by N-fertilization. According to Zhang *et al*. (2012), the soil C:N ratio, microbial biomass carbon, and pH are important factors affecting soil nematode communities.

The results of this study show that soil water availability and organic matter content positively affect the nematode population under cotton cultivation. The distribution of nematodes was higher in the root system of cotton, whereas a higher diversity of nematodes occurred in the soil of root zone.

ACKNOWLEDGEMENTS

The authors wish to thank the Australian Government for funding provided to GGD.

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