Original Research Article

Inventory of parasitic nematodes associated with cotton in Burkina Faso

ABSTRACT:

Aims: An inventory of parasitic nematodes associated with cotton was carried out during the 2017-2018 wet season in the major production areas in Burkina Faso.

Study Design: Indeed, the cotton plant is attacked by a large number of pests, including plant parasitic nematodes, which are observed at high population levels in the country's main cotton-growing areas.

Place and Duration of Study: The study was conducted in Burkina Faso, for the Institute of Environment and Agricultural Research, Farako-Bâ station for twelve months.

Methodology: A total of 94 samples of roots and adjoining soils were taken and nematodes were extracted from 250 cubic centimeters (cc) of soil using the Seinhorst elutriator method. The nematodes present in the roots were extracted by the Seinhorst sprinkler method. Population densities were expressed in terms of number of nematodes/dm^3 of soil and number of nematodes/g of roots.

Results: About ten (10) genera of plant-parasitic nematodes have been identified and are represented by *Meloidogyne, Pratylenchus, Helicotylenchus, Scutellonema, Tylenchorhynchus, Telotylenchus, Rotylenchulus, Xiphinema, Criconemella* and *Paratrichodorus*. Under the conditions of Burkina Faso, five (5) nematodes can be considered as being able to cause yield losses on cotton, namely *Helicotylenchus, Scutellonema, Tylenchorhynchus, Pratylenchus and Telotylenchus* because they are frequent and abundant with frequencies between 100% and 36% for densities varying between 7,328 and 1,360 nematodes/dm^3 of soil.

Conclusion: On the other hand, the nematodes *Meloidogyne* and *Rotylenchulus* as major pests of cotton throughout the world have been observed at low frequencies but at often high levels of population abundance, which suggests that their development requires particular soil and soil moisture conditions.

Keywords: cotton; parasitic nematode; abundance; frequency; Burkina Faso

1. INTRODUCTION

Agriculture employs more than 80% of the population of Burkina Faso and contributes nearly 40% to the Gross Domestic Product (GDP). It is essentially rainfed agriculture and cotton

Comment [1]: Capitalised "c"

Comment [2]: Capitalised c

Comment [3]: Rewrite in active voice

Comment [4]: Replace with "primary"

Comment [5]: Rewrite in active voice

Comment [6]: Rewrite in active voice

Comment [7]: Rewrite in active voice

Comment [8]: Insert a coma

Comment [9]: Delete the words

Comment [10]: Rewrite the sentence in active voice

Comment [11]: Rewrite in active voice

Comment [12]: Rewrite in active voice

Comment [13]: Capitalised n

Comment [14]: Capitalised n

Comment [15]: Rewrite in active voices

Comment [16]: Rewrite in active voice

Comment [17]: Capitalised c

Comment [18]: Delete the words

Comment [19]: CAPITALISED C

occupies an important place because the crop employs nearly 4 million people and contributes more than 4% to GDP and about 14% of export earnings in recent years [1]. The area sown in 2016-2017 was estimated at nearly 740,000 ha and the production estimated at nearly 683,000 tons of seed cotton with relatively low yields of less than one ton per hectare [2]. The cotton sector has experienced a significant decline in recent years with a production of 407,308 tons with yields of 655 kg/ha during the 2022-2023 agricultural season [3]. This situation can be explained, among other things, by uncertain climatic conditions (rainfall and temperature) and damage due to crop pests [3]. Finally, the intensification of agricultural production in the cotton-growing area has favored the development of pests and diseases and the destruction of the many useful auxiliary organisms present in the soil [4]. Indeed, the cotton plant is attacked by a large number of pests, including plant-parasitic nematodes, which are observed at high population levels in the country's main cotton-growing areas. However, significant losses due to this group of pests, and particularly to the root-knot nematodes *Meloidogyne incognita*, have been reported on cotton throughout the world ([5]; [6]). [7] have noted that the genera *Helicotylenchus, Pratylenchus, Hoplolaimus, Rotylenchulus* can be considered as the most important and likely to cause yield losses on cotton. *Meloidogyne incognita* and *Rotylenchulus reniformis* are considered to be the major pests limiting cotton yield in the United States of America [8]. Cotton is known to be heavily attacked by the root-knot nematodes Meloidogyne spp. with yield losses of up to 60% for population densities of 1,000 nematodes/100 cm^3 of soil estimated as a threshold of harmfulness ([9]; [10]; [11]). M. incognita is one of the world's largest loss nematodes with estimated annual losses of US$100 billion on crops [12] and US$283 million on cotton in the United States of America ([13]; [8]).

Comment [20]: Rewrite as 'occupy"

Comment [21]: Rewrite in active voice

Comment [22]: Insert coma

Comment [23]: Insert the word "was"

Comment [24]: Replace the words with "producing"

Comment [25]: Replace with 'beneficial"

Comment [26]: Rewrite in active voice

Comment [27]: Replace the word with "many"

Comment [28]: Rewrite in active voice

Comment [29]: Capitalised c

Comment [30]: Rewrite in active voices

Comment [31]: Insert the word with 'and"

Comment [32]: Rewrite in active voice

Comment [33]: Capitalised c

Comment [34]: Rewrite in active voice

Comment [35]: Capitalised c

Comment [36]: Rewrite in active voice

Comment [37]: Italicised

Comment [38]: Replace with "most significant"

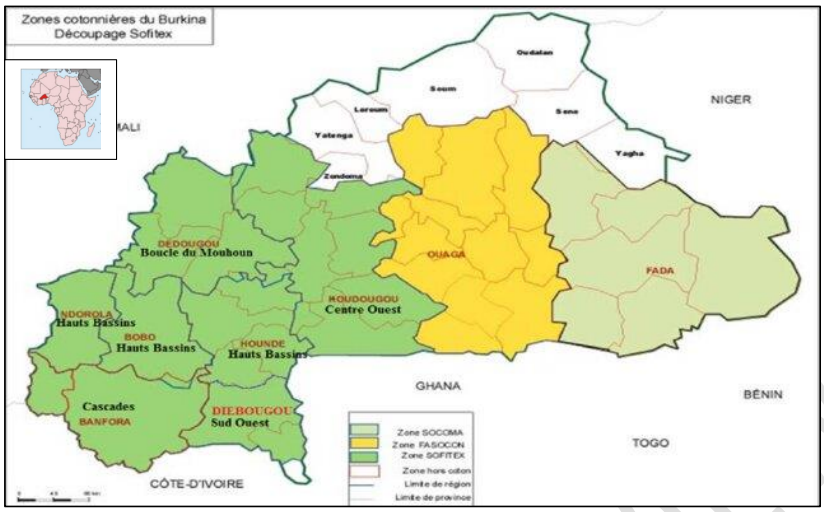
Comment [39]: Add coma

Comment [40]: Capitalised c

2. MATERIAL ET METHODS

The inventory of cotton parasitic nematodes concerns the three cotton-growing areas represented by the Société des Fibres Textiles (SOFITEX), the Société Cotonnière du Gourma (SOCOMA) and Faso Coton, during the 2017-2018 agricultural campaign (Map 1).

Comment [41]: add coma



Map 1: Cotton-growing areas of Burkina Faso (**Source**: Updated by Edouard Idrissa Rachid Sanou, PhD 2019)

The composite sample consisted of 10 samples of roots and adjoining soils in the horizons 0 - 20 cm were collected for seed production fields at the capsulation-early maturity stage. A total of 94 samples of roots and adjoining soils were taken and nematological analyses were carried out at the Nematology Laboratory of the Institute of Environment and Agricultural Research (INERA), Farako-Bâ/Bobo-Dioulasso Station. Nematodes were extracted from 250 cubic centimeters (cc) of soil using the [14] elutriator method. The nematodes present in the roots were extracted by the sprinkler method [15]. Population densities were expressed in terms of number of nematodes/dm3 of soil and number of nematodes/g of roots. The data analysis focused on the frequency and abundance of parasitic nematode populations recorded. Frequency is calculated as the total number of samples where the nematode is present divided by the total number of samples collected multiplied by 100.

Comment [42]: delete

Comment [43]: Insert the word " horizon"

Comment [44]: delete

Comment [45]: Rewrite in active voices

Comment [46]: Rewrite in active voice

Comment [47]: Rewrite in active voice

Comment [48]: Rewrite in active voice

Comment [49]: Rewrite in active voice

Comment [50]: Capitalised n

Comment [51]: Capitalised n

$$\textbf{Frequency F} = \frac{e}{n} \times 100$$

e = number of samples where the nematode considered is present

n = Total number of samples

Abundance is calculated by the sum of the samples where the nematode is present divided by the number of samples.

Comment [52]: Rewrite in active voices

$$\textbf{Abundance A} = \frac{\sum Xi}{n}$$

Xi = Number of individuals of the nematode per dm3 of soil or per gram of roots

n = Number of samples where the nematode under consideration is present

The importance of the main genera of nematodes parasitic on cotton is determined according to the method of [16] which proposed that a nematode is said to be abundant in the soil, if the abundance is ≥ 200 individuals/dm3 of soil and in the roots if the abundance is ≥ 20 individuals/g of roots. A nematode is said to be common in soil or roots, if it is observed in at least 30% of the samples. Statistical analyses were performed with the XLSTAT 2016 software and the separation of the means according to the Newman Keuls test.

Comment [53]: Capitalised c

Comment [54]: Add coma

Comment [55]: Replace with "share"

Comment [56]: Rewrite in active voice

Comment [57]: Rewrite in active voice

3. RESULTS AND DISCUSSION

3.1. RESULTS

3.1.1. Frequency and abundance of observed nematodes

About ten genera of parasitic nematodes are associated with the cotton plant and are represented by *Meloidogyne, Pratylenchus, Helicotylenchus, Scutellonema, Tylenchorhynchus, Telotylenchus, Rotylenchulus, Xiphinema, Criconemella* and *Paratrichodorus* (Table 1).

Comment [58]: Rewrite in active voice

3.1.2. Nematodes extracted from soil samples

Helicotylenchus, Scutellonema, Tylenchorhynchus, Pratylenchus and *Telotylenchus* are considered frequent and abundant with frequencies between 100% and 36% for densities varying between 7,328 and 1,360 nematodes/dm^3 of soil. According to the method of [16], this group of nematodes can be considered as the most important on cotton and likely to cause significant damage (frequency >30% and abundance <200 nematodes/dm^3 of soil). *Xiphinema, Rotylenchulus* and *Meloidogyne* are infrequent (<30%) but abundant (<200 nematodes/soil dm3) and their presence may be associated with particular environmental conditions (soil texture, humidity, etc.). *Paratrichodorus Minor* and *Criconemella onoensis* are uncommon (<30%) and not very abundant (<200 nematodes/dm^3 of soil) and can be considered as little damage to cotton.

Comment [59]: Rewrite in active voice

Comment [60]: Rewrite in active voice

Comment [61]: Capitalised c

Comment [62]: Capitalised f

Comment [63]: Add coma

Comment [64]: Add coma

Comment [65]: Capitalised c

3.1.3. Nematodes extracted from the roots

Pratylenchus is observed in 73% of the samples with root population densities of 30 nematodes/g of roots; This nematode is considered to be frequent and abundant (frequency >30 and abundance >30%) and can be considered as a parasite of cotton according to the method of [16]. The nematodes *Scutellonema* and *Helicotylenchus* are infrequent (>30%) and scarce (<20 nematodes/g of roots). This group of nematodes is considered mainly as ectoparasites and therefore little observed in the roots.

Comment [66]: Replace with "viewed"

Comment [67]: Capitalised c in all words 'cotton"

Table 1: Frequency and densities of nematode communities observed on cotton

Nematode genera	Frequency	Minimum	Maximum	Average	standard error
Extracted from soils	(%)	Nber N/dm^3	Nber N/dm^3	Nber N/dm^3	Nber N/dm^3
Helicotylenchus	100	40	37,040	7,328	± 781
Scutellonema	100	60	4,800	1,133	± 107
Tylenchorhynchus	75	0	7,560	464	± 117
Pratylenchus	71	0	4,940	584	± 93
Telotylenchus	36	0	1,360	121	± 27
Xiphinema	26	0	380	25	± 781
Rotylenchulus	19	0	1,460	41	± 18
Meloidogyne	13	0	200	7	± 3
Paratrichodorus	9	0	120	6	± 2
Criconemella	3	0	20	1	± 0
Extracted from roots	(%)	Nber N/g	Nber N/g	Nber N/g	Nber N/g
Pratylenchus	73	0	30	3	± 1
Scutellonema	14	0	7	1	± 0
Helicotylenchus	27	0	14	1	± 0

Legend: Nber/dm^3: number of nematodes/dm^3 of soil; Nber/g: number of nematodes/g of roots

3.1.4. Nematode community densities by cotton-growing areas and prospecting localities

The nematode samples were taken in the 3 cotton-growing areas represented by the cotton companies SOFITEX (18 sites), SOCOMA (7 sites) and Faso Coton (7 sites).

The high population densities of *Pratylenchus* are observed in the SOFITEX zone with 1,029 nematodes/dm^3 of soil with the highest densities observed on the Sarba site with 2,960 nematodes/dm^3 of soil (P<0.05). Respective population densities of 350 and 187 individuals/dm^3 of soil are observed respectively in the SOCOMA and Faso Coton zones. The cotton-growing area of SOCOMA appears to be more infested with Helicotylenchus (1,0408 individuals/dm3 soil), *Scutellonema* (1,546/dm^3 soil), *Tylenchorhynchus* (243/dm^3 soil) and Telotylenchus (264/dm^3 soil) (P<0.05), representing, with *Pratylenchus*, the group of nematodes likely to cause significant damage to cotton. The SOFITEX zone appears to be less infested for these nematodes, compared to the Faso Coton zone except for *Helicotylenchus* with an average density of 7,239 individuals/dm^3 of soil. The highest population densities of Helicotylenchus were observed at the Dédougou site with 29,600 individuals/dm^3 of soil in the SOFITEX zone and at the Gongongwana/Pama site with 25,280 individuals/dm^3 of soil in the Faso cotton zone. The total population densities of all parasitic nematodes observed in soil samples are higher in the SOCOMA zone with 12,911 individuals/dm^3 of soil (P<0.05). In the SOFITEX zone, the total soil populations are estimated at 9,583 nematodes/dm3 of soil and 6,624/dm^3 of soil in the Faso Coton

Comment [68]: Rewrite in active voice
Comment [69]: Replace with "three"
Comment [70]: Add coma
Comment [71]: Rewrite in active voice
Comment [72]: Add coma
Comment [73]: Add coma
Comment [74]: Delete the words
Comment [75]: Add coma
Comment [76]: Add coma
Comment [77]: Add coma

zone. Total populations of root-extracted nematodes are relatively low across cotton-growing areas with less than 10 nematodes/g of roots.

Table 2: Population densities of the main parasitic nematodes according to cotton-growing areas and sampling sites

Comment [78]: Replace with "leading"

Cotton-Zone	Location	Pray/dm^3	Heli/dm^3	Scute/dm^3	Tyle/dm^3	Telo/dm^3	Tot/dm^3	Tot/g rac.
	Satiri	4,680	3,360	680	560	0	9,280	12
	Sara	1,160	10,030	650	180	0	12,070	5
	Bondokuy	1,180	3,755	1,030	55	0	6,140	7
	Ouarkoye	1,193	4,267	587	67	0	6,307	5
	Dédougou	0	29,600	800	80	0	30,560	1
	Dara	847	3,167	733	207	0	4,960	1
	Boron	700	10,640	1,180	180	0	12,940	1
	Tcheriba	900	6,040	340	340	0	7,640	2
SOFITEX	Bognounou	380	3,180	880	100	0	4,620	3
	Lon	1,345	4,250	915	90	25	6,675	7
	Tabou	1,090	3,390	1,273	170	203	6,243	2
	Sarba	2,960	10,920	1,720	40	280	16,600	4
	Bafor	45	6,290	1,280	170	0	7,810	4
	Klesso	1,320	3,140	420	0	120	5,160	4
	Soumousso	260	5,380	1,820	180	260	7,940	7
	Gnafogo	150	8,720	1,030	60	110	10,110	1
	Noumoudara	193	5,527	733	53	20	6,600	3
	Tapoko	120	8,640	1,860	20	0	10,840	1
Average		**1,029**	**7,239**	**996**	**142**	**57**	**9,583**	**4**
	Kouaré	749	7,832	335	886	349	10,194	7
	Niendouga	270	7,410	590	80	460	8,830	26
	Gongongwana	25	25,280	2,205	45	435	28,560	1
SOCOMA	Diapangou	80	17,100	1,330	260	20	18,830	4
	Dourtenga	327	1,660	1,393	147	60	3,593	2
	Tangonko	7	973	3,800	173	433	5,400	9
	Koghin	990	12,600	1,170	110	90	14,970	3
Average		**350**	**10,408**	**1,546**	**243**	**264**	**12,911**	**7**
	Gonbloré V6	67	1,567	247	4,793	0	6,680	1
	Gonbloré V7	0	1,560	100	4,640	0	6,300	0
	Gnangdin	0	7,707	2,107	7	0	9,820	1
Faso coton	Bittou	100	3,090	870	150	70	4,280	1
	Zekeze	900	5,967	1,740	20	0	8,647	2
	Ouadav1	200	260	3,560	0	0	4,020	1
	Kaïbo Sud	45	4835	1,085	648	8	6,620	1
Everage		**187**	**3,569**	**1,387**	**1,465**	**11**	**6,624**	**1**

Legend : Praty. : *Pratylenchus* ; Heli : *Helicotylenchus* ; Scute : *Scutellonema*
Tyle : *Tylenchorhynchus* ; Telo : *Telotylenchus ;* Tot : Total in soil and roots

3.2. DISCUSSION

The results of this study, which covered all major areas of Burkina Faso, are in line with the work of [7] which had identified *Helicotylenchus*, *Pratylenchus*, *Hoplolaimus*, *Tylenchorhynchus*, *Rotylenchulus* and *Meloidogyne* as the main nematodes associated with the cotton-maize-sorghum cropping system in the cotton basin of the Houndé zone in western Burkina Faso. This study did not make it possible to rule on the pathogenicity of the root-knot nematodes *Meloidogyne* spp. on cotton, unlike several studies conducted in the major production areas of the United States and South Africa where *Meloidogyne incognita* race 3 is known to cause significant damage [17]. *M. incognita* (Cophoid and white), Chitwood and *Rotylenchulus reniformis* (Linford and Oliveira) are identified as major yield-limiting pests of upland cotton [18]. *M. incognita* is considered to be the nematode causing yield losses on a global scale on crop plants [12]. Our research in the main cotton-growing areas of Burkina Faso shows that the root-knot nematodes *Meloidogyne* spp. do not constitute a major problem because they are observed at low frequencies (13%) and at average densities of 7 nematodes/dm^3 of soil. Studies on the pathovars of *Meloidogyne incognita*, recognized as the dominant species, would make it possible to decide on its pathogenicity. However, *M. acronea*, which is known to be a parasite on cotton and present in South Africa and Malawi, is not present in Burkina Faso [19]. The present study showed a predominance of the lesion nematode *Pratylenchus brachyurus* in the SOFITEX zone, a former cotton production area in western Burkina Faso ($P<0.05$) where cotton is generally in rotation with maize, the preferred host plant of this group of nematodes. Its abundance in this area confirms its adaptation to this culture. The lesion nematode *Pratylenchus* is known to cause significant damage to cotton and [20] have shown that the presence of *P. brachyurus* would induce a decrease in *Meloidogyne incognita* populations. Similar competition has been observed between *Meloidogyne incognita* and *Rotylenchulus reniformis*. As for the kidney-shaped nematode *Rotylenchulus reniformis*, it is known as an important pest of cotton throughout the world mainly in soils with a high silt/clay content ([17]; [21]). This species may pose a danger to cotton in Burkina Faso where it is observed in high populations but limited to a few sites with 1,460 nematodes/dm3 of soil. The species has experienced a strong expansion in the southern United States where it causes significant damage and losses to cotton ([22]; [8]). Several ectoparasitic nematodes have been identified on cotton, mainly in the major cotton-producing states of the United States of America, but their pathogenicity has not been demonstrated. These are mainly *Helicotylenchus*, *Paratrichodorus minor*, *Tylenchorhynchus* spp. but with very low population levels (less than 100 nematodes/100cm^3 of soil or less than 10/dm^3 of soil) ([23]; [24]). On the other hand, other studies have shown high densities of these groups of nematodes, which are often considered secondary but likely to cause yield losses on cotton ([25]; [26]). The high populations of the nematodes

Comment [79]: Replace with “primary”

Comment [80]: Replace with “three’

Comment [81]: Add coma

Comment [82]: Replace with ‘significant”

Comment [83]: Delete

Comment [84]: Insert “is”

Comment [85]: Add coma

Comment [86]: Add coma

Comment [87]: Insert “is”

Comment [88]: Replace with “substantial”

Comment [89]: Add coma

Comment [90]: delete

Comment [91]: Replace wit “causing”

Comment [92]: Rewrite in active voice

Comment [93]: Replace with “central”

Comment [94]: Replace the words with “mostly”

Comment [95]: Capitalised b

H*elicotylenchus, Scutellonema, Tylenchorhynchus* and *Telotylenchus annulatus* observed on cotton can cause significant damage to this crop under the conditions of Burkina Faso.

4. Conclusion

About ten genera of parasitic nematodes are associated with cotton in Burkina Faso, seven (7) of which can be considered as likely to cause yield losses on cotton in Burkina Faso. These are *Meloidogyne, Pratylenchus, Helicotylenchus, Scutellonema, Rotylenchulus, Tylenchorhynchus* and *Telotylenchus*. The nematodes *Meloidogyne* and *Rotylenchulus*, known as major pests of cotton throughout the world, have been observed at low frequencies but often at high population levels, suggesting their development in particular soil and soil moisture conditions. In perspective, it will be a question of identifying the existence of races of nematodes belonging to the species *Meloidogyne javanica* and *M. incognita* by molecular characterization that can attack cotton in Burkina Faso.

Comment [96]: Replace the words with 'are'

Comment [97]: Delete the words

Comment [98]: Replace with 'cotton pests"

4. REFERENCES

[1] - **AICB. 2023a.** Rapport du Burkina Faso. 81ème Assemblée Plénière du Comité Consultatif International du Coton. Mumbai, 02 au 05 décembre 2023. 8p.

[3] - **AICB. 2023b.** Campagne cotonnière 2023-2024 au Burkina Faso. Ministère de l'Industrie, du Commerce et de l'Artisanat. ttps://www.commerce.gov.bf/accueil/actualites.

[2] **AICB. 2008.** Note d'information sur la filière coton du Burkina. 10p.

[4] - **Berimey M. A., 2012.** Contrôle des nématodes et des symphyles, parasites des racines de l'ananas par l'utilisation de plantes de service. Master En Sciences – Technologies –Sante, Université Des Antilles Et De La Guyane. 30p

[5] - **Taylor AL., Sasser J.N. and Nelson L.A., 1982.** Relationship of climatic and soi1 characteristics to geographical distribution of nematode species in agricultural soils, Raleigh, North Carolina State University and USAID, NC., 65 p.

[6] - **Pages S.L.J., 1983.** Biolgoical studies of the African cotton root nematode, *Meloidogyne acronea*. Ph.D thesis, University of London., 294 p.

[7] - **Sawadogo A., Dakouo D., Konaté Y. A. & Thio B. 1998-1999.** Les nématodes parasites associés au système de culture coton-maïs-sorgho dans la zone de Houndé (Ouest du Burkina Faso). *Sci. et Tech., Série Sciences Naturelles*, Vol. 23, n° 2 - juillet-décembre 1998 - Janvier - juin 1999.

[8] - **Lawrence K., 2022.** Reniform nematode (*Rotylenchulus reniformis*) and its interactions with cotton (Gossypium hirsutum) Pp. 94-99 in R. A. Sikora, J. Desaeger, and L. Molendijk, eds. Integrated nematode management: state of-the-art and visions for the future. Oxfordshire, UK: CAB International. doi:10.1079/9781789247541.0014.

[9] - **Blasingame D., Gazaway W., Goodell P., Kemerait R., Kirkpatrick T., Konning S., Lawrence G. W., McClure M., Mueller J., Newman M., Overstreet C., Phipps P., Rich J., Thomas S., Wheeler T. and Wrather A. 2002.** Cotton nematodes: your hidden enemies National Cotton Council, Memphis, TN.

[10] - **Doshi R. A., King R. L. and Lawrence G. W.. 2010.** Classification of *Rotylenchulus reniformis* numbers in cotton using remotely sensed hyperspectral data on self-organizing maps. *Journal of Nematology* 42:179–193.

[11] - **Moore S. R. and Lawrence K. S. 2012.** *Rotylenchulus reniformis* in cotton: current methods of management and the future of site-specific management. *Nematropica* 42:227–236.

[12] - **Wram, C. L., and Zasada, I. A. 2019.** Shortterm effects of sublethal doses of nematicides on Meloidogyne incognita. *Phytopathology* 109:1605- 1613. doi:10.1094/phyto-11-18-0420.

[13] - **Forghani, F., and Hajihassani, A. 2020.** Recent advances in the development of environmentally benign treatments to control root-knot nematodes. *Frontiers in Plant Science* 11:1125. doi:10.3389/fpls.2020.01125.

[14] - **Seinhorst J.W., 1962.** Modifications of the elutriation method for extracting nematodes from soils. *Nematologica.* 8 : 117- 28.

[15] - **Seinhorst J.W., 1950.** De betekenis van de grond voor het optreden van aanstasting door het stengelaaltje (*Ditylenchus dipsaci*) (Kühn Filipjev). Tijdschr. *Plantenzietkten*, 56: 289-348.

[16] - **Fortuner R., Merny G., 1973.** Les nématodes parasites des racines associés au riz en Basse Casamance (Sénégal) et en Gambie. *Cah. ORSTOM, Sér. Biol.*, 21: 3-20.

[17] - **Starr J.L., Carneiro R.G. et Ruano O. 2005.** Nematode Parasites of Cotton and other Tropical Fibre Crops. *In* Luc M., Sikora R.A. and Bridge J., eds. *Plant Parasitic Nematodes in Subtropical and Tropical Agriculture*. Wallingford, U.K: CAB International, 733-750.

[18] - **Moore S. R. and Lawrence K. S. 2013.** The Effect of Soil Texture and Irrigation on Rotylenchulus reniformis and Cotton. *J. Nematol*, 45(2):99–105.

[19] - **CABI, 2019.** *Meloidogyne acronea* (African cotton root nematode). datasheet on Meloidogyne acronea covers Identity, Overview, Distribution, Dispersal, Hosts/Species Affected, Diagnosis, Biology & Ecology, Natural Enemies. https://www.cabidigitallibrary.org ›.

[20] - **Gay, C.M. and Bird, G.W. 1973.** Influence of concomitant populations of *Pratylenchus brachyurus* and *Meloidogyne incognita* on root penetration and population dynamics. *Journal of Nematology* 5,212–217.

[21] - **Gordon, K. L., Schrimsher, D. W., and Lawrence, K. S. 2022.** Additional fertilizer and nematicide combinations on upland cotton to manage *Rotylenchulus reniformis* and *Meloidogyne inco*gnita in Alabama. *Journal of Nematology* 54:1-15.

[22] - **McLean, K.S. and Lawrence, G.W. 2003.** Efficacy of aldicarb to *Rotylenchulus reniformis* and biodegradation in cotton field soils. *Journal of Nematology* 35, 65–72.

[23] - **Bridge, J. 1992.** Nematodes.: Cotton Diseases. R. J. Hillocks, ed. CAB International. Wallingford, UK. 331-353.

[24] - **Wrather, J. A., Niblack, T. L., and Milam, M.R. 1992.** Survey of plant-parasitic nematodes in Missouri cotton fields. Suppl. *J. Nematol*. 24:779-782.

[25] - **Singh A.U. and Mishra, S.D. 2016.** Nematode problems in cotton crop and their management Archana. *Current Nematology*, 27 (1): 103–113.

[26] - **Schumacher, L.A.; Grabau, Z.J.; Wright, D.L.; Small, I.M.; and Liao, H.L. 2020.** Nematicide influence on cotton yield and plant-parasitic nematodes in conventional and sod-based crop rotation. *Journal of Nematology* 52: e2020-34. DOI: 10.21307/jofnem-2020-034.