ECOLOGY AND PATHOGENICITY OF THE NEMATODE *PARALONGIDORUS BULLATUS* (NEMATA: LONGIDORIDAE) IN SEMI-ARID REGIONS OF WEST AFRICA

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ABSTRACT

Baujard, P., B. Martiny, and A. Traore. 1993. Ecology and pathogenicity of the nematode *Paralongidorus bullatus* (Nemata: Longidoridae) from semi-arid regions of West Africa. Nematropica 23:149–157.

Paralongidorus bullatus was found deep in sandy soils of Niger and Senegal in the Sahelian zone of West Africa. Laboratory studies showed that reproduction is favored by high soil temperatures (32–36 °C) and moderate soil moisture (7–11% water content). Males were found for the first time. Cowpea, millet, and peanut were good hosts, whereas sorghum was a poor host. Vermiform stages were not able to enter anhydrobiosis and the nematode probably survives the dry season in the egg stage or by migrating deep into the soil. *Paralongidorus bullatus* was pathogenic to the most important crops of these Sahelian countries (millet, peanut, and sorghum) and it is suspected to be a major pathogen of peanut in semi-arid regions of West Africa.

Key words: cowpea, ecology, millet, pathogenicity, *Paralongidorus bullatus*, peanut, reproduction, sorghum, survival, West Africa.

RESUMEN

Baujard, P., B. Martiny y A. Traore. 1993. Ecología y patogenicidad de el nematodo *Paralongidorus bullatus* (Nemata: Longidoridae) de las regiones semiáridas del Africa occidental. Nematrópica 23:149–157.

Paralongidorus bullatus se encontró profundamente en suelos arenosos de Niger y Senegal en la zona saheliana del Africa occidental. Estudios de laboratorio mostraron que la reproducción se favoreció por las temperaturas altas del suelo (32–36 °C) y la humedad moderada (7–11% de contenido acuoso). Los machos fueron encontrados por primera ocasión. El caupí, el millo y el maní resultaron buenas hospedantes, mientras que el sorgo no lo fué. Los estadíos filiformes no fueron capaces de entrar en anhidrobiosis por lo que el nematodo probablemente sobrevive durante la estación seca en el estadío de huevo o moviendose a las zonas profundas del suelo. *Paralongidorus bullatus* resultó patogénica en los cultivos más importantes de estas países (millo, maní y sorgo) y se sospecha que sea un patógeno de mayor importancia en el maní en las regiones semiáridas de Africa occidental.

Palabras clave: Africa occidental, ecología, maní, millo, *Paralongidorus bullatus*, patogenicidad, reproducción, sobrevivencia, sorgo.

INTRODUCTION

The nematode *Paralongidorus bullatus* Sharma & Siddiqi, 1990 was first identified in sandy soils from Niger, West Africa, around roots of peanut showing "poor growth" symptoms (9,10,11). In Niger, it is widespread in a region lying between latitudes 12° and 14° north (10). Surveys conducted by ICRISAT teams in 1989 during the rainy season did not reveal the presence of *P. bullatus* in Benin, Burkina Faso, or Nigeria (8).

Nothing is known about the ecology and pathogenicity of this species, although

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it belongs to a genus containing species that are major pests of tropical crops around the world (6).

Paralongidorus bullatus was found recently (1990–1991) in Niger and Senegal during the course of studies on the ecology of nematodes from the Sahelian zone of West Africa (1,2,3,4). The following studies examined its distribution and edaphic factors influencing reproduction, survival, and pathogenicity to major crops in the Sahel.

MATERIALS AND METHODS

Geographical and vertical distribution: Data on geographical distribution were compiled from published work, nematological surveys, and the slide collection of the Muséum National d'Histoire Naturelle, Paris, France.

Soil samples (1 000 cm^3 in general, 5 000 cm^3 at Sadore) were collected as follows: during the rainy season (September 1990), in peanut, millet, and fallow fields at Tara, Niger; during the dry season (December 1990) in a field previously planted with millet at Nebe, Senegal; and in December 1991 in a field under fallow at Sadore, Niger. Soil samples were taken 0–30 cm deep at Tara, below 50 cm deep at Nebe, and 0–30 as well as 50–80 cm deep at Sadore. Nematodes were extracted by elutriation (7) of 250-cm^3 subsamples. Elutriate was placed on Baermann trays and the nematodes that were collected were counted daily during the first 4 days following elutriation.

The soil samples taken at Sadore from both depths (0–30 cm and more than 50 cm) were subdivided into two parts after homogenization. Four subsamples of the first part were extracted by elutriation and counting was done after 1, 2, 3, 4, 7, and 21 days on Baermann trays to ensure recovery of anhydrobiotic nematodes or juveniles hatched from eggs. Subsamples (250 cm^3) of the second part were bioassayed by growing cowpea, millet, peanut, and sorghum at 30, 32, 34 and 36 °C constant soil temperature and 7% constant soil moisture (1 replication per temperature and depth) in a growth chamber. Constant temperature and moisture were achieved as described below for all other experiments. After 30 days, nematodes were extracted by elutriation and counted 1, 2, 3, 4, and 7 days after elutriation.

Nematodes collected at Tara in 1990 were cultured in a growth chamber on peanut at 34 °C constant soil temperature, 10% constant soil moisture. Cultures were renewed every 2 months afterwards by elutriation and inoculation of 100 hand-picked nematodes; these pots constituted the stock cultures for all subsequent experiments.

Experiments on multiplication rate, anhydrobiosis, and pathogenicity: All experiments were done in pots made of PVC plastic tubes (4.5 cm diam, 17.5 cm high) with a small external PVC plastic rim (0.5 cm high) on the top, and filled with sterilized sandy soil collected in the field at Nebe (2.8% clay, 1.0% fine loam, 4.6% coarse loam, 61.7% fine sand, 30.4% coarse sand; pH_{H2O} 5.3, pH_{KCl} 4.9; 0.21% total carbon; 0.019% total nitrogen). Tubes were put down up to the rim into holes made on the top of closed and thermostated wooden boxes. Constant soil temperature was achieved by air heating inside the boxes. Constant soil moisture was achieved by adding twice a day an amount of water calculated by weighing; this technique permitted determination of water consumption in each tube during the experiments. Host plants were cowpea cv. N58 57 [*Vigna unguiculata* (L.) Walp], millet cv. Souna III (*Pennisetum typhoides* Rich.), peanut cv. 55 437 (*Arachis hypogaea* L.) and sorghum cv. 51 69 (*Sorghum vulgare*

L.). Nematodes were inoculated at 8 cm deep in the tube just before seeding with 10 seeds per tube for millet, 5 seeds per tube for sorghum, and one 2-day-old seedling per tube for peanut and cowpea. Nematodes were extracted from soil by elutriation. Data were analysed by ANOVA at the 0.05 confidence level (Newman & Keul's test).

Effect of soil temperature on multiplication rate: Tubes were inoculated with 59 ± 8 nematodes, planted with peanut, and maintained at four constant soil temperature levels (30, 32, 34, 36 °C) with seven replications for each temperature level, at 10% constant soil moisture, during 60 days in a growth chamber with artificial lighting (16-hr photoperiod).

Influence of soil moisture on multiplication rate: Tubes were inoculated with 89 ± 14 nematodes, planted with peanut, and maintained at four constant soil moisture levels (5, 7, 9, 11%) at 34 °C constant soil temperature during 60 days in a greenhouse with natural lighting; the four treatments were replicated 10 times in a completely randomized design.

Effect of host on multiplication rate and preliminary test for anhydrobiotic survival: Tubes were inoculated with 40 ± 5 nematodes, planted with one of the four host plants (cowpea, millet, peanut, or sorghum), and maintained at 34 °C constant soil temperature and 10% constant soil moisture in the greenhouse. The four treatments were replicated 20 times in a completely randomized design. After 60 days, nematodes were extracted from 10 replications to obtain final population counts. At this time, watering was stopped for the 10 remaining replications of each treatment. These tubes were kept at 34 °C constant soil temperature and weighed daily to monitor soil desiccation. Sixty days later, nematodes were extracted by elutriation.

Second experiment on anhydrobiosis: Seven tubes, each with a peanut plant, were inoculated with 50 nematodes and kept at 34 °C constant soil temperature, 10% constant soil moisture in the growth chamber. Nematodes were extracted from one tube by elutriation 60 days later; the six other tubes were allowed to dry another 60 days. Then the soil in each tube was thoroughly mixed. Nematodes were extracted from 50 g of soil from each tube and the rest of the soil was composited and equally distributed into six new PVC tubes topped with sterilized soil up to a volume of 250 cm^3. These tubes were planted with peanut and kept at 34 °C constant soil temperature and 10% constant soil moisture. Nematodes were extracted by elutriation 60 days after planting.

Pathogenicity to cowpea, millet, peanut, and sorghum: A separate experiment was conducted with each crop species at 34 °C soil temperature and 10% soil moisture in the growth chamber. Nematodes were inoculated onto each host at two inoculum levels: onto cowpea at 170 ± 11 and 340 ± 22, onto millet at 485 ± 33 and 970 ± 66, onto sorghum at 485 ± 33 and 970 ± 66, and onto peanut at 105 ± 10 and 210 ± 20 nematodes per tube. Nematode effects were compared to control plants without nematodes. The three treatments were replicated 10 times in a completely randomized design. After 40 days, nematodes were extracted from soil to determine the multiplication rate, and the fresh and dry weights of roots and shoots were measured.

RESULTS

Geographical distribution: Nematode surveys conducted in Mali and Senegal during the rainy and dry seasons by ORSTOM teams, and studies of the nematode slides deposited in the Collection

nationale des Nématodes, Muséum National d'Histoire Naturelle, Paris, France, show that, in Senegal, *P. bullatus* occupies a large area, traditionally called the bassin arachidier, located between latitudes 13.5 and 15.5° north (Fig. 1), and that it has not yet been detected in Mali.

Plant associations: In Senegal, *P. bullatus* was found around the roots of crop plants (*A. hypogaea, P. typhoides*), as well as around roots of perennial fallow plants (*Andropogon guayanus* Hack., *Guiera senegalensis* Lam., *Euphorbia balsamifera* Ait., *Acacia nilotica* L., and *Acacia tortilis* Hayne). The nematode was found 50–100 cm deep around roots of the first five species and 60–100 cm deep around roots of the latter two. Plants of *A. hypogaea* were chlorotic.

Vertical distribution at Sadore: The nematode was not detected by elutriation in the top 30 cm of soil and was uncommon below 30 cm (less than 1 nematode per 250 cm^3 of soil). Moreover, it was detected only after 14 days on Baermann trays (Table 1). Nevertheless, the nematode occurred in soil of both depths sampled because all host plants and soil temperatures

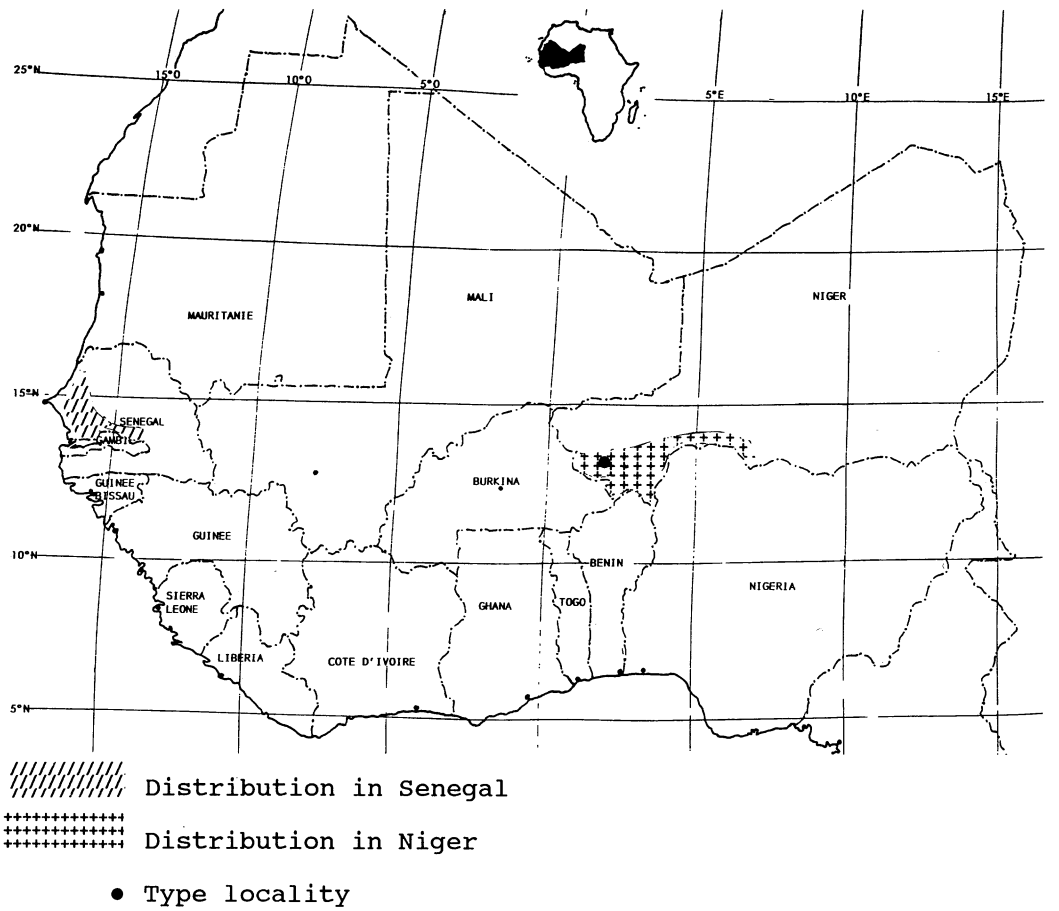

Fig. 1. Known geographical distribution of *Paralongidorus bullatus* in the Sahelian zone of West Africa.

Table 1. Numbers of *Paralongidorus bullatus* detected at two depths during the dry season at Sadore, Niger, when 250-cm³ soil samples were analyzed for nematodes before and after growing four crops in the soil at four temperatures. Nematodes were extracted by elutriation followed by final separation from soil debris on Baermann trays for 1–21 days.

Depth	Days on Baermann tray	Before cropping	After cropping for 60 days at 30, 32, 34, or 36 °C															
			Peanut				Millet				Sorghum				Cowpea			
			30	32	34	36	30	32	34	36	30	32	34	36	30	32	34	36
0–30 cm	1	0	2	0	15	40	0	0	10	15	0	1	15	10	0	0	5	10
	2	0	0	8	1	0	0	0	4	0	0	0	4	2	0	0	0	0
	3	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0
	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	7	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
	14	0																
	21	0																
Total		0	2	8	16	40	0	0	14	15	0	1	21	13	0	0	5	10
50 cm	1	0	10	10	15	120	0	5	25	90	5	5	20	65	0	15	9	35
	2	0	1	3	2	19	0	6	0	14	2	5	3	4	0	0	26	3
	3	0	0	0	0	2	0	0	0	3	0	0	0	0	0	0	0	0
	4	0	1	1	1	1	0	0	0	2	0	0	0	0	0	0	0	0
	7	0	0	0	0	0	0	0	0	4	0	0	2	2	0	0	0	0
	14	3																
	21	0																
Total		3	12	14	18	142	0	11	25	113	7	10	25	71	0	15	35	38

Values before cropping are the totals of four replications; values after cropping are numbers of nematodes recovered from one replication per crop and temperature.

resulted in nematode multiplication (Table 1).

Effects of soil temperature, soil moisture, and host plant on multiplication rate: Soil temperature, soil moisture, and host plants all had significant effects ($P < 0.05$) on the nematode multiplication rate. High soil temperatures (32–36 °C) and moderate soil moisture (7–11%) were optimum for reproduction. Nematodes reproduced on all plants, with the highest multiplication rates on peanut and millet (Fig. 2).

Males were found in low numbers in most treatments (Table 2). However, due to the low numbers of replications with males in these experiments, we could not establish correlations between any treatment and the occurrence of males.

Anhydrobiosis: No nematodes were recovered after soil desiccation even after subsequent cropping with peanut.

Pathogenicity to Sahelian crops: Paralongidorus bullatus had no significant effects on cowpea at the inoculum levels tested

Table 2. Numbers of males of *Paralongidorus bullatus* recovered from 250 cm³ soil in three experiments on multiplication rate.

Experiment	Treatment	Total number of males detected
Soil temperature	30 °C	1 (1)[z]
	32 °C	2 (2)
	34 °C	21 (2)
	36 °C	21 (3)
Soil moisture	5%	30 (2)
	7%	0 (0)
	9%	10 (1)
	11%	10 (1)
Host range	Peanut	20 (2)
	Millet	1 (1)
	Sorghum	11 (2)
	Cowpea	0 (0)

[z]Numbers of replications where males were found are given in parentheses. There were 7, 7, and 10 replications, respectively, in the soil temperature, soil moisture, and host range experiments.

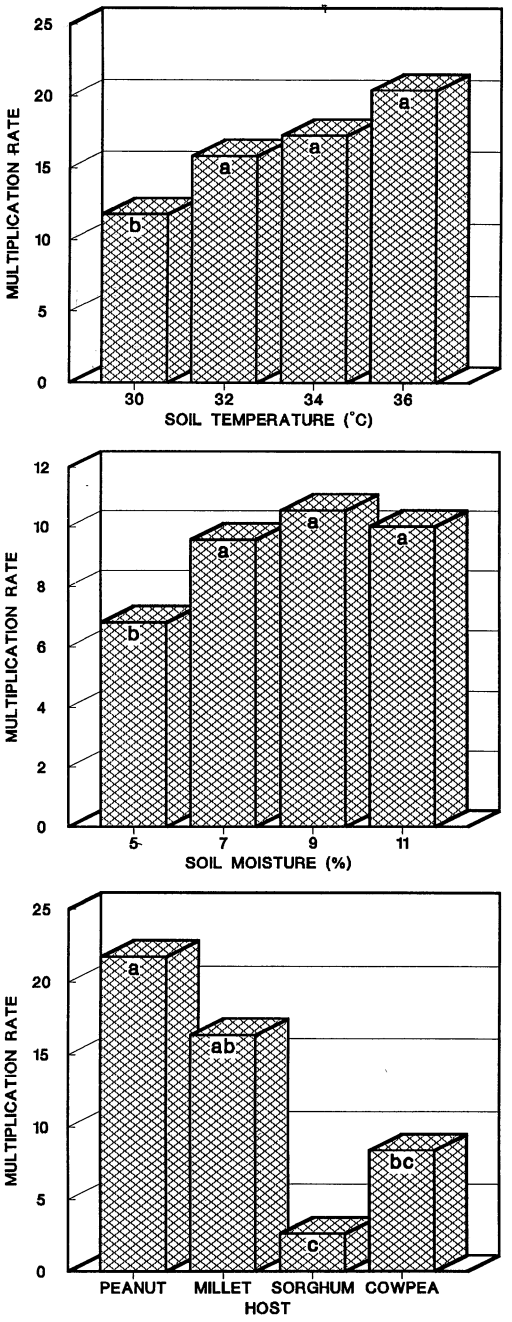

Fig. 2. Effects of soil temperature, soil moisture, and plant hosts on multiplication rate of *Paralongidorus bullatus*. Treatments with the same letter are not significantly different at $P < 0.05$.

(Table 3). No symptom appeared on aerial parts or root systems of plants. On millet, the nematode induced a significant reduction ($P < 0.05$) of fresh and dry weights of roots (Table 3). There was no measurable effect on plant water consumption or shoot weight (Table 3, Fig. 3). No foliar symptoms were observed and the reduction in root weight was not associated with a reduction of root length, *i.e.*, stubby root symptoms did not occur. On peanut, *P. bullatus* induced a significant reduction ($P < 0.05$) of fresh and dry weights of roots and aerial parts. Water consumption was also reduced. Leaves of some of the inoculated plants showed circular lesions (3–6 mm diam), which appeared 15–30 days after inoculation and turned from yellow into dark brown patches by the end of the experiment. Reduction of root weight was not associated with reduction of root length. On sorghum, *P. bullatus* reduced the fresh and dry weights of roots and aerial parts ($P < 0.05$) but did not affect water consumption. No foliar symptoms appeared during the experiment. Root weight reduction was not associated with stubby root symptoms.

DISCUSSION

There are only a few records of *P. bullatus* in the Sahelian zone of West Africa (mainly Senegal and Niger in soil samples collected during the rainy season) and it was not found in 2 800 soil samples collected during 5 years in a field where it was present in Senegal (Baujard, unpublished) because of its deep occurrence and the absence of anhydrobiotic juvenile or adult stages. Survival of the nematode during the dry season may depend on the ability of eggs to withstand soil dessication and hatch in response to soil moisture or root exudates, or the ability of the nematode to migrate deep into the soil at the end of the rainy season. The extraction of soil collected at Sadore under fallow showed that during the dry season vermiform stages of the nematode can be found in the deeper layers of soil. If present in

Table 3. Effects of two inoculum levels of *Paralongidorus bullatus* on host plants and multiplication rate after 40 days at 34 °C constant soil temperature and 10% constant soil moisture.

Host	Inoculum level (nematodes per tube)	Root weight (g)		Shoot weight (g)		Multiplication rate
		Fresh	Dry	Fresh	Dry	
Cowpea	0	4.93 a	0.44 a	5.61 a	1.23 a	—
	170	4.50 a	0.41 a	5.46 a	1.20 a	1.38
	340	4.44 a	0.40 a	4.98 a	1.14 a	1.40
Millet	0	3.07 a	0.48 a	4.17 a	0.65 a	—
	485	2.25 b	0.29 c	4.04 a	0.60 a	0.38
	970	2.44 b	0.37 b	4.24 a	0.65 a	0.37
Peanut	0	3.62 a	0.36 a	6.32 a	1.17 a	—
	105	2.60 b	0.23 b	4.91 b	0.98 b	15.20
	210	1.98 c	0.17 c	4.53 b	0.83 b	6.04
Sorghum	0	3.21 a	0.48 a	4.12 a	0.84 a	—
	485	1.32 b	0.22 b	2.85 b	0.49 b	0.44
	970	1.12 b	0.18 b	3.01 b	0.49 b	0.34

For each host, means within columns followed by the same letter are not different ($P < 0.05$).

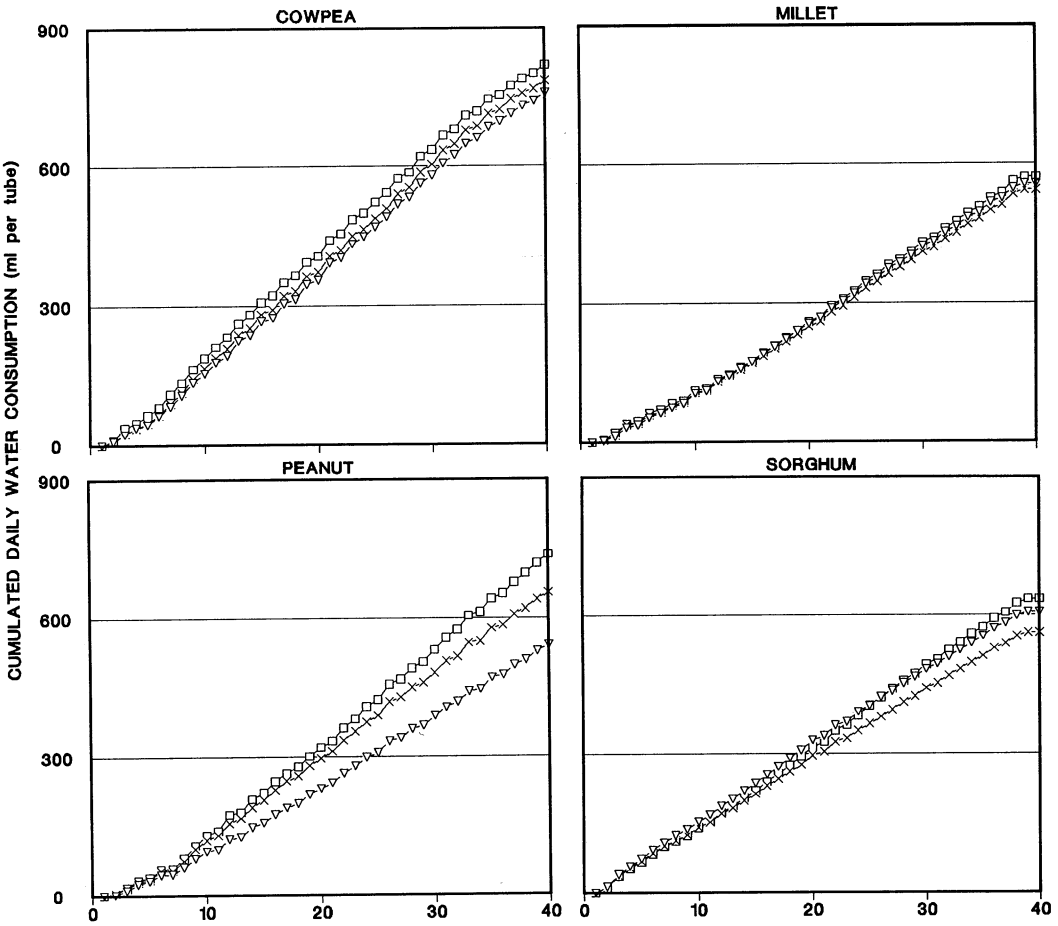

Fig. 3. Effects of *Paralongidorus bullatus* on daily water consumption of four crops grown in plastic tubes at 34 °C constant soil temperature, 10% constant soil moisture. Values for non inoculated controls are given as squares. Values for low and high inoculum levels are given as crosses and triangles, respectively. Inoculum levels (nematodes per plant) were: 170 and 340 for cowpea, 485 and 970 for millet, 105 and 210 for peanut, 485 and 970 for sorghum.

the upper layers, its survival stages were not extracted by elutriation. The cropping experiment established, however, that the nematode can also be present, probably in the egg stage, in the upper part of the soil.

Occurrence deep in soil and the absence of anhydrobiotic juvenile or adult stages is commonly observed in the dorylaimid genera *Xiphinema, Paralongidorus, Trichodorus*, and *Paratrichodorus* in the semi-arid region of West Africa. Species of these genera appear to be important parasites (under greenhouse conditions) of plants cropped in this region (Baujard and Martiny, unpublished data).

Our greenhouse experiments indicated that *P. bullatus* is well adapted to ecological conditions of these countries. It is able to reproduce at high soil temperature and

moderate soil moisture, and seems to be polyphagous, reproducing on leguminous and cereal plants. *Paralongidorus bullatus* was found in two countries where peanut crops exhibit growth problems (5,8), and our results indicate it is pathogenic to peanut. This suggests that *P. bullatus* is an important pest of peanut in semi-arid regions of West Africa.

Scutellonema cavenessi Sher, 1964 in Senegal and *S. clathricaudatum* Whitehead, 1959 in Niger have been considered (5) or suspected (8,10,11,12) to be the major pathogens of peanut in these countries because of their wide distribution and abundance in peanut cropping areas. This and previous studies (2,4) show that other nematode species associated with crops in these semi-arid regions may be equally pathogenic and should be systematically tested in the laboratory and evaluated in the field to determine their impact on crop losses in this biotope.

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