Asian Journal of Soil Science and Plant Nutrition

Volume 9, Issue 3, Page 1-15, 2023; Article no.AJSSPN.99897
ISSN: 2456-9682

Influence of Two Cover Crops (*Arachis repens* L. and *Desmodium adscendens* Sw.) on Root Infestation of the "Great Dwarf" Dessert Banana Cultivar (*Musa* sp.) by Plant-parasitic Nematodes in Southeast Côte d'Ivoire

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Authors' contributions

This work was carried out in collaboration among all authors. Author KEYG designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors YG, KKD, CB, CM and DAE managed the analyses of the study. Authors KDJ, YAS and AK managed the literature searches. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/AJSSPN/2023/v9i3181

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/99897

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Original Research Article

Received: 15/03/2023
Accepted: 19/05/2023
Published: 27/05/2023

ABSTRACT

Context: In Côte d'Ivoire, industrial banana plantations are faced with the problem of weediness. However, the use of herbicides as a means of control presents significant risks for human health and the environment. The abandonment of these products for more ecological alternatives such as cover crops is imminent.
Aims: This study aimed to compare the relative abundance and the density of the main plant-parasitic nematodes in the roots of banana and cover crops according to three weed management treatments.
Study Design and Methodology: The experimental design was a three-repeat Fisher block of three treatments consisting of implementation of *A. repens* and *D. adscendens* as cover crops and spraying of two synthetic herbicides (glufosinate and glyphosate) for weed management. The relative abundance and density of nematodes in the roots of banana and cover crops were assessed quarterly after extraction by the rapid double centrifugation-flotation method and enumeration under an optical microscope.
Results: Both cover crops and banana plants had their roots infested by the major parasitic nematodes evaluated (*Radopholus similis*, *Pratylenchus* spp., *Helicotylenchus* spp., *Meloidogyne* spp., *Rotylenchulus reniformis* and *Hoplolaimus pararobustus*). These infestations were not a function of weed management treatments. Compared to the use of herbicides, *A. repens* and *D. adscendens* used as ground cover did not significantly increase or decrease nematode dynamics in the plots. Individuals extracted from the roots of the cover crops, and particularly from *D. adscendens*, were more numerous than from the roots of the banana plants. In terms of proportions, *Pratylenchus* spp., *R. similis*, *Helicotylenchus* spp. and *Meloidogyne* spp. were most abundant. *R. reniformis* and *H. pararobustus* as well as various nematodes (plant parasites: *Hirschmanniella* spp., *Xiphinema* spp., ..., and non-plant parasites: fungivorous, carnivorous, bacterivorous, ...) were in the minority.
Conclusion: The results, particularly those of *A. repens,* could be useful in the biological, ecological and sustainable management of weed in banana plantations without important risks of pest pressure.

Keywords: Plant-parasitic nematodes; banana; cover crop; Côte d'Ivoire.

1. INTRODUCTION

The Great Dwarf dessert banana from *Musa* sp. [1] is a highly prized fruit because of its high carbohydrate, fibre, vitamin and mineral content [2]. Côte d'Ivoire is the African leader in exports to the European market [3]. However, banana plants face the pressure of several biotic constraints [4], among which weediness, accentuated by intensive monoculture, remains one of the most damaging in industrial plantations [5]. Weeds compete directly with banana plants for water, light and nutrients [6], and are potential host of pests, including plant-parasitic nematodes [7,8]. The latter are the second major constraint on banana plants after leaf spot diseases [9]. They have a stylet and glands secreting digestive enzymes in their mouth cavities [10]. These allow them to consume the cellular contents of roots and rhizomes, and to enter plant tissues to grow and reproduce at the expense of the latter [11]. The most reliable control practices of these parasites, but effective only for about a few months to a year, are preventive including sanitation and choice of plant varieties, fallowing, crop rotation or association. Based on this observation, weed control in banana plantations appears to be essential for the profitable and sustainable exploitation of this crop. The use of synthetic herbicides, which are effective and broad-spectrum, remains the most common practice for the control of weeds in banana plantations [12] and presents many environmental [13] as well as health risks [14]. With the aim of orienting cropping and control systems towards practices that meet the challenges of sustainable agriculture [15], researchers, in collaboration with

farmers, are exploring various alternatives including the use of plant extracts, herbicides with few residues in the soil and environment, as well as cover crops that are capable of preventing emergence and growth of some weeds [16]. In banana cultivation, several studies have been carried out on the use of annual and perennial plant cover for weed control [5,17,18]. Among the plants used are those of the Fabaceae family, to which the species *Arachis repens* and *Desmodium adscendens*, the subjects of this study, belong. However, few studies have taken into account the impact of these plants on nematode parasite pressure. This study aims to contribute to the biological control of weediness in banana plantations through the use of cover crops. The aim will be to compare the relative abundance and the density of the main plant-parasitic nematodes in the roots of banana and cover crops according to three weed management treatments (establishment of the cover crop *A. repens*, establishment of the cover crops *D. adscendens* and spraying of the herbicides glufosinate and glyphosate).

2. MATERIALS AND METHODS

2.1 Study Area

The trial was carried out in the Sud-Comoé region in the southeast of Côte d'Ivoire, in Ayamé, precisely in Akressi, in the industrial banana plantation belonging to the Société Agricole Kablan Joubin (SAKJ). Plot No. 14 of Block A located in sector C (CA14) at latitude 05° 41' 04.09" N, longitude 003° 3' 53.95" W and 100 m altitude was the experimental site. The climate is of the sub-equatorial type characterized by abundant rainfall, with more than 2,000 mm/year [19]. The daily temperature range is less than 1.6 °C, with an average temperature between 23°C and 29°C [20]. The soil is deep, ferrallitic with high base leaching [21] and silty or sandy-clay texture [22]. The relief is characterized by high plateaus of more than 30 m of altitude in the North, low plateaus whose maximum altitude is between 10 m and 12 m as well as coastal strips with sandy coasts in the South [23]. The hydrographic system includes an important river network composed of the Bia and Tanoé rivers, the Ebrié, Aby, Hébé and Kodjoboué lagoons, the Comoé River and the Atlantic Ocean [19].

2.2 Plant Materials

The plant material consists of the cover crops *Arachis repens* (L.) Handro and *Desmodium adscendens* (Sw.) DC. which are leguminous plants as well as banana trees (*Musa* sp., AAA, Cavendish, cultivar Great Dwarf). The seedlings of the first two species mentioned, 84 days old (about 3 months), were taken from cuttings made in the nursery in coconut fibre. The nurseries were set up in the greenhouse of the experimental station (SAKJ). The banana plants were obtained after acclimatization in coconut fibre and controlled conditions in the nursery for 77 days from imported (South Africa) vitro-plants.

2.3 Methods

2.3.1 Plot preparation and transplanting of cover crops

For the implementation of the trial, three successive blocks of elementary area of 1080 m² (108 m x 10 m), were selected within the CA14 banana plantation previously left in spontaneous fallow for 12 months to reduce in the soil the plant-parasitic nematode populations from previous cycles. Weeds were treated with glufosinate (SL 200 g/l) at a rate of 2 l/ha (the registered dose in banana cultivation in Côte d'Ivoire), using a knapsack sprayer, 2 weeks before transplanting the cover crops in order to kill the nematodes main food source. Daba weeding was then performed just before the implementation of the cover crops to remove all weeds outside of the experimental plot. Each block was subdivided into three equal individual plots of 330 m² (33 m x 10 m), with 3 m aisles between plots and a 1 m drain between two blocks. The cover crops were transplanted during the rainy season over the entire surface of the elementary plots. The seedlings were transplanted from the nursery at regular intervals of 30 cm into 5 cm deep pots, with one individual per pot. Light pressure was applied to the soil to pack and compact it around the plant. Before and after transplanting, the plot and the plants were regularly irrigated. At the time of transplanting the cover crops, the plot contained 8-week-old banana plants. The soil of the experimental plot was also well ploughed before planting banana seedlings without adding nematicides to better appreciate the impact of the weed control modalities tested on the evolutionary dynamics of plant-parasitic nematodes.

2.3.2 Experimental design

The experiment was designed in a Fisher block with three replications of three weed

management treatments. The studied factor was the weed management method consisting of the implementation of the cover crops *A. repens* and *D. adscendens* and spraying of the herbicides glufosinate and glyphosate. Thus, the three tested modalities were *A. repens, D. adscendens* and herbicides (control). Each unit plot was equivalent to a replication of one treatment and contained 60 banana trees planted at a density of 1,820 plants/ha in two double rows and staggered, i.e. 2.2 m between banana plants in the row and 1.7 m between double rows. The cover crops were transplanted at the density of 111,111 plants/ha, i.e. 30 cm x 30 cm spacing. The number of plants transplanted per experimental unit was 4,000. Within a block, plots were spaced 3 m apart. Two successive blocks were separated by a drain 1 m wide and 1 m deep.

2.3.3 Maintenance of the trial

Trial maintenance consisted of manual removal and transport of resistant weeds, among others *Panicum laxum* Sw., *Eleusine indica* (L.) Gaertn, *Phyllanthus amarus* Schum. & Thonn., *Ageratum conyzoides* L, *Strucium sparganophora* (L.) Kuntze, *Chromolaena odorata* (L.) R. King & H. Rob., *Amaranthus viridis* L., etc., from the banana plantation. For the control plots, weed management was done by applying the contact herbicide glufosinate (200 SL; 2 l/ha) adapted to banana young plants, during the first two months of the trial. Then the systemic herbicide glyphosate (SL 360 g/l) at the rate of 3 l/ha (the recommended dose in banana cultivation in Côte d'Ivoire) most suitable in relatively old banana plantations (more than 4 months) was applied regularly until the end of the experiment. These practices were carried out on warning when weeds began to dominate the cover crops or invade the control plots. Other maintenance activities included fertilization, irrigation, chemical and physical control of black leaf streak disease, defoliator pests and black weevils, and banana and fruit care.

2.3.4 Experimental period

The study ran from June 2019 to July 2020. The experimental period was subdivided into two phases. The first phase was from June to mid-December 2019. It covered the period from transplanting of cover crops in the plantation to harvesting of banana bunches from the plot. Thus, this phase included the 1st crop cycle of banana that started in April 2019. The second phase of the trials started in mid-December 2019 and ended in late July 2020. It took into account the time between the harvesting of the 1st cycle banana bunches and the harvesting of the fruits from the development of the successor suckers. Thus, this phase of the trials involves the second crop cycle of banana.

2.3.5 Evaluation of the effect of cover crops on parasitic nematodes of banana

2.3.5.1 Nematode trapping in the experimental banana plantation before the implementation of trial

One day before transplanting the cover crops, five soil samples were taken randomly from each experimental unit at a depth of 5–20 cm, to form a composite sample per unit plot. Each soil composite sample was distributed in three 1.5 L bottom-perforated pots, for a total of 27 pots for the nine test plots. Subsequently, 11-week-old banana plants of the variety 'Great Dwarf' from the SAKJ nursery were individually potted. These were then placed on a slightly elevated wooden rack. The plants were irrigated every 2 days until the 45th day after potting when their roots were sampled for nematological analysis.

2.3.5.2 Collection and preparation of banana and cover crops roots

At the end of the trapping, the banana seedlings were stripped and their roots were removed with a knife and scissors. The roots were pooled and mixed to form composite samples.

In banana plantations, the roots of banana trees and cover crops in the plots were collected every 3 months after the installation of the cover crops until the bunches of the successor suckers of the planted banana trees were harvested. For the first plants mentioned, samples were taken according to the method adapted from Tabarant [24] at a depth of 15–30 cm and within a radius of 15–30 cm, from five randomly selected individuals per elementary plot. Regarding cover crops, collections were made on individuals present around the sampled banana plants, within a radius of 15 cm to 30 cm. Composites were also made by species and by treatment. The collected samples were placed in labelled plastic bags and transported to the laboratory under refrigerated conditions to extract nematodes.

In the laboratory, the roots were rinsed twice in tubs containing tap water to remove sand and other debris before being cut into small pieces of about 1 cm. Then, a 50 g fraction of each sample was taken for nematode extraction.

2.3.5.3 Extraction of nematodes

The extraction of nematodes was done according to the rapid double centrifugation-flotation method developed by Jenkins [25] and modified by Coolen and d'Herde [26]. The principle consists in recovering nematodes according to their size as well as their density in relation to water (1 kg/l) and a magnesium sulphate solution (1.15 kg/l to 1.2 kg/l). Each root fraction was ground three consecutive times for 5 s in the presence of 350 ml of water in a blender. The grinding was spilled onto a battery of sieves (500, 80, 40, and 32 µm) and rinsed with a water jet. The rejects from the 40 µm and 32 µm sieves were centrifuged at 2,500 rpm for 5 min in the presence of 3 g of kaolinite. The resulting pellet was centrifuged again after addition of 50 ml of magnesium sulphate solution and homogenization. The supernatant was sieved (5 µm) and the contents of the sieve were collected by spraying water from a wash bottle into a glass vial to obtain the nematode suspension.

2.3.5.4 Identification and enumeration of nematodes

The nematode suspension was transferred to a graduated cylinder and its volume was determined. After homogenization with air blown into the suspension through the channel of a pipette, a volume of 2 ml was taken and spread on a gridded counting plate mounted under an optical microscope. This was connected to a camera and computer [27]. Identification and enumeration of major plant-parasitic nematode populations were performed at G x40 and G x100 magnifications based on their discriminating morphometric characters according to the determination keys of Siddiqi [28], Shurtleff and Averre [29], Hunt et al. [30] and Mekete [31]. Three observations were performed per nematode suspension. The number of nematodes per taxon was related to the volume of the initial suspension and then to 100 g of roots, according to the following formula used by Vawa et al. [27]:

$$X = \frac{N \times V}{M} \times 100$$

With: X = number of nematodes per 100 g of roots; N = number of nematodes/ml of suspension; V = volume of suspension (ml) and M = mass of root fraction used for extraction (g)

The quarterly evolution rate (QER) of nematode populations to evaluate the effect of each weed management modality on them was calculated according to the formula adapted from Yeo et al. [32] defined below:

$$\text{QER}\ (\%) = \left(1 - \frac{Tn}{T0}\right) \times 100$$

With: T0 = initial nematode population recorded per 100 g of roots; Tn = nematode population recorded at a given quarter per 100 g of roots.

The relative abundance of the different taxa, expressed as a percentage (%), was determined by the ratio of the number of individuals of each species to the total number of nematodes observed, multiplied by 100 [33].

2.3.6 Statistical analysis

The data obtained were processed using the XLSTAT software version 2016. An analysis of variance (ANOVA) was performed on the parameters evaluated according to the treatments studied. The means were classified using the Student-Newman-Keuls test at the 5% threshold when significant differences were observed.

3. RESULTS

3.1 Nematode Taxa Observed in Banana and Cover Crops Roots

Fig. 1 shows the six major plant-parasitic nematodes frequently observed under the microscope when counting populations extracted from roots. These are the taxa *Pratylenchus* spp. (A), *Radopholus similis* (B), *Meloidogyne* spp. (C), *Hoplolaimus pararobustus* (D), *Helicotylenchus* spp. (E) and *Rotylenchulus reniformis* (F). In addition to these taxa, some miscellaneous nematodes including plant parasites (*Hirschmanniella*, *Xiphinema*, etc.) and non-plant parasites (omnivorous, bacterivorous, fungivorous, carnivorous, etc.) were also encountered.

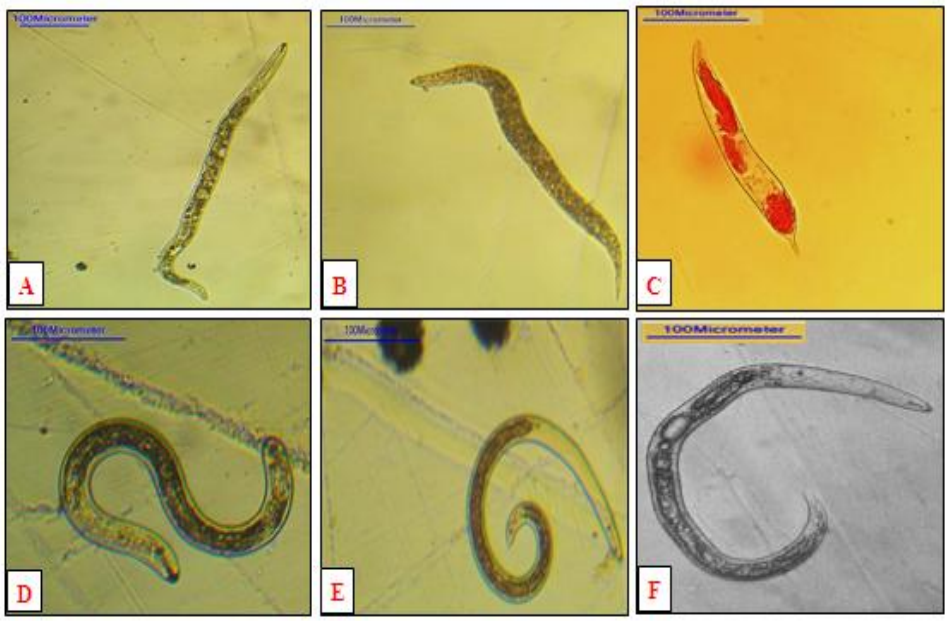

Fig. 1. Main plant-parasitic nematodes of banana observed at enlarging x100
A: Pratylenchus sp.; B: Radopholus similis; C: Meloidogyne sp.; D: Hoplolaimus pararobustus; E: Helicotylenchus sp.; F: Rotylenchulus reniformis

3.2 Relative Abundances of the Different Nematodes in Roots of Banana and Cover Crops

3.2.1 In the roots of banana trees

The relative proportions of abundance of the different nematode taxa observed in banana roots under the weed management treatments are presented in Fig. 2. Overall, the majority taxa were *Pratylenchus* spp. (29–34%), *Helicotylenchus* spp. (20–23%) and *R. similis* (18–23%). The other species were in the minority, most notably *H. pararobustus* (1–4%). Miscellaneous nematodes were in order of importance more frequent in the *D. adscendens* (10%), control (8%) and *A. repens* (5%) plots.

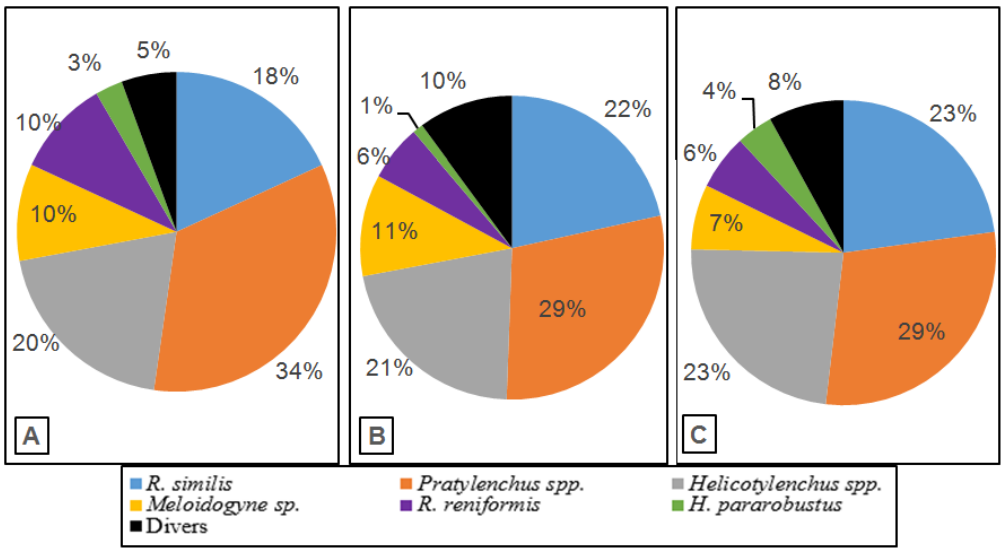

Fig. 2. Relative abundances of nematodes in banana roots associated with cover crops and control plots.
A: A. repens plots; B: D. adscendens plots and C: control plots (herbicide treated)

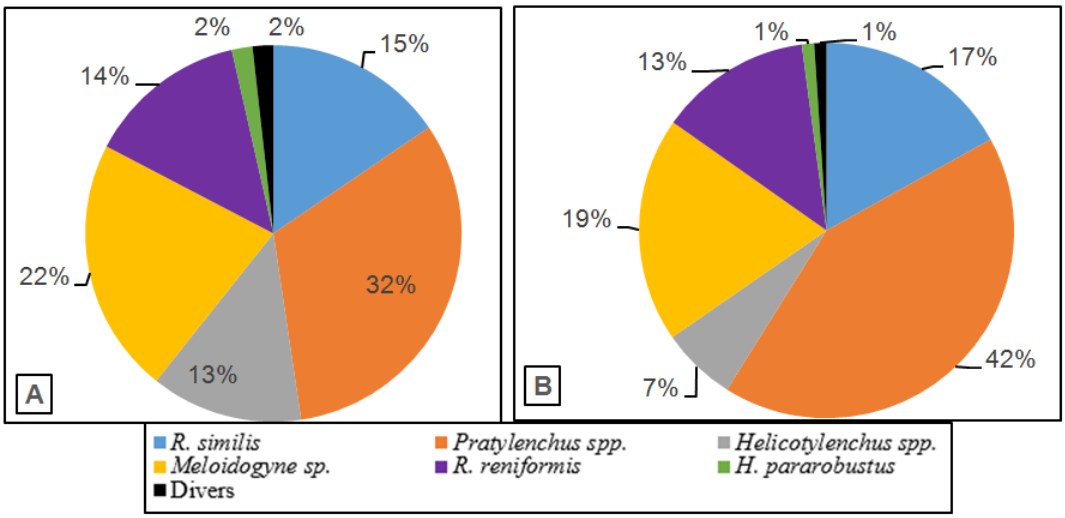

Fig. 3. Relative abundances of nematodes in the roots of cover crops used for weed management in banana plantations
A: A. repens; and B: D. adscendens

3.2.2 In the roots of cover crops

In cover crops, *Meloidogyne* spp. (19–22%), *Pratylenchus* spp. (32–42%) and *R. similis* (15–17%) were the most abundant nematodes in root tissue. Miscellaneous nematodes and *H. pararobustus* species were rarer, with rates of 1 to 2% (Fig. 3).

3.3 Population Dynamics of Major Nematodes in Banana and Cover Crops Roots

3.3.1 Populations of *Radopholus similis* and *Pratylenchus* spp.

Overall, the presence of cover crops did not significantly impact *Radopholus similis* and *Pratylenchus* spp. populations in banana roots. Nematode numbers were statistically identical regardless of treatment except at the 6th month after transplanting for *R. similis* and at the 12th month after transplanting for *Pratylenchus* spp. (P= .025 and P= .001). At these two time points, nematode numbers varied according to the treatments. They were statistically more abundant in the roots of banana plants associated with the cover crop *D. adscendens*, with density of 1,233.33 and 3,087.77 individuals/100 g of roots, respectively (Figs. 4A and 4B), as well as rates of increase of 366.39 and 175.15% (Tables 1 and 2). Roots from banana plants associated with the cover crop *A. repens* and from herbicide-treated control plots had the lowest and statistically identical values.

Population numbers of *R. similis* and *Pratylenchus* spp. in cover crop roots did not fluctuate following weed management treatments, except at the 9th and 3rd month after transplanting, respectively for the two taxa mentioned (P= .019 and P= .014). At these evaluation periods, *D. adscendens* species had the highest density of these nematodes in its roots, with a number of 2,280.61 and 4,965 individuals/100 g root (Figs. 4C and 4D). The rate of increase recorded at month 9 for *R. similis* was 63.15%. *A. repens* roots recorded the lowest numbers throughout the evaluations (Tables 1 and 2).

Numbers of *R. similis* and *Pratylenchus* spp. in cover crop roots were greater than those in banana roots, especially in *D. adscendens*.

3.3.2 Populations of *Helicotylenchus* spp. and *Meloidogyne* spp.

Overall, the numbers of *Helicotylenchus* spp. and *Meloidogyne* spp. extracted from both banana roots and cover crops roots (*A. repens* and *D. adscendens*) did not vary significantly according to the weed control treatment. For these nematodes, the numbers of individuals were statistically identical regardless of weed management treatment and evaluation periods, except at month 6 for *Helicotylenchus* spp. in banana roots (P= .000). In this case, nematode density fluctuated among treatments. They were more numerous in the roots of banana trees associated with the cover crop *D. adscendens*,

with a density of 2,235.55 individuals/100 g of roots (Figs. 5A and 5B) and an increase rate of 1,036.72% (Tables 3 and 4).

The roots of the cover crop *A. repens* were the least infested throughout the evaluations. In contrast to *Helicotylenchus* spp. populations, *Meloidogyne* spp. nematodes, were more abundant in cover crop roots than in banana roots, singularly in *D. adscendens*.

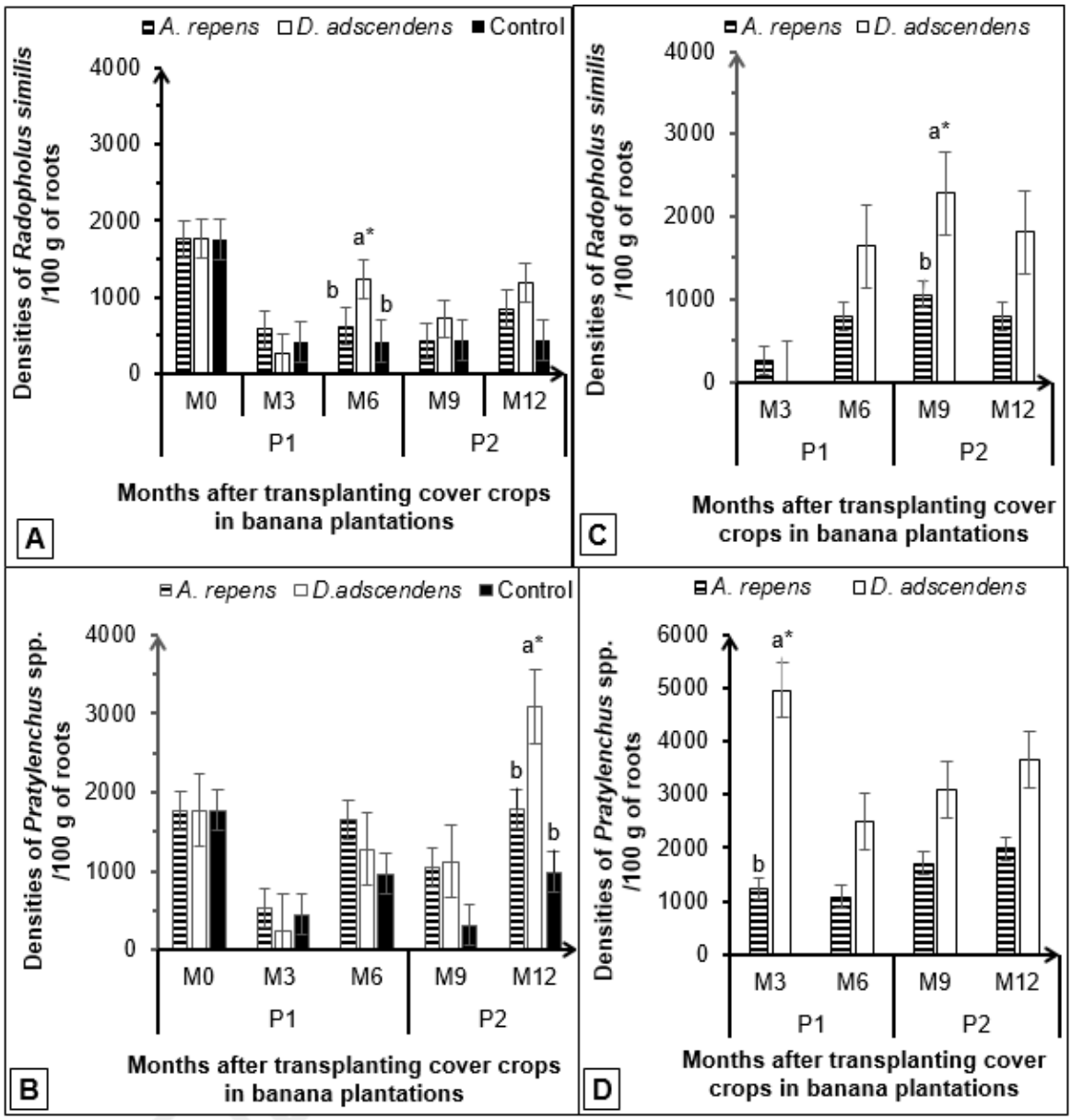

Fig. 4. Quarterly population trends of *R. similis* and *Pratylenchus spp*. from roots of banana and cover crops used for weed management

A and B: banana roots; C and D: cover crop roots;

P1: during the 1st phase of the trials (from the transplanting of the cover crops in the banana plantation to the harvesting of the bunches of the 1st crop cycle of banana plants);

P2: during the 2nd phase of the trials (from the harvesting of the 1st cycle bunches to the harvesting of the 2nd cycle bunches of banana trees);

M0: at transplanting of cover crops in plantations; M3 to M12: 3rd to 12th month after transplanting.

**In the histograms, for each evaluation period, the bars of means without letters do not differ and those followed by different letters differ statistically at the 5% threshold (Student-Newman-Keuls test). * P < 0.05*

Table 1. Quarterly population change rates of *R. similis* in 100 g of banana roots and cover crops used for weed management

Weed management treatments	Rate of change of *R. similis* populations (%)						
	Months after transplanting cover crops in banana plantations						
	Banana roots				Cover crops roots		
	P1		P2		P1	P2	
	M_3	M_6	M_9	M_{12}	M_6	M_9	M_{12}
A. repens	67,26	-6,57	31,16	-99,74	-29,79	-63,15	52,23
D. adscendens	84,96	-366,39	42,34	-67,34	-	-39,05	45,77
Herbicides (glufosinate and glyphosate)	76,49	-1,89	-3,43	2,30	-	-	-
Average	76,24	-124,94	23,36	-54,93	-29,79	-51,10	49

P1: during the 1st phase of the trials (from the transplanting of the cover crops in the banana plantation to the harvesting of the bunches of the 1st cycle of banana plantations); P2: during the 2nd phase of the trials (from the harvesting of the 1st cycle bunches to the harvesting of the 2nd cycle banana trees); M3 to M12: 3rd to 12th month after transplanting of cover crops in banana plantations.In the table, positive (+) and negative (-) values correspond to reductions and increases in nematode populations, respectively

Table 2. Quarterly population change rates of *Pratylenchus* spp. in 100 g of banana roots and cover crops used for weed management

Weed management treatments	Rate of change of *Pratylenchus* spp. populations (%)						
	Months after transplanting cover crops in banana plantations						
	Banana roots				Cover crops roots		
	P1		P2		P1	P2	
	M_3	M_6	M_9	M_{12}	M_6	M_9	M_{12}
A. repens	70,15	-210,50	36,81	-72,80	-53,78	-14,87	-47,58
D. adscendens	86,27	-425,11	12,17	-175,15	39,37	-0,52	-12,09
Herbicides (glufosinate and glyphosate)	75,04	-116,83	67,79	-217,99	-	-	-
Average	77,15	-250,82	38,92	-155,31	-7,20	-7,69	-29,83

P1: during the 1st phase of the trials (from the transplanting of the cover crops in the banana plantation to the harvesting of the bunches of the 1st cycle of banana plantations); P2: during the 2nd phase of the trials (from the harvesting of the 1st cycle bunches to the harvesting of the 2nd cycle banana trees); M3 to M12: 3rd to 12th month after transplanting of cover crops in banana plantations, In the table, positive (+) and negative (-) values correspond to reductions and increases in nematode populations, respectively

Table 3. Quarterly population change rates of *Helicotylenchus spp.* in 100 g of banana roots and cover crops used for weed management

Weed management treatments	Rate of change of *Helicotylenchus* spp. populations (%)						
	Months after transplanting cover crops in banana plantations						
	Banana roots				Cover crops roots		
	P1		P2		P1	P2	
	M_3	M_6	M_9	M_{12}	M_6	M_9	M_{12}
A. repens	57,73	-87,46	75,67	-65,71	84,74	-79,63	37,41
D. adscendens	87,81	-1 036,72	78,33	-5,96	92,42	- 90	62,96
Herbicides (glufosinate and glyphosate)	70,95	-36,02	51,92	-140,58	-	-	-
Average	72,16	-386,73	68,64	-70,75	88,58	-84,81	50,18

P1: during the 1st phase of the trials (from the transplanting of the cover crops in the banana plantation to the harvesting of the bunches of the 1st cycle of banana plantations); P2: during the 2nd phase of the trials (from the harvesting of the 1st cycle bunches to the harvesting of the 2nd cycle banana trees); M3 to M12: 3rd to 12th month after transplanting of cover crops in banana plantations. In the table, positive (+) and negative (-) values correspond to reductions and increases in nematode populations, respectively.

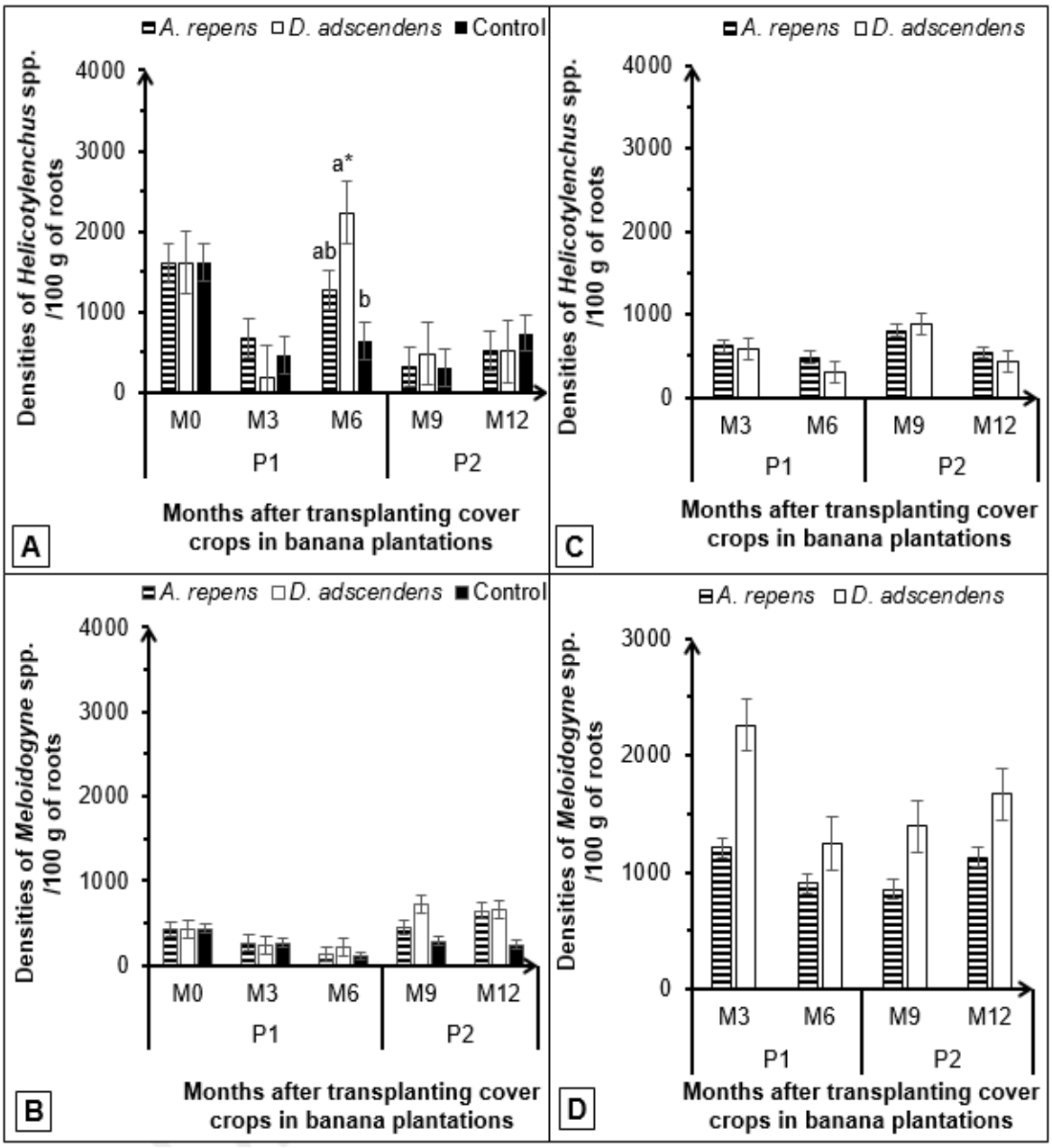

Fig. 5. Quarterly population trends of *Helicotylenchus* spp. and *Meloidogyne* spp. from roots of banana and cover crops used for weed management

A and B: banana roots; C and D: cover crop roots;

P1: during the 1st phase of the trials (from the transplanting of the cover crops in the banana plantation to the harvesting of the bunches of the 1st crop cycle of banana plants);

P2: during the 2nd phase of the trials (from the harvesting of the 1st cycle bunches to the harvesting of the 2nd cycle bunches of banana trees);

M0: at transplanting of cover crops in plantations; M3 to M12: 3rd to 12th month after transplanting.

** In the histograms, for each evaluation period, the bars of means without letters do not differ and those followed by different letters differ statistically at the 5% threshold (Student-Newman-Keuls test). * P < 0.05*

Table 4. Quarterly population change rates of *Meloidogyne* spp. in 100 g of banana roots and cover crops used for weed management

Weed management treatments	Rate of change of *Meloidogyne* spp. populations (%)						
	Months after transplanting cover crops in banana plantations						
	Banana roots				Cover crops roots		
	P1		P2		P1	P2	
	M_3	M_6	M_9	M_{12}	M_6	M_9	M_{12}
A. repens	38,07	51,26	-243,10	-45,73	43,43	40,05	-26,25
D. adscendens	46,66	9,27	-246,24	7,30	73,80	-22,62	-21,27
Herbicides (glufosinate and glyphosate)	37,55	60	-166,67	16,02	-	-	-
Average	40,76	40,18	-218,67	-7,47	58,61	8,71	-23,76

P1: during the 1st phase of the trials (from the transplanting of the cover crops in the banana plantation to the harvesting of the bunches of the 1st cycle of banana plantations);P2: during the 2nd phase of the trials (from the harvesting of the 1st cycle bunches to the harvesting of the 2nd cycle banana trees);M3 to M12: 3rd to 12th month after transplanting of cover crops in banana plantations.In the table, positive (+) and negative (-) values correspond to reductions and increases in nematode populations, respectively

4. DISCUSSION

Populations of the nematodes *Radopholus similis*, *Pratylenchus* spp, *Helicotylenchus* spp, *Meloidogyne* spp, *Rotylenchulus reniformis* and *Hoplolaimus pararobustus* extracted from banana roots and cover crops were often identical regardless of the weed management treatment. The populations counted were, in general, below the infestation threshold of 4,000 individuals/100 g of roots [34], to trigger chemical control. This finding implies that the cover crops *A. repens* and *D. adscendens* would not be excellent nematode hosts. However, nematode numbers were slightly higher in plots treated with both cover crops. This would be due to the fact that these plants belong to the Leguminosae family. Similar results were obtained by Yeo et al. [35]. These authors, investigating the nematoregulatory effect of cover crops, found that the legumes *Cajanus cajan* and *Crotalaria retusa* were less likely than the Poaceae *Panicum maximum* to induce a reduction in major plant-parasitic nematodes. Similarly, a trap plant status in these cover legumes could be the cause as demonstrated by Kerridge and Hardy [36] in Arachis. Numbers were somewhat high in *D. adscendens*, which recorded a high population of *Pratylenchus* spp. in its roots in the third month, with 4,956 individuals. This situation would be the consequence of the low coverage of the banana plantations by the latter [37], thus favouring the free proliferation of various weed hosts of nematodes such as *P. amarus*, *A. conyzoides*, *E. indica*, *P. laxum*, *Euphorbia* spp., *C. diffusa*, and thus the reproduction of these parasites [8,38]. Concerning *A. repens*, its high production of biomass and thus organic matter [37] would have improved the numbers of omnivorous and predatory nematodes that prey on soil parasitic taxa [39,40]. Also, omnivorous and predatory nematodes alter the microbial, physical, and chemical activity of the environment that limits the hatching, reproduction, and proliferation of those pests [10,41]. In the control plots, the overall low nematode density observed was attributed to the absence of plant cover, and hence weed hosts and nutrients for them, destroyed by the synthetic herbicides used. Similar results were reported in the work of Baghel et al. [42] on the impacts of conservation agriculture and herbicides on weeds, nematodes, herbicide residue and productivity in direct-seeded rice. These authors showed that the broad-spectrum herbicide Pendimethalin controlled weediness and contributed to a significant reduction in the density of the main plant-parasitic nematodes of rice, namely *Tylenchorhynchus brevilineatus*, *Pratylenchus thornei*, *Meloidogyne graminicola* and *Hirschmanniella oryzeae*, as well as their trophic groups.

The high populations observed at trapping (M0) could reflect a predominance, during spontaneous fallow, of nematode host weed species as pointed out by Coyne et al. [17,43]. According to the latter author, spontaneous fallows favour the multiplication of *Pratylenchus spp*. and *R. similis*. This justifies the recommendations to install non-host plants of these parasites in the intercultural phase with the aim of suppressing their resources and habitats, and thus their populations [35,44].

Of the nematodes extracted, the most abundant in banana and cover crop roots were *Pratylenchus* spp. and *R. similis*. *Helicotylenchus* spp. and *Meloidogyne* spp. were in the majority in banana and cover crops, respectively. *R.*

reniformis and *H. pararobustus* were less common in the roots of banana plants and both cover crops. These observations would likely be related to the variable multiplication rate among nematode species [45] and may be different for other plants and soil types [46,47]. These results can be paralleled with several works in banana cultivation [8,20,48], especially in Côte d'Ivoire [38,49] where these different levels of plant-parasitic nematode abundance have been revealed. Miscellaneous nematodes were more frequent in *D. adscendens* plots, probably due to the diversity and abundance of weeds in the plots covered by this plant.

5. CONCLUSION

Biological weed control trials with cover crops in industrial banana plantations in southeastern Côte d'Ivoire showed, overall, that both cover crops and banana plants were infested with the main parasitic nematodes evaluated. These infestations did not depend on weed management treatments. The cover crops did not significantly increase or decrease nematode dynamics in the plots. However, individuals extracted from the roots of cover crops, and particularly from *D. adscendens*, were more numerous than from banana roots. Furthermore, in terms of proportions, *Pratylenchus* spp., *Radopholus similis*, *Helicotylenchus* spp. and *Meloidogyne* spp. were the most abundant. *Rotylenchulus reniformis* and *Hoplolaimus pararobustus* as well as miscellaneous nematodes were in the minority. Thus, A. repens may be suggested in industrial banana plantations for an ecological, sustainable and healthy management of weediness. As for *D. adscendens*, it could also be associated with *A. repens* in banana plantations as a lure to divert nematodes from attacking banana roots while controlling weediness during the cultivation in a context of biological and sustainable agriculture without herbicides and nematicides.

ACKNOWLEDGEMENTS

The authors would like to thank the Interprofessional Fund for Agricultural Research and Consultancy (FIRCA) for financial support and Mr. TCHIMOU Stanislas and the Agricultural Company Kablan Joubin (SAKJ) for material and technical support.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Lassois L, Busogoro JP, Jijakli H. Banana: from its origin to its commercialization. Biotechnology Agronomy Society and Environment. French. 2009;13(4):575–586.
2. Qamar S, Shaikh A. Therapeutic potential and compositional changes of valuable compounds from banana-A review. Trends in Food Science & Technology. 2018;79: 1–9.
Available:https://doi.org/10.1016/j.tifs.2018.06.016
3. FIRCA, Fruit Sectors, Generated Technologies. Report, Abidjan, Côte d'Ivoire. 2020;20. Assessed 01 December 2021.
Available: https://firca.ci/wp-content/uplaods/2020/03/FRUIT-ET-TECHNO.pdf. French.
4. Israeli Y, Lahav E. Tropical agriculture: banana. Encyclopedia of Applied Plant Sciences. 2017;2(3):363–381.
Available: https://doi.org/10.1016/B978-0-12-394807-6.00072-1
5. Tardy F, Moreau D, Dorel M, Damour G. Trait-based characterization of cover plants' light competition strategies for weed control in banana cropping systems in the French West Indies. European Journal of Agronomy. 2015;71:10–18.
Available:https://doi.org/10.1016/j.eja.2015.08.002
6. Koch W, Beshir ME. Unterladstatter R. Crop losses due to weeds. In: Improving weed management, FAO Plant Production and Protection Paper, 44, Rome, Italy. 1982;154–165.
7. Quénéhervé P, Chabrier C, Auwerkerken A, Marie-Luce S. Weeds as potential reservoir of *Radopholus similis* in banana fields in Martinique; 32nd annual meeting of ONTA, 16–20/04/2000, Auburn, Alabama, USA. 2000;6.
8. Quénéhervé P, Chabrier C, Auwerkerken A, Topart P, Martiny B, Marie-Luce S. Status of weeds as reservoirs of plant-parasitic nematodes in banana fields in Martinique. Crop Protection. 2006;25: 860–867.
Available:https://doi.org/10.1016/j.cropro.2005.11.009
9. Kosma P, Ambang Z, Ten Hoopen GM, Begoude D. In: Fok, Michel (ed.), Ndoye, Ousmane (ed.), Koné, Siaka (ed.). AGRAR-2013: Agriculture and the challenge of food and nutrition in Africa:

What is the contribution of research in the cotton-producing countries? Gembloux: PAG, pp. 511–524. Conference of African Research on Agriculture, Food and Nutrition. 1, 2013-06-04/2013-06-06, Yamoussoukro, Côte d'Ivoire. French; 2015.

10. Chauvin C. Influence of service plants use on nematode communities and soil functions in a banana agro-ecosystem in intercultural phase. PhD thesis, Ecosystems and Agronomic Sciences, University of Montpellier, Montpellier, France. 2015:287. Available: https://agritop.cirad.fr/580083/. French.
11. Siddiqi MA. Studies on the effect of organic soil amendments on plant parasitic nematodes. Doctoral Thesis, Departement of botany, Aligarh Muslim University, Aligarh, Inde. 1986;402.
12. Kouadio YP, Tiébré M-S, Kassi NJ, N'Guessan KE. Floristic diversity and determinants of weediness in industrial banana plantations of Dabou in southern Côte d'Ivoire. Journal of Applied Biosciences. 2013;68:5404–5416. Available:https://doi.org/10.4314/jab.v68i0.95066 . French.
13. Pleasants JM, Oberhauser KS. Milkweed loss in agricultural fields because of herbicide use: effect on the monarch butterfly population. Insect Conservation and Diversity. 2013;6(2):135–144. Available: https://doi.org/10.1111/j.1752-4598.2012.00196.x
14. Decoin M. Glyphosate: what the CIRC, EFSA and ANSES say about it. Phytoma. French. 2016; 694:10–14.
15. Tilman D, Cassman KG, Matson PA, Naylor R, Polasky S. Agricultural sustainability and intensive production practices. Nature (London). 2002; 418 (6898): 671–677. Available:https://doi.org/10.1038/nature01014
16. Knezevic SZ, Jhala A, Datta A. Integrated Weed Management. In: Brian Thomas, Brian G Murray and Denis J Murphy (Ed). Encyclopedia of Applied Plant Sciences. 2017;3:459–462.
17. Deloné B. Agroecological alternatives to the use of chemical inputs in plantain plantations, the case of two Caribbean regions: Guadeloupe and Haiti. Doctoral thesis, Physiology and Biology of organisms-populations-interactions, University of Antilles and Guyane, Pointe-à-Pitre, France. French. 2014;130.
18. Tardy F, Damour G, Dorel M, Moreau D. Trait-based characterization of soil exploitation strategies of banana weeds and cover plant species. PLOSONE. 2017;12(3):e0173066. Available:https://doi.org/10.1371/journal.pone.0173066
19. Kouamé MLO, Egnankou MW, Traoré D. Ordination and classification of wetland vegetation in southeastern Côte d'Ivoire. African Agronomy. 2009;21(1): 1–13.
20. Lassoudière A. Banana and its cultivation. Editions Quæ, Versailles, France. French. 2007;383.
21. Koua G. Situation of coffee production in Côte d'Ivoire: case of Aboisso department, state of play and perspectives. Thesis for the Diploma of Advanced Agronomy. École Supérieure d'Agronomie (ESA), INPHB, Yamoussoukro, Côte d'Ivoire. French. 2007;151.
22. Godefroy F. Evolution of soil nutrient contents under banana cultivation. Chemical characteristics of the soils of Côte d'Ivoire. Fruits. 1976;31(2):75–83. Available: https://agritop.cirad.fr.414643/ French.
23. SECA-BRL/BDPA/RCT. Ivorian White Book. Ministries of Foreign Affairs, France. French. 2004;46.
24. Tabarant P. Effects of organic matter input on the biological control of parasitic nematodes of banana in Guadeloupe. Doctoral Thesis of Paris Tech, Institute of Life Sciences and Industries and the Environment, Paris, France. French. 2013;176.
25. Jenkins WR. A rapid centrifugal flotation technique for separating nematodes from soil. Plant Disease Reporter. 1964;48(19): 692.
26. Coolen WA, d'Herde CJ. A Method for the Quantitative Extraction of Nematodes from Plant Tissue. State Agricultural Research Centre, Ghent, Belgium. 1972;77.
27. Vawa OST, Gnonhouri GP, Adiko A, Zakra N, Otchomou A. Annual replanting of plantain orchards: a management strategy for endoparasitic nematodes *Radopholus similis* and *Pratylenchus coffea* in Côte d'Ivoire. Journal of Applied Biosciences. 2015;92 :8659–8666. Available:http://dx.doi.org/10.4314/jab.v92i1.10 . French

28. Siddiqi MR. Tylenchidae: Parasites of Plants and Insects. 2nd Edn, CABI Publishing, Wallingford, Oxon, UK. 2000;833.
29. Shurtleff MC, Averre CW. Diagnostic des maladies des plantes causées par les nématodes. Paul (Minnesota), American Phytopathological Society Press. 2000; 187.
30. Hunt DJ, Luc M, Manzanilla-López RH. Identification, Morphology and Biology of Plant Parasitic Nematodes. In Plant Parasitic Nematodes in Subtropical and Tropical Agriculture, 2nd Edition (eds M. Luc, R.A. Sikora, J. Bridge), CABI Publishing, UK. 2005:11–52.
Available:http://dx.doi.org/10.1079/9780851997278.0011
31. Mekete T, Dababat A, Sekora N, Akyazi F, Abebe E. Identifcation key for agriculturally important plant-parasitic nematodes Prepared for the International Nematode Diagnosis and Identifcation Course 2012-A manual for nematology. Mexico. 2012;39.
32. Yeo G, Sorho F, Johnson F, Kassi FM, Badou OJ, Koné D. Control of banana-parasitic nematode populations using *Azadirachta indica* and *Ocimum gratissimum* extract-based bionematicides in Côte d'Ivoire. International Journal of Current Research in Biosciences and Plant Biology. 2018;5(10):21–31.
Available:https://doi.org/10.20546/ijcrbp.2018.510.004
33. Koffi AL, Bongoua-Devisme AJ, Kouadio K-KH, Kouassi AL, Ettien DJB, Ndoye F, Diouf D. Evaluation of the mycorrhizal potential of polluted soils of the M'Ploussoue landfill in Bonoua, Ivory Coast. International Journal of Biological and Chemical Sciences. 2021;15(6):2297–2313.
Available:https://doi.org/10.4314/ijbcs.v15i6.5. French.
34. Guérout R. Relationship between populations of *Radopholus similis* Cobb and growth of banana. Fruits. 1972;27:331–337.
Available: https://agritop.cirad.fr/425146. French.
35. Yeo G, Kassi KFJ-M, N'Guessan PH, Fatogoma S, Koné D. Nematuregulatory effect in industrial banana plantations of service plants, *Crotalaria retusa, Cajanus cajan, Brachiaria decumbens* and *Panicum maximum* in fallow land in the South Comoe region of Côte d'Ivoire. International Journal of Plant Soil Science. 2020;32(17):11–19.
Available:https://doi.org/10.9734/ijpss/2020/v32i1730382
36. Kerridge PC, Hardy BE. Biology and agronomy of forage Arachis. CIAT Publication N° 240, Cali, Colombia. 1994;209.
37. Kouadio EYG, Cherif M, Kouame KF, Kassi KF-M, Kouame KD et al. Growth of Two Cover Crops [*Arachis repens* (L.) and *Desmodium adscendens* (Sw.)] and Effect on Weediness in Industrial Banana Plantations in the Southeastern of Côte d'Ivoire. European Journal of Scientific Research. 2022;161(01):47–62.
38. Gnonhouri GP. Integrated management of the migratory endoparasitic nematodes *Radopholus similis* (Cobb, 1913) and *Pratylenchus coffeae* (Zimmermann, 1898) by fallowing with Tithonia diversifolia (Helsl.) Gray (Asteraceae) in dessert banana (Cavendish) intercrop in Côte d'Ivoire. Doctorate from National Polytechnic Institut Félix Houphouët-Boigny, Polytechnic Doctoral School, Yamoussoukro, Côte d'Ivoire. French. 2020:211.
39. Chitwood DJ. Phytochemical based strategies for nematode control. Annual Review Phytopathology. 2002;40:221–225.
Available:https://doi.org/10.1146/annurev.phyto.40.032602.130045
40. Dorel M, Tixier P, Dural D, Zanoletti S. Alternatives to chemical inputs in banana cultivation. Innovations Agronomiques. French. 2011;16:1-11.
41. Tabarant P, Villenave C, Risède JM, Roger-Estrade J, Dorel M. Effects of organic amendments on plant-parasitic nematodes populations, root damage, and banana plant growth. Biology and Fertility of Soils. 2011;47(3):341–347.
Available: https://doi.org/10.1007/s00374-011-0541-9
42. Baghel JK, Das TK, Pankaj, Mukherjee I, Nath CP, Bhattacharyya R, Ghost S, Raj R. Impacts of conservation agriculture and herbicides on weeds, nematodes, herbicide residue and productivity in direct-seeded rice. Soil Tillage Research. 2020;201(104634):1–14.
Available:https://doi.org/10.1016/j.still.2020.104634
43. Coyne DL, Nicol JM, Claudius-Cole B. Plant nematodes. A practical guide to field

and laboratory techniques. SP-IPM Secretariat, International Institute of Tropical Agriculture (IITA), Cotonou, Benin, French. 2010;82.

44. Chabrier C, Quénéhervé P. Control of the burrowing nematode (*Radopholus similis* Cobb) on banana: Impact of the banana field destruction method on the efficiency of the following fallow. Crop Protection. 2003;22:121–127.
Available: https://doi.org/10.1016/S0261-2194(02)00121-7.
45. Duyck PF, Dortel E, Tixier P, Vinatier F, Loubana PM, Chabrier C, Quénéhervé P. Niche partitioning based on soil type and climate at the landscape scale in a community of plant-feeding nematodes. Soil Biology and Biochemistry. 2012; 44:49–55.
Available:https://doi.org/10.1016/j.soilbio.2011.09.014
46. Daneel M, Dillen N, Husselman J, De Jager K, De Waele D. Population census of nematodes in banana gardens in South Africa and Swaziland. InfoMusa. 2003;12 (2):8-11.
Available:www.musalit.org/seeMore.php?id=8147 . French.
47. Nandjui J, Gnonhouri PG, Tondoh JE, Tano Y. Response of nematodes to forest disturbance in the Oumé region, Côte d'Ivoire. Science Nature. French. 2007; 4(2):189–196.
Available:https://doi.org/10.4314/scinat.v4i2.42142 .
48. Gowen SR, Quénéhervé P, Fogain R. Nematode parasites of bananas and plantains. Plant parasitic nematodes in subtropical and tropical agriculture - M.Luc, R.A. Sikora and J. Bridge - Cabi Books (Eds), London, UK. 2005; 611-643.
Available:https://doi.org/10.1079/9780851997278.0611
49. Gnonhouri GP, Adiko A, Kobenan K, Aké S. Relationship between banana orchards longevity and infestation by the parasitic nematodes *Radopholus similis* and *Pratylenchus coffeae* in Côte d'Ivoire. Journal of Applied Biosciences. French. 2009;19:1082–1093.

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