

Original Research Article

Host status of two cover crops (*Arachis repens* L. and *Desmodium adscendens* Sw.) and effect on root infestation of the “Great Dwarf” dessert banana cultivar (*Musa* sp.) by plant-parasitic nematodes in Southeast Côte d’Ivoire

Comment [Ma1]: Influence of 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

ABSTRACT

In Côte d’Ivoire, industrial banana plantations are faced with the problem of weediness. However, the use of herbicides, particularly glyphosate, as a means of control presents significant risks for human health and the environment. In the context of the imminent abandonment of these products for more ecological alternatives such as cover crops, this study aimed to compare the nematode host status of the latter as well as their effect on the infestation of banana plantations by these parasites. The experimental design was a three-repeat Fisher block of three treatments consisting of *A. repens* and *D. adscendens* used as cover and two synthetic herbicides for weed management. The relative abundance and density of nematodes in the roots of banana and cover crops were assessed quarterly after extraction by double centrifugation-flotation method and enumeration under an optical microscope. 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*). On the whole, 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. Overall, 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., *Radopholus similis*, *Helicotylenchus* spp. and *Meloidogyne* spp. were most abundant. *Rotylenchulus reniformis* and *Hoplolaimus pararobustus* as well as various nematodes (plant parasites: *Hirschmanniella*, *Xiphinema* ..., and non-plant parasites: omnivorous, fungivorous, carnivorous, bacterivorous, ...) were in the minority. The results of this study could be useful in the biological management of weed in banana plantations without the risk of pest pressure.

Comment [Ma2]: It is possible to use an herbicide other than glyphosate, which has few residues in the environment and soil.

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 space [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]. Based on this observation, weed control in banana plantations appears to be essential for

Comment [Ma3]: and nutrients.

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 the use of cover crops that are capable of preventing weed emergence and growth [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 host status of nematodes of the species *A. repens* and *D. adscendens*, and to evaluate their effects on the infestation of banana roots by these parasites.

Comment [Ma4]: It was possible to use plant extracts or other herbicides to control the weeds associated with bananas

Comment [Ma5]: The most reliable practices are preventive, including sanitation and choice of plant varieties. You can reduce existing infestations through fallowing, crop rotation, and soil solarization. However, these methods reduce nematodes primarily in the top of the soil, so they are effective only for about a year

2. MATERIAL 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 of weed control by cover crops. 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 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 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].

Comment [Ma6]: Some types weed cannot be controlled by using cover crops, such as johnsongrass .

2.2 Plant Material

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 (*Musasp.*, 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. The banana plants were obtained after acclimatization in the nursery for 77 days from imported (South Africa) vitro-plants.

Comment [Ma7]: Why not plow the soil well before planting banana seedlings or add a pesticide to the soil to kill these worms

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. Weeds were treated with glufosinate (SL 200 g/l) at a rate

of 2 l/ha, using a knapsack sprayer, 2 weeks before transplanting the cover crops. Daba weeding was then carried out to remove all resistant weed strains. 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 watered. At the time of transplanting the cover crops, the plot contained 8-week-old banana plants.

Comment [Ma8]: What is meant here is to manually remove the weeds.

Comment [Ma9]: irrigated

2.3.2 Experimental design

The experiment was designed in a Fisher block with three replications of three treatments. The studied factor was the weed management method, with the modalities *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.

Comment [Ma10]: What are these methods? more explain

2.3.3 Maintenance of the trial

Trial maintenance consisted of manual removal and transport of resistant weeds from the banana plantation. For the control plots, weed management was done by applying glufosinate every 4 weeks during the first two months of the trial and then glyphosate (SL 360 g/l; 3 l/ha) every 8 weeks until the end of the experiment. These practices occurred 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.

Comment [Ma11]: Here, the glyphosate herbicide was used in two concentrations, and it must be noted why another herbicide was not used to control the existing weeds

Comment [Ma12]: The types of weed in the field were not mentioned

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 watered 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 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 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 sulfate solution (1.15 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 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 sulfate solution and homogenization. The supernatant was sieved (5 µm) and the contents of the sieve were collected by spraying water from a pissette 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:

$$\text{QER (\%)} = \left(1 - \frac{T_n}{T_0}\right) \times 100$$

With: T_0 = initial nematode population recorded per 100 g of roots ; T_n = 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 Evaluation of the effect of cover crops on parasitic nematodes of banana

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 *Radopholussimilis*, *Pratylenchus* spp, *Helicotylenchus* spp, *Meloidogyne* spp, *Rotylenchulusreniformis* and *Hoplolaimuspararobustus*. 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

A :*Pratylenchus* sp. ; B : *Radopholus similis* ; C :*Meloidogyne* sp.
 D :*Hoplolaimus pararobustus* ; E :*Helicotylenchus* sp. ; F : *Rotylenchulus reniformis*

Comment [Ma13]: It is preferable to mention the power of enlarging the figure

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.

Comment [Ma14]: The use of plant covers will increase soil moisture and thus will be a good environment for nematode reproduction

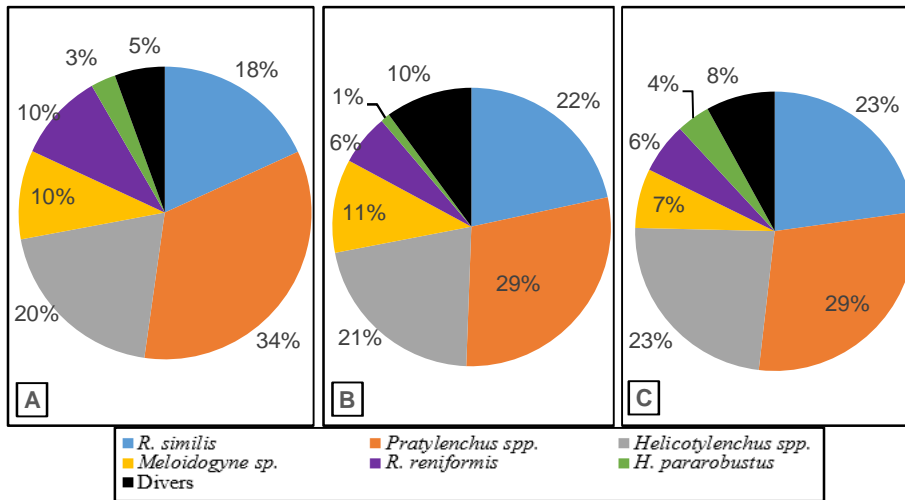


Fig. 2: Relative abundances of nematodes in banana roots associated with cover crops and control plots.

A: *A. repens* plots; B: *D. adscendens* plots and C: control plots (herbicide treated).

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).

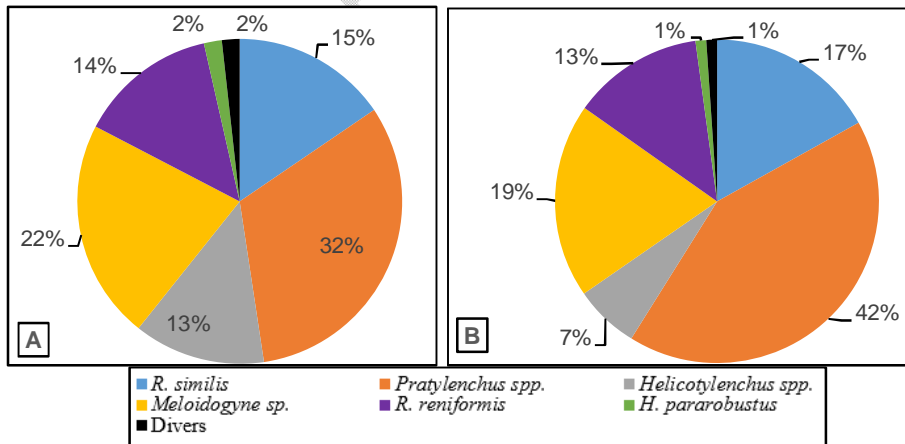


Fig. 3: Relative abundances of nematodes in the roots of cover crops used for weed management in banana plantations

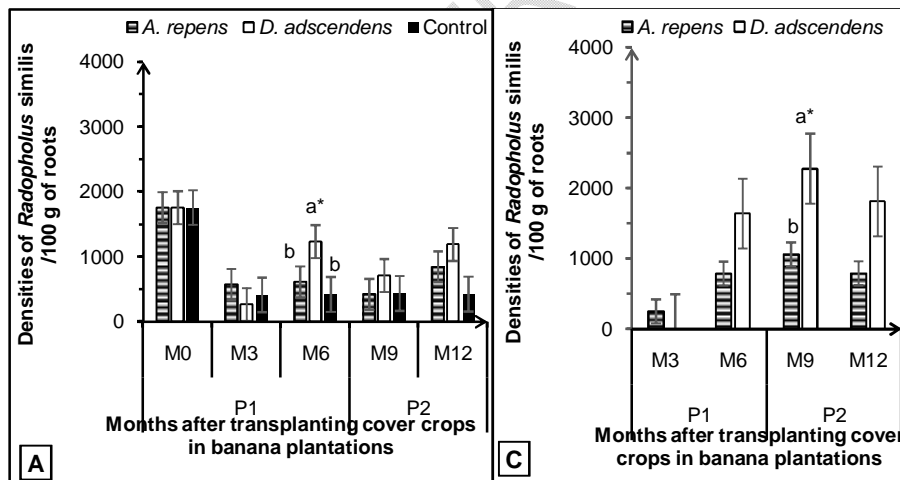
A : *A. repens* ; and B : *D. adscendens*

3.3 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*.



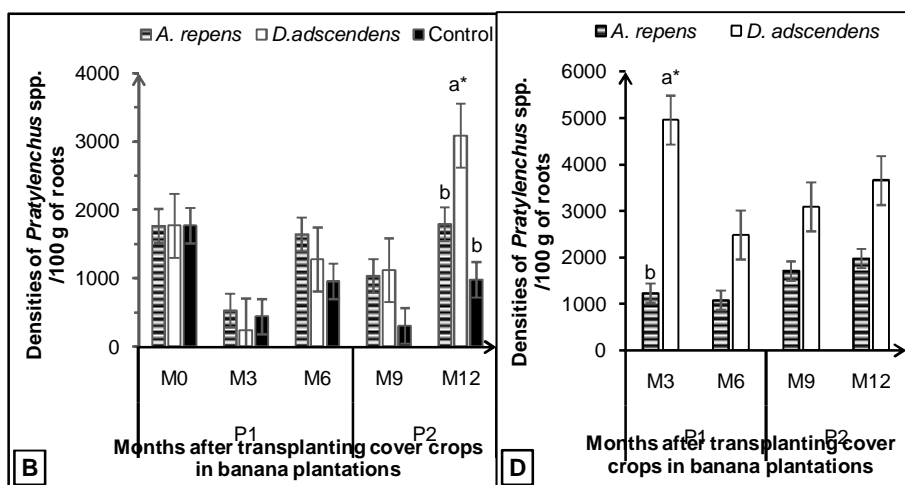


Fig. 4: Quarterly population trends of *R. similis* and *Pratylenchus* spp. from roots of banana and cover crops used for weed management

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 <i>R. similis</i> populations (%)						
	Months after transplanting cover crops in banana plantations						Cover crops roots
	Banana roots				Cover crops roots		
	P1		P2		P1	P2	
M ₃	M ₆	M ₉	M ₁₂	M ₆	M ₉	M ₁₂	
<i>A. repens</i>	67,26	-6,57	31,16	-99,74	-29,79	-63,15	52,23
<i>D. adscendens</i>	84,96	-366,39	42,34	-67,34	-	-39,05	45,77
Herbicides	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.

Comment [Ma15]: What are these herbicides?

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 <i>Pratylenchus</i> 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
<i>A. repens</i>	70,15	-210,50	36,81	-72,80	-53,78	-14,87	-47,58
<i>D. adscendens</i>	86,27	-425,11	12,17	-175,15	39,37	-0,52	-12,09
Herbicides	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.

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*.

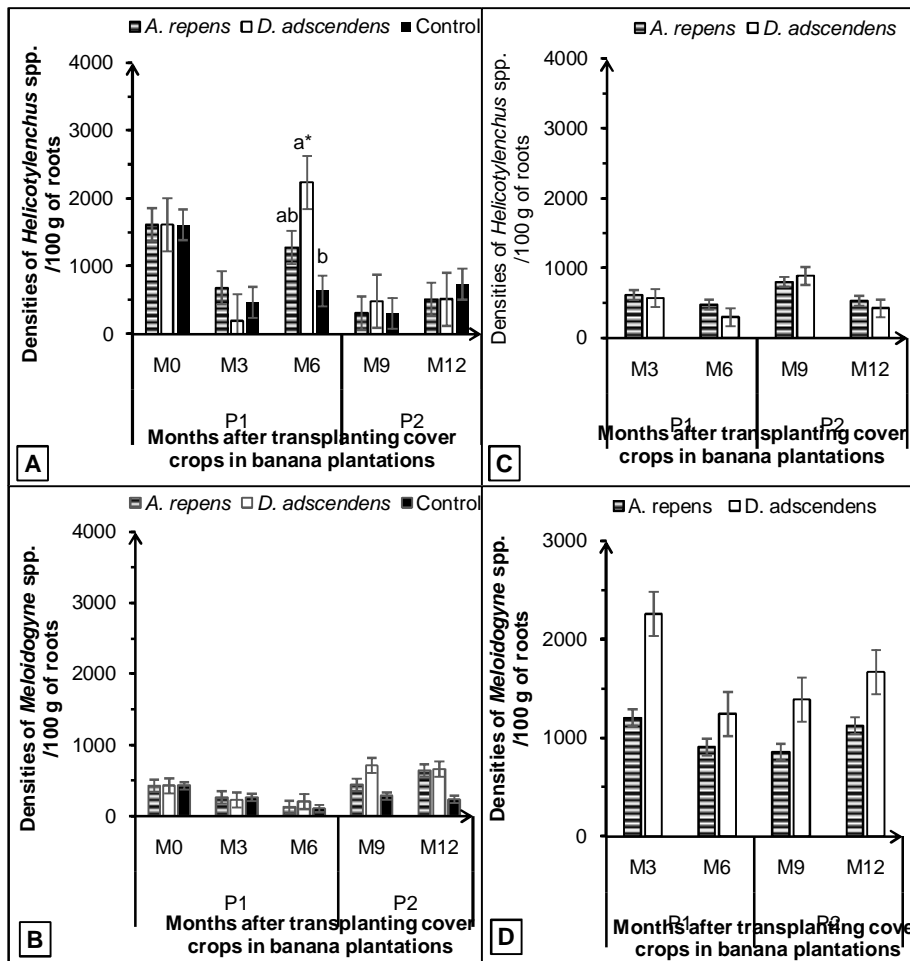


Fig. 5: Quarterly population trends of *Helicotylenchus* spp. and *Meloidogyne* spp. from roots of banana and cover crops used for weed management

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 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 <i>Helicotylenchus</i> 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
<i>A. repens</i>	57,73	-87,46	75,67	-65,71	84,74	-79,63	37,41
<i>D. adscendens</i>	87,81	-1 036,72	78,33	-5,96	92,42	- 90	62,96
Herbicides	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.

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 <i>Meloidogyne</i> 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
<i>A. repens</i>	38,07	51,26	-243,10	-45,73	43,43	40,05	-26,25
<i>D. adscendens</i>	46,66	9,27	-246,24	7,30	73,80	-22,62	-21,27
Herbicides	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 oryzae*, 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 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.

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

Comment [Ma16]: The researcher did not mention the effect of these factors on the characteristics of vegetative growth and yield.

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 used as a lure to divert nematodes from attacking banana roots.

Comment [Ma17]: Why is the nematode not eliminated by using some pesticides that are mixed with the soil and not the need to grow crops for loading, which is also a suitable environment for the growth and reproduction of nematodes?

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