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Research Article

PATHOLOGICAL ACTIVITIES OF *SCUTELLONEMA BRADYS* MORPHOTYPES ON TWO ECONOMICALLY IMPORTANT YAM CULTIVARS IN CÔTE D'IVOIRE

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ABSTRACT. *Scutellonema bradys* is one of the most economically important pre-harvest and post-harvest nematodes of yams. Three morphotypes of *S. bradys* occur in Côte d'Ivoire, but their pathogenicity on yams is unknown. Therefore, this study assessed the pathogenicity of three *S. bradys* morphotypes (LNE-Sb, MCN-Sb, and SC-Sb) on two economically important yam cultivars in Côte d'Ivoire. The study comprised two trials conducted under greenhouse and post-harvest conditions. Each one-month-old yam plant, cultivated under greenhouse conditions, was inoculated with 1000 individuals of a morphotype of *S. bradys*. Under post-harvest conditions, each tuber was buried in 1 L of sterilized soil and infested with 500 individuals of a morphotype of *S. bradys*. Trials lasted four months after inoculation. The tuber's sanitary state, dry rot index, final density, and reproductive fitness of the *S. bradys* morphotypes were assessed. Dry rot was observed on both freshly harvested and stored tubers. However, pathogenic activity varied among the morphotypes of *S. bradys*. The LNE-Sb morphotype from the dry tropical savannah zone caused the most severe dry rot (56.25% to 60.75% at harvest and 59.16% to 71.95% post-harvest). Its reproductive fitness on both yam cultivars ranged from 4.13 to 5.91. In contrast, the MCN-Sb morphotype from the transitional forest zone caused the least severe dry rot (15%), and reproductive fitness varied between 1.70 and 2.97 on both yam cultivars. The morphotypes of *S. bradys* exhibited varying levels of pathogenicity on yams. The morphotype from the dry tropical savannah zone was the most aggressive and reproductive, unlike that of the transitional forest zone. Effective management of *S. bradys* populations is essential to protect and sustain this source of income for yam farmers and traders in Côte d'Ivoire.

Keywords: *Côte d'Ivoire, Morphotypes, Pathogenicity, Scutellonema bradys, Yams*

INTRODUCTION

Yams (*Dioscorea* spp.) are the staple food for millions of people in West Africa [1]. It is the leading food crop in Côte d'Ivoire [2], with 7.96 million tons of tubers produced in 2023 [3]. People grow yams for their carbohydrate-rich edible tubers. Originally a subsistence crop, yams have now become a cash crop due to rising urban demand [4]. As a result, tubers of several *D. cayenensis-rotundata* cultivars, such as Kponan, Krenglè, and Assawa, are highly valuable in Côte d'Ivoire [2]. Yam production is a significant source of income, generating annual profits ranging from 857,000 to 863,000 FCFA (USD 1,419–1,429) per hectare [5]. Marketing yam tubers in urban areas is also profitable, offering a return on investment between 59% and 203% annually [5]. Yam production, processing, and marketing chains employ thousands of people [6].

Despite its socio-economic importance, yam production in Côte d'Ivoire is subject to various phytosanitary constraints, including dry rot attributed to *Scutellonema bradys*. As a migratory endoparasite, *S. bradys* moves through intracellular pathways in plant tissues. It causes cell wall disruption, loss of cell content, and necrosis [7]. As the process continues, necrosis spreads from cell to cell, forming a continuous layer of brown or black tissue beneath

the epidermis [8]. External cracks may appear on tuber surfaces. Some parts may also flake, exposing rotten tissue [9]. Dry rot is more prevalent and severe on post-harvest tubers [10]. It thus reduces the quality, commercial value, and edible parts of tubers [7]. As a result, traders must remove the rotten parts of infected tubers and sell the remaining parts at a low price. This situation represents a shortfall in earnings for traders who sell yam tubers at a cost per kilogram.

Furthermore, Kouakou et al. [11] identified three morphotypes of *S. bradys* associated with yam dry rot in Côte d'Ivoire. The agroecological zones closely correlate with the distribution of morphotypes. Individuals from the dry tropical savannah zone in the northeast are large. Those in the dense semi-deciduous forest zone in the center are small. On the other hand, those in the transitional forest zone, located in the Center-North, are of medium size. They found that the prevalence of yam dry rot varied according to agroecological zones. Yam dry rot was more prevalent and severe in the dry tropical savannah zone in northeastern Côte d'Ivoire than in the other agroecological zones. Given the presence of *S. bradys* morphotypes and the variation in the agroecological characteristics of the yam production zone, there may be pathological variability within the *S. bradys* population in Côte d'Ivoire. Therefore, this study aimed to assess the pathogenicity of three morphotypes of *S. bradys* on two economically important yam cultivars in Côte d'Ivoire.

MATERIALS AND METHODS

Experimental design

The study consisted of two trials: a post-harvest trial conducted under laboratory conditions and a pre-harvest trial conducted under greenhouse conditions. Each trial included two factors: yam cultivars and *S. bradys* morphotypes. Yam cultivars included two treatments: Kponan and Krenglè. Tubers of yam cultivars have a high economic value in Côte d'Ivoire. Three treatments corresponding to *S. bradys* morphotypes (LNE-Sb, MCN-Sb, and SC-Sb) were applied, along with an uninfected control, for each yam cultivar. According to Kouakou et al. [11], individuals of the LNE-Sb morphotype are large and originate from the dry tropical savannah zone of Côte d'Ivoire. In contrast, individuals of the MCN-Sb and SC-Sb morphotypes are medium-sized and small, respectively, and come from the transitional and semi-deciduous dense forest zones.

Post-harvest trial

Tubers of Kponan and Krenglè cultivars, belonging to the *D. cayenensis-rotundata* species, were purchased from the local market. Ninety-six tubers (48 per cultivar), weighing 516 to 673 g, were sampled and washed in soapy water. They were disinfected in a 1% sodium hypochlorite solution for 1 hour and rinsed three times with sterile distilled water.

Meanwhile, individuals of the three morphotypes of *S. bradys* were reared on white bean plants (*Vigna unguiculata*, cv. KN1) cultivated under greenhouse conditions at the experimental station of Nangui Abrogoua University (Côte d'Ivoire). Individuals of each morphotype of *S. bradys* were collected from the roots of bean plants using the maceration method [12]. The surface of nematodes was sterilized in a 1% sodium hypochlorite solution for 20 min and then rinsed with sterile distilled water [13]. Individuals were then exposed to a 2% gentamicin solution for 30 minutes [14]. They were rinsed with sterile distilled water and then resuspended in distilled water in tubes before soil infestation.

Soil infestation was performed using the modified method of Mwamula et al. [10]. A soil sample was collected from a fallow plot at Nangui Abrogoua University's experimental station. The soil was sterilized and divided into 96 polyethylene containers (1 L of soil per container). Each container's soil was infested with a 25 mL aliquot containing 500 individuals of one morphotype of *S. bradys*. The infested soil in each container was mixed thoroughly. One tuber

was buried in each container's soil, covering about 70% of it with infested soil. Forty-eight (48) tubers were used per cultivar, with 12 tubers per *S. bradys* morphotype and 12 control tubers. Control tubers were buried in soil moistened with 25 mL of sterile distilled water. Tubers were covered with perforated lids and incubated at room temperature for four months, during which pathological parameters were assessed.

Pathological parameters assessed were dry rot index, tuber weight loss, nematode density, and reproductive fitness. Three tubers were randomly selected per treatment each month. Only the part of the tuber in contact with the soil was considered for evaluating the dry rot index. This part of the tuber was peeled to highlight the state of the parenchyma. The severity of dry rot was assessed using the modified Plowright and Kwoseh [15] scale, and the dry rot index was calculated according to Zewain's [16] formula.

Tuber weight was measured using a balance each month after inoculation. Tuber weight loss was computed in the fourth month after inoculation using the Etudaiye et al. [17] formula:

$$\mathrm{TWL} = \frac{\mathrm{ITW}-\mathrm{FTW}}{\mathrm{ITW}} \times 100$$

Eqn. 1

TWL: Tuber weight loss; ITW: Initial tuber weight; FTW: Final tuber weight

Peels from each yam tuber were weighed using a balance. *Scutellonema bradys* individuals were extracted from five 10-g subsamples of yam peels using the maceration method [12]. They were counted under a microscope (bscope) using a counting plate. The density of *S. bradys* morphotypes in each yam tuber was calculated using the formula below.

$$\mathrm{DNN} = \frac{1}{\mathrm{n}}\sum\left(\frac{\mathrm{TPW}\times\mathrm{NN}}{10}\right)$$

Eqn. 2

DNT: Density of nematodes per tuber; TPW: Tuber peel weight; NN: Number of nematodes recovered from 10g of tuber peels; n: number of replicates

Nematodes were extracted from soil using the Whitehead tray method [12], with five 100-mL soil subsamples. Nematode density per 100 mL of soil was used to estimate the total nematode density in the soil of each container. The combined nematode densities from the tuber and its corresponding soil constituted the final population for each morphotype per container. Four months after inoculation, nematode reproductive fitness was calculated using the formula of Rivoal et al. [18], and the mean reproductive fitness was determined per morphotype.

$$\mathrm{Rf} = \frac{1}{\mathrm{n}}\sum\left(\frac{\mathrm{Pf}}{\mathrm{Pi}}\right)$$

Eqn. 3

Rf: Average reproductive fitness of *S. bradys* morphotype; Pf: final population of the morphotype; Pi: Initial population of the morphotype (500 individuals); n: number of replicates (three tubers).

Pre-harvest trial

A soil sample was collected from a fallow plot at the experimental station of the University Nangui Abrogoua (Abidjan, Côte d'Ivoire). It was sterilized and distributed in 40 perforated pots (3 L per pot). Ten nematode-free tubers of the yam cultivars Kponan and Krenglè were purchased from a local market. The tubers were cut into seedlings, weighing about 200 g. Yam seedlings were planted (one seedling per pot). Twenty seedlings were used per cultivar, with five per *S. bradys* morphotype and five control plants.

Then, an inoculum containing 1000 individuals of each *S. bradys* morphotype was prepared using yam peels. A preliminary test was performed to find the peel weight, from which it was possible to obtain 1000 individuals per morphotype of *S. bradys*. One month after the yam seedlings emerged, the top layers of soil were removed from each pot to expose the roots of the yam plants. Yam peels, measuring 7.03 g, 8.41 g, and 12.14 g and containing 1000 individuals of the LNE-Sb, SC-Sb, and MCN-Sb morphotypes, respectively, were spread on roots and then covered with the removed soil. The control yam plants were not inoculated. The yam plants were watered as required and staked in the second month after seedling emergence.

Yam plants were uprooted four months after inoculation. Roots, tubers, and adhering soil from each plant were bagged and sent to the laboratory for analysis. Roots and tubers were washed with running tap water, after which symptoms on both organs were described. The modified Plowright and Kwoseh [15] scale was used to assess the severity of dry rot on yam tubers. The dry rot index was calculated according to Zewain [16].

Nematodes from soil samples were extracted using the Whitehead tray method [12]. The total root and tuber peel weights of each yam plant were measured. Nematodes were extracted from 10 g of roots and 10 g of peels using the maceration method [12] with five replicates. The density of *S. bradys* in the roots and tubers of each yam plant was determined using equation 2. The final density (sum of individuals in soil, roots, and tubers) was calculated per morphotype and plant. The reproductive fitness of nematodes was calculated using equation 3.

Statistical analysis

The density of *S. bradys* was normalized using the log10 (x+1) function. However, the dry rot index, tuber weight loss, and reproductive fitness of *S. bradys* were normalized using the arcsin√p function [19]. A one-factor analysis of variance was performed at the 5% level for each parameter. If a significant difference occurred, Fisher's LSD test or Dunnett's test highlighted the level of pathogenicity of *S. bradys* morphotypes. The relationship between the dry rot index, tuber weight loss, reproductive fitness, and density of *S. bradys* was established. Statistical analyses were performed using Statistica 7.1 software (StatSoft, France).

RESULTS

Dry rot development on post-harvested yam tubers

State of yam tubers

After four months of storage, yam tubers buried in soil infested with *S. bradys* morphotypes showed dry rot. Their external appearance was similar to that of the control tubers (Fig. 1). As a result, no external symptoms were observed on the tubers. However, dry rot was noted under the epidermis of the inoculated tubers.

Dry rot index

The dry rot index on tubers ranged from 7.29% to 71.95%, depending on *S. bradys* morphotypes (Table 1). The morphotypes of *Scutellonema bradys* had a significant effect on the dry rot index ($P < 0.001$). Statistical analysis showed that the LNE-Sb morphotype caused the most severe dry rot, affecting 71.95% of the surface on Kponan tubers and 59.16% on Krenglè tubers. In contrast, the MCN-Sb morphotype resulted in the least severe dry rot, with less than 15% of the affected surface.

Fig. 1. *State of yam tubers four months after inoculation with Scutellonema bradys morphotypes a: tuber not inoculated; b: tuber inoculated with the LNE-Sb morphotype; c: tuber inoculated with the SC-Sb morphotype; d: tuber inoculated with the MCN-Sb morphotype.*

Table 1. *Dry rot index of yam tubers according to Scutellonema bradys morphotypes*

Scutellonema bradys morphotypes	Yam cultivars	
	Kponan	Krenglè
Control	0	0
SC-Sb	22.13 ± 4.17**b**	15.08 ± 2.11**b**
MCN-Sb	07.29 ± 3.42**c**	13.78 ± 2.94**b**
LNE-Sb	71.95 ± 2.19**a**	59.16 ± 3.51**a**
P	*0.000*	*0.000*

Values with the same letter in each column are statistically identical at the 5% level; p: Probability value; LNE-Sb, MCN, and SC-Sb: morphotypes of Scutellonema bradys from the North-East, Centre-North, and Centre of Côte d'Ivoire, respectively.

Tuber weight loss

Tuber weight loss ranged from 5.44% to 23.9% for Kponan tubers and from 4.84% to 15.67% for Krenglè tubers according to *S. bradys* morphotypes. Inoculating yam tubers with *S. bradys* morphotypes caused them to lose more weight than control tubers (3.81% for Kponan and 3.03% for Krenglè). Statistical analysis revealed that four months after inoculation, the morphotypes of *S. bradys* significantly affected tuber weight loss ($P < 0.001$). Yam tubers inoculated with the LNE-Sb morphotype showed the highest weight loss (23.9% for Kponan and 15.67% for Krenglè). In contrast, tubers inoculated with the MCN-Sb morphotype showed the lowest weight loss (5.44% for Kponan and 4.84% for Krenglè).

Table 2. *Yam tuber weight loss four months post-inoculation with Scutellonema bradys morphotypes*

Scutellonema bradys morphotypes	Yam cultivars	
	Kponan	Krenglè
Control	3.81 ± 1.19**d**	3.03 ± 0.73**d**
SC-Sb	8.90 ± 4.31**b**	6.86 ± 1.41**b**
MCN-Sb	5.44 ± 2.92**c**	4.84 ± 1.94c
LNE-Sb	23.9 ± 1.78**a**	15.67 ± 1.91**a**
P	*0.000*	*0.000*

Values with the same letter in each column are statistically identical at the 5% level; p: Probability value; LNE-Sb, MCN, and SC-Sb: morphotypes of S. bradys from the North-East, Centre-North, and Centre of Côte d'Ivoire, respectively.

Dynamics of Scutellonema bradys morphotypes

The density of *S. bradys* morphotypes increased during the four months of storage of yam tubers (Fig. 2A-B). The density of the SC-Sb morphotype varied from 500 to 1680 individuals in Kponan tubers. However, the density of the MCN-Sb morphotype increased from 500 to 1040 individuals, while the LNE-Sb morphotype went up from 500 to 2250. The density of SC-Sb and MCN-Sb morphotypes in Krenglè tubers rose from 500 to 1540 and 500 to 880 individuals, respectively. On the other hand, the density of the LNE-Sb morphotype increased from 500 to 2070 individuals.

Regardless of the tuber origin and the yam cultivar, the density of the *S. bradys* morphotypes dropped from 500 to less than 400 individuals during the first month after inoculation. Thereafter, the density of *S. bradys* morphotypes gradually increased in the stored tubers. Depending on the morphotypes of *S. bradys*, this density reached 2250 individuals in Kponan tubers and 2070 in Krenglè. During the trials, the LNE-Sb morphotype had the highest density (230 to 2250 individuals in Kponan tubers and 330 to 2070 individuals in Krenglè tubers). In contrast, the density of the MCN-Sb morphotype remained the weakest, with 240-1040 individuals in Kponan tubers and 170-880 individuals in those of Krenglè.

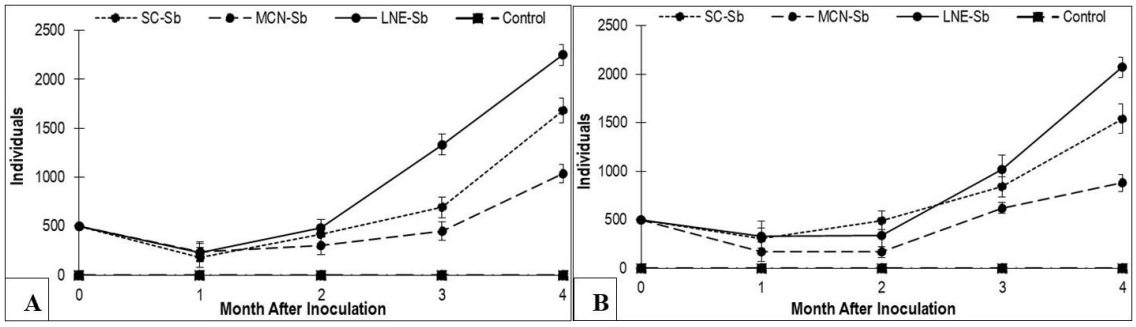

Fig. 2. *Fluctuation in the density of Scutellonema bradys morphotypes in stored yam tubers*
A: Kponan cultivar; B: Krenglè cultivar; LNE-Sb, MCN, and SC-Sb: morphotypes of Scutellonema bradys from the North-East, Centre-North, and Centre of Côte d'Ivoire, respectively.

Reproductive fitness of Scutellonema bradys morphotypes

The reproductive fitness of *S. bradys* morphotypes ranged from 2.08 to 4.52 for Kponan tubers and 1.75 to 4.13 for Krenglè tubers (Table 3). A highly significant difference was noted between *S. bradys* morphotypes based on their reproductive fitness ($P < 0.001$). The LNE-Sb morphotype exhibited the highest reproductive fitness in the tubers of both cultivars, scoring 4.52 in Kponan and 4.13 in Krenglè. However, the MCN-Sb morphotype had the lowest reproductive fitness in the tubers of both cultivars (2.08 for Kponan and 1.75 for Krenglè).

Table 3. *Reproductive fitness of Scutellonema bradys morphotypes on yam cultivars*

Scutellonema bradys morphotypes	Reproductive fitness	
	Kponan	Krenglè
Control	0	0
SC-Sb	3.35 ± 0.04**b**	2.89 ± 0.04**b**
MCN-Sb	2.08 ± 0.03**c**	1.75 ± 0.04**c**
LNE-Sb	4.52 ± 0.07**a**	4.13 ± 0.10**a**
P	*0.000*	*0.000*

Values with the same letter in each column are statistically identical at the 5% level; p: Probability value; LNE-Sb, MCN, and SC-Sb: morphotypes of Scutellonema bradys from the North-East, Centre-North, and Centre of Côte d'Ivoire, respectively.

Correlations between the pathological variables of Scutellonema bradys

Correlation coefficients between the pathological variables of *S. bradys* ranged from 0.71 to 0.99 (Table 4). The density of each *S. bradys* morphotype increased significantly with its reproductive fitness, as indicated by a highly significant positive correlation ($r = 0.99$; $P = 0.001$). The dry rot index and tuber weight loss increased significantly with the density of S. bradys morphotypes. This relationship was characterized by positive and highly significant correlation coefficients ($0.71 \leq r \leq 0.94$; $P < 0.001$). Finally, the dry rot index increased as the weight of the yam tuber decreased. This interaction is justified by positive and very highly significant correlation coefficients ($0.77 \leq r \leq 0.95$; $P < 0.001$).

Table 4. *Correlation coefficients between pathological variables of Scutellonema bradys in stored yam tubers*

Variables	Dry rot İndex	Tuber weight loss	Nematode density	Nematode multiplication
Kponan Cultivar				
Dry rot index	1.00			
Tuber weight loss	0.95 (0.00)	1.00		
Nematode density	0.94 (0.00)	0.94 (0.00)	1.00	
Nematode multiplication	0.95 (0.00)	0.94 (0.00)	0.99 (0.00)	1.00
Krenglè Cultivar				
Dry rot index	1.00			
Tuber weight loss	0.77 (0.00)	1.00		
Nematode density	0.85 (0.00)	0.71 (0.00)	1.00	
Nematode multiplication	0.89 (0.00)	0.77 (0.00)	0.99 (0.00)	1.00

Values in parentheses are P-values.

Dry rot development on yam plants

State of freshly harvested tubers

All *S. bradys* morphotypes induced symptoms on the roots and tubers of yam plants four months after inoculation (Fig. 3). Meanwhile, the roots and tubers of the control plants showed no apparent symptoms (Fig. 3A). Root necrosis (Fig. 3B) and yellow and brown lesions under the epidermis of freshly harvested tubers (Fig. 3C) were observed on inoculated yam plants.

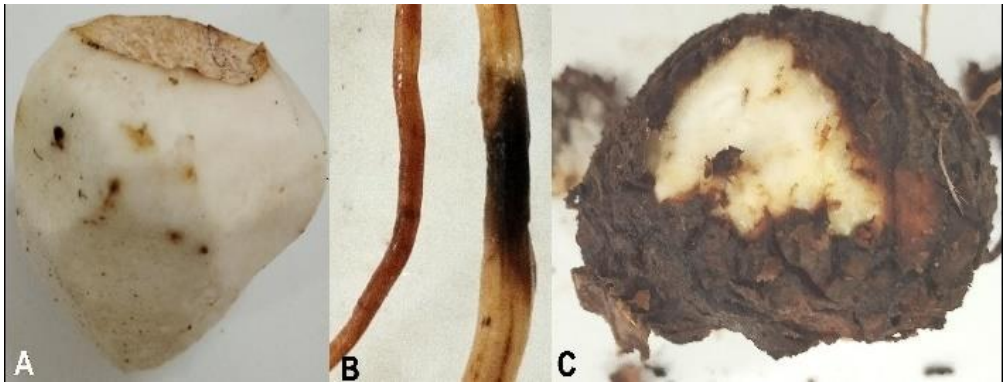

Fig. 3. *State of yam roots and tubers infected by Scutellonema bradys*
A. Control tuber; B. Root necrosis; C. Brown lesions under the tuber epidermis

Dry rot index

The dry rot index varied depending on the morphotypes of *S. bradys*. It ranged from 12.21% to 60.75% on Kponan tubers and from 11.42% to 56.35% on those of Krenglè (Table 5). The dry rot index was highly influenced by *S. bradys* morphotypes (*P < 0.001*). The LNE-Sb morphotype induced dry rot more severely than other morphotypes. It was 60.75% on the

Kponan tubers and 56.25% on those of Krenglè. The SC-Sb morphotype induced 30.89% and 26.14% dry rot index on the Kponan and Krenglè tubers, respectively. On the other hand, dry rot caused by the MCN-Sb morphotype was the least severe, with less than 15% of the infested surface on both cultivars.

Table 5. *Dry rot index of freshly harvested yam tubers according to Scutellonema bradys morphotypes*

Scutellonema bradys morphotypes	Yam cultivars	
	Kponan	Krenglè
Control	0	0
SC-Sb	30.89 ± 2.91**b**	26.14 ± 4.72**b**
MCN-Sb	12.21 ± 1.49**c**	11.42 ± 2.13**c**
LNE-Sb	60.75 ± 3.52**a**	56.25 ± 3.67**a**
P	*0.000*	*0.000*

Values with the same letter in each column are statistically identical at the 5% level; p: Probability value. LNE-Sb, MCN, and SC-Sb: morphotypes of Scutellonema bradys from the North-East, Centre-North, and Centre of Côte d'Ivoire, respectively.

Reproductive fitness of Scutellonema bradys

Based on *S. bradys* morphotypes (Table 6), the reproductive fitness ranged from 2.97 to 5.91 for Kponan tubers and 1.70 to 5.43 for Krenglè tubers. A highly significant difference was noted between *S. bradys* morphotypes based on their reproductive fitness ($P < 0.01$). The LNE-Sb morphotype had the highest reproductive fitness on both cultivars (5.91 on Kponan and 5.43 on Krenglè). Next was the SC-Sb morphotype, with 3.88 on Kponan and 2.69 on Krenglè. The MCN-Sb morphotype had the lowest reproductive fitness, with values of 2.97 in Kponan and 1.70 in Krenglè.

Table 6. *Reproductive fitness of Scutellonema bradys morphotypes on yam cultivars*

Scutellonema bradys morphotypes	Yam cultivars	
	Kponan	Krenglè
Control	0	0
SC-Sb	3.88 ± 0.56**b**	2.69 ± 0.77**b**
MCN-Sb	2.97 ± 0.56**b**	1.70 ± 0.24**c**
LNE-Sb	5.91 ± 0.57**a**	5.43 ± 0.41**a**
P	*0.002*	*0.000*

Values with the same letter in each column are statistically identical at the 5% level; p: Probability value. LNE-Sb, MCN, and SC-Sb: morphotypes of Scutellonema bradys from the North-East, Centre-North, and Centre of Côte d'Ivoire, respectively.

DISCUSSION

All morphotypes of *S. bradys* resulted in dry rot on yam tubers. This result highlights the pathological character of *S. bradys* morphotypes on yams (*D. cayenensis-rotundata*) in Côte d'Ivoire. However, dry rot is not perceptible externally on yam tubers four months after inoculation. Only brown lesions were observed under the yam tubers' epidermis. They indicated no external symptoms of dry rot when the disease is in its early stages. Several factors could be responsible for this result, including an insufficient nematode inoculum, experimental conditions, and yam cultivars that appear unfavorable to developing *S. bradys* morphotypes. However, in some cases, despite the high levels of *S. bradys* inoculum, the tubers do not exhibit external symptoms. Scratching off the epidermis revealed extensive rot that developed without any epidermal cracking or flaking.

In terms of inoculum, the applied level was one individual per 2 mL of soil. This inoculum level is lower than the one individual per milliliter of soil commonly used [8, 20]. Kolombia et al. [20] observed epidermal cracking of yam tubers following soil infestation with an estimated inoculum of one *S. bradys* individual per milliliter of soil. On the other hand, Kwoseh et al. [21] noted cracks in the yam epidermis when one *S. bradys* individual was present in 2 mL of soil. The discrepancy in results could stem from the fact that Kwoseh et al. [21] and Kolombia et al. [20] conducted their studies on developing yam plants. Immature roots and tubers with a soft, thinner epidermis were essential in increasing *S. bradys* populations. These characteristics allowed the development of dry rot and the appearance of epidermal cracking two months after inoculation. On the other hand, the current study used post-harvest yam tubers. Under such conditions, the nematodes must overcome the substantial physical barrier of the epidermis to infect the mature tuber. The epidermis of the mature tuber is rough, leathery, and thicker, making it less susceptible to nematode attack. This phenomenon could explain the development of internal dry rot four months after inoculation. Thus, prolonging the storage period of infected tubers would contribute to epidermal cracking and flaking.

Despite the development of internal dry rot, the density of each morphotype of *S. bradys* fluctuated in the tubers during the storage period. A significant decrease in the density of *S. bradys* morphotypes was noted one month after the inoculation of the tubers. The decline in the density of *S. bradys* morphotypes indicates the death of some individuals. The study was conducted with individuals at different stages of development (juveniles and adults). Furthermore, the change in environmental conditions during the assay likely affected the nematodes, ultimately leading to their death. Indeed, during inoculum preparation, nematodes were exposed to sodium hypochlorite [13] and gentamycin [14] solutions. Then, they were inoculated into the soil in a polyethylene container for several weeks with a thick, resistant epidermis of plant material. All these factors could potentially contribute to the mortality of vulnerable individuals. Dutta and Phani [22] said that changing environmental conditions affect plant-parasitic nematodes.

In contrast, one month after soil infestation, the density of *S. bradys* morphotypes increased with the duration of tuber storage. This suggests that the remaining individuals reproduce after the more vulnerable ones die. Several factors could contribute to the rise in nematode density, including nutrient availability, favorable conditions for reproduction, and stress on the yam tubers. Once inside the tubers, *S. bradys* individuals feed on the water-rich, starchy parenchyma cells, which also contain other important nutrients. The dry rot caused by *S. bradys* significantly reduces the level of starch, amylopectin, and amylose in tubers. As the tubers decompose, they release nutrients and sugars that feed the nematodes. The decay process increases nutrient availability, which in turn promotes the growth of *S. bradys* morphotypes. The presence of nutrients, a suitable storage environment, and the physical and biological stress on the tubers all contribute to the development of *S. bradys*. As a result, the severity of dry rot increases. These findings are consistent with Enchill et al. [23], who reported that *S. bradys* populations can become large in stored yam tubers, causing significant damage during storage.

Accordingly, the density of *S. bradys* populations in yam tubers increases alongside the dry rot index and tuber weight loss. This result could be due to the dehydration of infected tubers. Being a migratory endoparasite, *S. bradys* breaks down the host cell wall during its trophic activity [7]. This breakdown leads to the loss of cell contents and the formation of cavities, resulting in water loss from the yam tubers [9]. Thereby, when the density of *S. bradys* increases in tubers, its trophic activity rises, and much water is lost, which causes the tubers to dry out and lose weight. Additionally, the development of dry rot leads to the degradation of tuber cells, which in turn increases weight loss due to tissue degradation. This result differs from what Nzeako et al. [24] found, which showed that nematode density decreased as the water content in yam tubers (*D. cayenensis* and *D. rotundata*) increased. Whedie et al. [25]

indicated that weight loss was higher in nematode-infected yam tubers. Siddique and Grundler [26] added that nematode-feeding sites are areas of high metabolic activity. They stated that the infected areas act as metabolic sinks, feeding the nematodes.

Additionally, *S. bradys* morphotypes showed pathological variability in the yam cultivars. This difference in pathogenicity could be due to genetic variability between morphotypes and the specificity of the host-parasite interaction. *Scutellonema bradys* morphotypes originate from three distinct agroecological zones. According to Kouakou et al. [11], each morphotype of *S. bradys* exhibits specific morphological characteristics. Individuals from the dry tropical savannah zone are large, those from the semi-deciduous dense forest zone are small, and those from the transitional forest zone are medium-sized. This suggests that the *S. bradys* morphotype native to an agroecological zone may have developed specific abilities to infect the yams cultivated within that zone. Supporting this, Baimey et al. [27] noted that *S. bradys* populations originating from three localities in Benin (Save, Toui, and Glazoue) displayed differing pathogenicity in yam cultivars. Moreover, each plant exhibits a specific interaction with its parasite. This interaction depends on several factors, including the nutritional status and immune system of the host, the virulence and reproductive fitness of the parasite, and environmental conditions [28]. Some interactions favor the parasite or host, which could explain the pathological variability between *S. bradys* morphotypes.

Trials showed that the LNE-Sb morphotype from the dry tropical savannah zone is more aggressive than other morphotypes. This result corroborates that of Costa et al. [29], who found that Radopholus similis populations originating from Bahia and Pernambuco in Brazil were more aggressive than those from other areas on bananas. The capacity for environmental adaptation and the susceptibility of yam cultivars could justify the high pathogenicity of the LNE-Sb morphotype. Under similar experimental conditions, only the LNE-Sb morphotype demonstrated the highest reproductive fitness. It multiplied at least fourfold over four months under both laboratory and greenhouse conditions. Furthermore, the origin of this population of *S. bradys* is from an area that widely cultivates the Kponan cultivar [30]. Coevolution occurred between the Kponan cultivar and this dependent *S. bradys* morphotype. Although cropped in several areas, the Kponan and Krenglè cultivars appear susceptible to *S. bradys*, which originates in the dry tropical savannah zone. All these factors contribute to the development of dry rot, which is extremely severe on Kponan and Krenglè tubers.

CONCLUSION

This study indicates that all *S. bradys* morphotypes are pathogenic to yams (*D. cayenensis-rotundata*, cultivars Kponan and Krenglè). They cause pre-harvest and post-harvest dry rot on tubers. Pathogenicity varies according to the morphotypes of *S. bradys*. The LNE-Sb morphotype of *S. bradys*, originating from the dry tropical savannah zone of Côte d'Ivoire, exhibited the highest reproductive fitness and aggressiveness on both economically important yam cultivars. Given the parasitic risks and the high demand for these cultivars, effective management of *S. bradys* populations is necessary to protect and sustain this source of income for yam farmers and traders in Côte d'Ivoire.

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