Population of nematodes in soils under bananas, cv. Poyo, in the Ivory Coast.
5. Screening of nematicides and horticultural results

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SUMMARY

Screening of fumigant and non fumigant nematicides was conducted on banana plants on the Ivory Coast between 1981 and 1984 on mineral and organic soils. The methodology used permitted separation of the effects on the growth from the effects on the harvest. This study also revealed the different components of nematode damages in banana plantations in the Ivory Coast : *i)* lengthening of the vegetative cycle without reduction of the total harvest; *ii)* lengthening of the vegetative cycle and reduction of the total harvest; *iii)* reduction of the longevity of the plantation. These types of damages can be observed mixed in a same plantation with a severity in relation with the soil type. Nematode damage was more important on mineral soil than on organic soil. On organic soil, nematicidal and horticultural results from peat soil and clay soil were very different, despite an apparent similar nematode community. Numerous varied relationships were found between nematode species in portion of the root system and horticultural parameters. In this study, all chemicals did not show an equal efficacy in reducing the nematode population, optimizing the vegetative growth and increasing the total harvest. In mineral soils, aldicarb gave the more consistent results, both from a nematological and horticultural point of view.

RÉSUMÉ

Populations de nématodes associés à la culture du bananier cv. Poyo en Côte d'Ivoire.
5. Tests de nématicides et résultats agronomiques

Des essais comparatifs de produits nématicides, fumigants et non fumigants, ont été mis en place sur bananiers en Côte-d'Ivoire entre 1981 et 1984 sur sols minéraux et organiques. La méthodologie employée a permis de séparer les effets sur la croissance, des effets sur la récolte proprement dite. Cette étude a également permis de préciser les différents types de dommages agronomiques associés à la présence de nématodes et observés en Côte-d'Ivoire, à savoir : *i)* allongements des cycles végétatifs sans incidence sur la récolte; *ii)* allongements des cycles végétatifs et diminution de la récolte; *iii)* réduction de la durée de la plantation. Ces types de dommages pouvant être observés en mélange sur une même plantation et avec une sévérité en relation avec le type de sol. Les dommages agronomiques furent plus importants sur sols minéraux que sur sols organiques. Sur sols organiques, l'activité nématicide et les résultats agronomiques furent très différents sur argile et sur tourbe, même si la nématofaune associée était apparemment identique. De nombreuses corrélations furent trouvées entre l'infestation en nématodes de différentes parties du système racinaire et les résultats agronomiques mesurés. Dans cette étude, les produits testés n'ont pas démontré la même efficacité à contrôler les populations de nématodes, améliorer la croissance végétative et augmenter la récolte. Sur sols minéraux, l'aldicarbe a donné les résultats les plus constants, à la fois d'un point de vue nématologique et agronomique.

This study was conducted mainly to select chemicals that give acceptable nematode control and results in good growth and yield of bananas in the different soil types of the Ivory Coast. For additionnal details on the effect of nematicide application, dose and timing, readers are invited to refer to other works on this subject (Vilardebò *et al.*, 1988; Sarah *et al.*, 1988). This study was carried out between 1981 and 1984 in the banana producing areas during two consecutive cycles for each trial. The nematode communities encountered, their relations with the soil type, and the seasonal dynamics of populations have already been published (Fargette & Quénéhervé, 1988; Quénéhervé, 1988; 1989*a*; 1989*b*).

Material and methods

The trials were conducted on commercial, irrigated banana plantations when replanting in infested fields. Chemical and granulometric characteristics of these soils are given by Quénéhervé (1988).

For each trial, banana plants (*Musa* AAA, cv. Poyo) were planted with mother plants (bullheads). The trials were monitored for two vegetative cycles using normal cultural practices (double propping with bamboo, overhead sprinkler irrigation when needed, fertilization, control of weeds, control of the banana borer weevil and aerial spraying of fungicides). Fumigant nematicides

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were applied in the planting hole and in soil surface application during vegetation after planting, after dilution in 12 liters of water per plant, in a circle of 0.8 m diameter around the main sucker. EDB was used in place of DBCP when the latter became unavailable locally early in 1982. Non-fumigant nematicides were spread within the planting hole and on the soil surface during vegetation after planting in an area described above.

In the field, each banana plant was labelled with a code number and phenological stages were monitored weekly. Time of flowering, of harvest and bunch weight were recorded separately for each banana plant. Horticultural results were expressed as growth (intervals between phenological stages in days) and harvest. Parameters that were measured and compared (analysis of variance followed by a Newman-Keuls test) for each treatment included : the intervals between planting and flowering (IPF), planting and harvest (IPH), flowering and harvest (IFH), harvest and harvest (IHH), average bunch weight in kilograms (BW), percentage of harvested bunches (HB), total harvest weight (THW), percentage of uprooted plants (UP).

The growth data for each treatment were measured as the median observation (e.g. IPF recorded when fifty percent of the banana plants in the considered plot is flowered). The average weight per bunch (BW) was calculated as the mean at fifty percent of the harvest. The total harvest weight (THW) was calculated at the end of the harvest and expressed in metric tons per hectare. The application of the median over the arithmetic mean is sometimes preferred in biological populations with skewed distribution (Wisiol, 1987). Use of the median is also preferred in cases where it may be difficult or impossible to obtain and measure all of the items to calculate a mean (Sokal & Rholf, 1981). These two situations are commonly encountered in experiments on perennial plants in which the harvest may be spread over a long period of time. In banana plantations, particularly during the early cycles after planting, the bunch distribution curve is highly skewed to right. In these cases, the median is a more meaningful statistic than the arithmetic mean in the estimate of the growth parameters.

Nematode populations were sampled every 28-32 days for each treatment. Roots of bananas, and corm when mentioned, were sampled and analysed according to the method described by Quénéhervé and Cadet (1986) with six replicates per sampling date. Standardized extraction techniques were used on soil (Seinhorst, 1962) and roots (Seinhorst, 1950). Results of infestation were expressed as nematode densities per cubic decimetre of soil and per gram of roots or corm, belonging to the mother plant or bullhead (RPM, EPM), of the first principal sucker (R1Y, E1Y), of the second principal sucker (R2Y, E2Y), of the pruned suckers (R2YØ, E2YØ), etc. In order to estimate the level of infestation corresponding to the whole plant for each sampling date, a " global root infestation " was calculated as the mean of the partial infestation on the different parts of the root system. Then, a statistical analysis was conducted on the different nematode fluctuations by a Friedman two-way analysis of variance followed by a multiple range test, in order to classify the tested treatments according to their efficacy in reducing the nematode populations.

Cumulative sums of the nematode infestation were calculated (by species and for all species combined), occuring respectively on the roots (and/or the corm) of the main sucker, of the entire root system, of the main and following suckers. Correlations were conducted in order to find relationships between horticultural results and levels of nematodes $[\log_{10}(x + 1)]$, as calculated above. Linear regression equations were computed for relationships having significant ($P < 0.05$) correlation coefficients. Plots treated with EDB were excluded because of evident phytotoxicity on the reproductive phase during the second cycle at site 1 (Dominique 1) and at site 5 (Yace 25).

Rainfall records were collected daily on each site. Canopy level irrigation occurred in the dry season (about 24 mm of water per irrigation per week).

Site 1, Dominique 1

This trial was located near Azaguié on a ferrallitic soil (24.9 % clay, 13.4 % silt, 59.6 % sand, 1.1 % org. matter, pH 5.5) with a sloping terrain.

Treatments were arranged in a completly randomized design with six replications. Each plot consisted of at least 48 banana plants. Six treatments were applied : 1,2-dibromo-3 chloropropane (DB), [15 cm³/plant, DBCP 75 EC] or 1,2-dibromoethane (DB), [8 cm³/plant, EDB 95 EC]; fenamiphos (FEN), [3 g a.i./plant, Nemacur ® 10G, Bayer]; isazophos (ISA), [2.5 g a.i./plant, Miral ® 10G, Ciba-Geigy]; carbofuran (CAR), [4 g a.i./plant, Furadan ® 10G, FMC]; aldicarb (ALD), [4 g a.i./plant, Temik ® 10G, Rhône-Poulenc]; untreated control (CTR). Treatments were applied on a regular basis every three to four months after planting with bullheads on June 5, 1981 (9 Nov. 81; 19 Mar. 82; 27 Jul. 82; 9 Nov. 82; 25 Mar. 83).

Site 2, Monet 12

This trial was located in a valley near Azaguié on a sandy clay soil (14.0 % clay, 16.4 % silt, 64.7 % sand, 2.9 % org. matter, pH 6.3).

Treatments, identical to those applied at site 1, were arranged in a randomized complete block design with six replications. Each plot consisted of at least 48 banana plants. Blocks were separated from one another by a drain. Treatments were applied on a regular basis every three to four months after planting with bullheads on June 25, 1981 (10 Nov. 81; 19 Mar. 82; 27 Jul. 82; 24 Nov. 82; 1 Apr. 83).

Site 3, Aboisso Bia 3-66

This trial was located near Aboisso on an alluvial soil (21.7 % clay, 50.0 % silt, 23.0 sand, 2.5 % org. matter, pH 5.9).

Treatments were identical to those applied at sites 1 and 2 except for an additional treatment with isofenphos (ISO), [3 g a.i./plant, Oftanol ® 10G, Bayer]. Treatments were arranged in a randomized complete block design with six replications. Each plot consisted of at least 48 banana plants. Blocks were separated from one another by a drain. Treatments were applied on a regular basis every three to four months after planting with bullheads on April 19, 1982 (20 Jul. 82; 16 Nov. 82; 22 Mar. 83; 26 Jul. 83; 22 Nov. 83; 17 Mar. 83).

Site 4, Agbo 115

This trial was located in the Nieky valley on an almost pure clay soil (61.2 % clay, 20.5 % silt, 0.4 % sand, 14.2 % org. matter, pH 4.0).

Treatments were arranged in a randomized complete block design with six replications. Each plot consisted of at least 48 banana plants. Blocks were separated from one another by a drain. Six treatments were applied : 1,2-dibromo-3 chloropropane (DB), [15 cm^3/plant, DBCP 75 EC] or 1,2-dibromoethane (DB), [8 cm^3/plant, EDB 95 EC]; fenamiphos FEN), [3 g a.i./plant, Nemacur ® 10G, Bayer]; isazophos (ISA), [2.5 g a.i./plant, Miral ® 10G, Ciba-Geigy]; carbofuran (CAR), [4 g a.i./plant, Furadan ® 10G, FMC]; aldicarb (ALD), [4 g

Table 1

Percentage reduction of the cumulative nematode populations in soil, roots and corm during the first and second vegetative cycle relative to treatments at site 1 (Dominique 1) and site 2 (Monet 12).

	Helicotylenchus			*Hoplolaimus*			*Radopholus*			*Cephalenchus*
	soil	roots	corm	soil	roots	corm	soil	roots	corm	soil
Site 1										
1st cycle										
Aldicarb (ALD)	77.8	94.2	*	— 9.0	37.2	*	86.5	79.5	73.3	68.0
Carbofuran (CAR)	73.0	97.0	*	— 20.4	32.0	*	18.8	35.2	9.2	72.6
DBCP (DB)	84.5	98.8	*	— 3.5	27.5	*	78.2	66.5	82.1	83.7
Fenamiphos (FEN)	16.3	32.5	*	— 9.9	42.6	*	26.3	30.4	11.5	65.6
Isazophos (ISA)	88.1	93.6	*	8.6	41.5	*	— 40.2	43.5	37.2	56.0
2nd cycle										
Aldicarb (ALD)	98.8	99.4		33.3	— 97.3		68.4	40.7		64.9
Carbofuran (CAR)	92.5	96.4		— 14.2	— 77.4		65.4	2.8		13.5
DBCP/EDB (DB)	98.0	99.3		36.7	— 15.0		68.4	0.4		85.3
Fenamiphos (FEN)	56.5	63.7		15.9	— 17.2		47.9	0.1		53.8
Isazophos (ISA)	90.7	91.9		55.1	38.7		72.4	1.6		37.5
Site 2										
1st cycle										
Aldicarb (ALD)	49.4	90.3	*	49.4	53.5	*	77.6	82.7	88.8	66.8
Carbofuran (CAR)	86.5	98.9	*	50.6	56.9	*	32.9	45.5	49.4	84.9
DBCP (DB)	69.4	89.2	*	12.0	34.2	*	56.6	79.3	80.1	65.9
Fenamiphos (FEN)	83.0	90.5	*	49.4	42.4	*	65.1	77.7	51.0	75.4
Isazophos (ISA)	94.5	99.2	*	56.1	55.6	*	59.2	50.7	34.4	46.0
2nd cycle										
Aldicarb (ALD)	91.7	88.1		45.6	16.1		72.7	90.7		60.5
Carbofuran (CAR)	87.5	87.1		35.5	16.4		— 45.1	26.0		34.3
DBCP/EDB (DB)	99.9	98.3		7.5	41.9		5.3	43.0		4.1
Fenamiphos (FEN)	99.9	80.8		19.0	17.2		65.2	18.9		68.0
Isazophos (ISA)	97.9	97.9		45.6	53.4		3.0	39.2		36.1

Asterisk (*) indicates not calculable percentage reduction due to low levels and inconsistencies in the recovery of these species from the corm tissue.

Table 2

Classification of the treatments according to the sum of ranks at site 1 (Dominique) and site 2 (Monet 12) for the first and second vegetative cycle (Friedman Two-way analysis of variance). Sums of ranks in a column followed by the same letter are not significantly different according to a multiple range test ($P > 0.05$).

Helicotylenchus		*Hoplolaimus*		*Radopholus*			*Cephal.*	Comb. Endo.
soil	roots	soil	roots	soil	roots	corm	soil	
SITE 1								
1st cycle								
p = 0.0203	p = 0.0001	NS	NS	p = 0.0033	p = 0.0066	p = 0.0012	NS	p = 0.0001
ALD (20)	DB (16.5)			ALD (18.5)	ALD (18)	DB (18.5)		ALD (159.5) *a*
DB (21.5)	CAR (20)			DB (20)	DB (23.5)	ALD (18.5)		DB (167.5) *ab*
ISA (22)	ALD (27.5)			FEN (22.5)	CAR (32.5)	ISA (29)		ISA (203.5) *abc*
CAR (28.5)	ISA (30.5)			CTR (30.5)	ISA (33)	CAR (38)		CAR (223) *bcd*
FEN (36.5)	FEN (45)			CAR (33.5)	FEN (35)	DEN (42)		FEN (233.5) *cd*
CTR (39.5)	CTR (49.5)			ISA (43)	CTR (47)	CTR (43)		CTR (273) *d*
2nd cycle								
p = 0.0001	p = 0.0001	NS	p = 0.0007	NS	NS	*	p = 0.0189	p = 0.0001
ALD (14)	ALD (15.5)		ISA (10.5)				DB (14.5)	ALD (131) *a*
DB (16)	DB (16)		CTR (23)				ALD (22.5)	DB (139) *a*
CAR (26)	CAR (21.5)		FEN (27)				FEN (29.5)	ISA (143) *ab*
ISA (29)	ISA (29)		DB (28.5)				ISA (31)	CAR (181.5) *abc*
FEN (36)	FEN (38)		ALD (39)				CAR (34.5)	FEN (194.5) *bc*
CTR (47)	CTR (48)		CAR (40)				CTR (36)	CTR (219) *c*
SITE 2								
1st cycle								
p = 0.0054	p = 0.0009	NS	p = 0.0056	p = 0.0387	p = 0.0019	p = 0.0003	p = 0.0001	p = 0.0001
ISA (19)	CAR (22.5)		ISA (21.5)	ALD (20.5)	ALD (19)	ALD (15)	CAR (15.5)	ALD (177) *a*
FEN (19)	ISA (22.5)		CAR (22)	FEN (29)	DB (25)	DB (21)	FEN (21.5)	ISA (192.5) *a*
DB (26.5)	DB (30.5)		ALD (25)	DB (30)	FEN (26)	CAR (31.5)	DB (33)	CAR (198.5) *a*
CAR (27)	ALD (32)		FEN (34.5)	ISA (31)	ISA (34)	FEN (34.5)	ALD (33.5)	FEN (203.5) *a*
ALD (36.5)	FEN (33)		DB (41)	CAR (34)	CAR (35)	ISA (40)	ISA (35)	DB (213) *a*
CTR (40)	CTR (48.5)		CTR (45)	CTR (44.5)	CTR (50)	CTR (47)	CTR (50.5)	CTR (317.5) *b*
2nd cycle								
p = 0.0001	p = 0.0001	NS	p = 0.0041	p = 0.0138	p = 0.0004	*	NS	p = 0.0001
DB (24.5)	ISA (18.5)		ISA (15.5)	ALD (19)	ALD (10)			ISA (148.5) *a*
FEN (24.5)	DB (19.5)		DB (22)	FEN (21)	FEN (30)			ALD (153) *a*
ISA (27)	ALD (30)		FEN (34)	ISA (32)	DB (32)			DB (177.5) *ab*
ALD (29.5)	CAR (32.5)		CAR (37.5)	DB (38.5)	ISA (33)			FEN (178.5) *ab*
Car (35)	FEN (37.5)		ALD (39)	CAR (39)	CAR (38)			CAR (210) *bc*
CTR (48.5)	CTR (51)		CTR (41)	CTR (39.5)	CTR (46)			CTR (266.5) *c*

Asterisk (*) indicates unavailable date; NS : not significant; Comb. Endo. : Combined endoparasites; *Cephal* : *Cephalenchus;* the other abbreviations used for chemicals are defined in Table 1.

Table 3

Percentage reduction of the cumulative nematode populations in soil and roots during the first and second vegetative cycle relative to treatments at site 3 (Bia 3-66).

	Helicotylenchus		*Hoplolaimus*		*Pratylenchus*		*Radopholus*		*Ceph.*	*Hemi.*	*Rotyl.*
	soil	roots	soil	roots	soil	roots	soil	roots	soil	soil	soil
1st cycle											
Aldicarb (ALD)	75.2	95.0	77.1	12.3	*	3.6	72.6	76.3	72.3	6.9	40.1
Carbofuran (CAR)	65.0	79.3	90.6	73.2	*	90.3	26.4	39.7	84.8	18.1	75.2
DBCP (DB)	78.9	96.6	50.0	54.7	*	95.4	43.5	16.4	91.6	— 40.7	93.9
Fenamiphos (FEN)	69.7	85.8	68.2	46.0	*	— 6.9	55.9	38.2	84.5	87.3	55.3
Isazophos (ISA)	87.4	86.6	84.4	53.9	*	82.8	60.8	54.1	86.1	77.4	91.2
Isofenphos (ISO)	60.6	47.9	72.9	45.4	*	46.9	66.0	42.4	84.4	— 4.4	26.5
2nd cycle											
Aldicarb (ALD)	96.3	94.8	32.0	— 2.2	71.4	86.5	48.0	26.5	76.2	60.0	— 114.1
Carbofuran (CAR)	75.7	86.9	70.1	1.4	92.9	93.9	22.0	— 7.9	91.7	— 37.5	1.4
DBCP/EDB (DB)	95.2	98.0	62.9	15.1	91.1	96.0	31.0	33.7	80.7	12.5	93.0
Fenamiphos (FEN)	72.9	33.3	19.6	17.0	67.9	81.9	19.0	22.1	53.2	3.1	93.0
Isazophos (ISA)	96.3	93.0	82.5	63.6	92.9	83.6	19.0	28.2	89.9	100.0	95.8
Isofenphos (ISO)	93.3	62.1	74.2	54.8	23.2	73.6	45.0	— 4.1	95.4	— 225.0	96.5

Asterisk (*) indicates not calculable percentage reduction due to low levels and inconsistencies in the recovery of this species from the soil. *Ceph.* = *Cephalenchus; Hemi.* = *Hemicycliophora; Rotyl.* = *Rotylenchulus.*

Table 4

Classification of the treatments according to the sum of ranks at site 3 (Bia 3-66) for the first and second vegetative cycle (Friedman Two-way analysis of variance). Sums of ranks in a column followed by the same letter are not significantly different according to a multiple range test (P > 0.05).

Helicotylenchus		*Hoplolaimus*		*Pratylenchus*		*Radopholus*		*Ceph.*	*Hemi.*	*Rotyl.*	Comb. Endo.
soil	roots	soil	roots	soil	roots	soil	roots	soil	soil	soil	
1st cycle											
p = 0.0118	p = 0.0001	NS	p = 0.0034	*	p = 0.0002	p = 0.0198	p = 0.0001	p = 0.0013	p = 0.0312	NS	p = 0.0001
ISA (30)	DB (25.5)		CAR (25.5)		DB (23.5)	ISO (28.5)	ALD (19.5)	ISA (33)	ISA (28)		CAR (343) *a*
DB (32)	ALD (30)		ISA (31)		CAR (26.5)	ALD (38.5)	FEN (36)	DB (38)	FEN (31)		ISA (352) *a*
FEN (41.5)	CAR (32.5)		DB (40)		ISA (41)	FEN (41)	ISA (37)	FEN (38)	DB (44)		DB (354.5) *a*
ALD (45.5)	ISA (48.5)		ISO (47.5)		ISO (49.5)	ISA (44.5)	ISO (42)	ISO (42)	ALD (49)		ALD (373) *a*
CAR (45.5)	FEN (51)		FEN (49.5)		ALD (49.5)	CAR (45)	CAR (44.5)	CAR (42)	CTR (49)		ISO (405) *a*
ISO (49.5)	CTR (59)		ALD (53)		FEN (57)	DB (45.5)	DB (59)	ALD (43)	ISO (53)		FEN (412) *a*
CTR (64)	ISO (61.5)		CTR (61.5)		CTR (61)	CTR (65)	CTR (70)	CTR (72)	CAR (54)		CTR (532.5) *b*
2nd cycle											
p = 0.0001	p = 0.0001	p = 0.024	p = 0.0006	p = 0.0493	p = 0.0011	NS	p = 0.0029	p = 0.0004	p = 0.0071	p = 0.001	p = 0.001
DB (24)	DB (20.5)	ISA (20)	ISA (18.5)	ISA (28)	DB (21)		ALD (26)	ISO (20.5)	ISA (16)	ISA (25)	ISA (249) *a*
ISA (24)	ALD (24.5)	ISO (30.5)	ISO (22.5)	CAR (29.5)	ISA (35)		DB (28)	CAR (29)	ALD (26)	ISO (27.5)	DB (267) *ab*
ALD (26)	ISA (28)	CAR (31)	FEN (46)	DB (31)	CAR (35.5)		ISA (31)	DB (29.5)	ISO (39.5)	FEN (28.5)	ALD (316) *abc*
ISO (27)	CAR (34)	DB (35)	DB (46.5)	FEN (34)	ALD (36.5)		FEN (37.5)	ISA (30.5)	DB (40.5)	DB (31)	ISO (343) *bc*
CAR (43.5)	FEN (54.5)	ALD (43.5)	ALD (47)	ALD (38)	FEN (40)		CAR (48.5)	ALD (39.5)	CTR (42.5)	ALD (45.5)	CAR (356) *c*
FEN (49.5)	ISO (55.5)	FEN (43.5)	CTR (47.5)	ISO (45)	ISO (50.5)		CTR (53)	FEN (51)	FEN (43.5)	CTR (47)	FEN (377.5) *c*
CTR (58)	CTR (63)	CTR (48.5)	CAR (50)	CTR (46.5)	CTR (61.5)		ISO (56)	CTR (52)	CAR (44)	CAR (47.5)	CTR (471.5) *d*

Asterisk (*) indicates unavailable data; NS = not significant; Comb. Endo. = Combined endoparasites; *Ceph.* = *Cephalenchus; Hemi.* = *Hemicycliophora; Rotyl.* = *Rotylenchulus;* the other abbreviations used for chemicals are defined in Table 3.

a.i./plant, Temik ® 10G, Rhône-Poulenc]; untreated control (CTR). Treatments were also applied on a regular basis every three to four months after planting with bullheads on April 29, 1981 (3 Aug. 81; 19 Nov. 81; 18 Mar. 82; 12 Aug. 82; 16 Nov. 82; 10 Mar. 83).

Site 5, Yace 25

This trial was located in the Nieky valley on a pure peat soil (pH 3.4).

Treatments in this experiment were arranged in a randomized complete block design with six replications. Each plot consisted of at least 48 banana plants. Blocks were separated from one another by a drain. Treatments were identical to those applied at site 4 with an additional treatment before planting with methyl bromide (MBR) [100 g a.i./m^2] and no further application of any chemicals during vegetation.

All other treatments were applied on a regular basis every three to four months after planting with bullheads on April 7, 1982 (28 Jul. 82; 18 Nov. 82; 31 Mar. 83; 13 Jul. 83; 3 Nov. 83).

Results

NEMATICIDAL ACTIVITY

Site 1, Dominique 1

At this site, *Helicotylenchus multicinctus, Radopholus similis* and *Hoplolaimus pararobustus* were 50.7 %, 38.9 % and 9.6 % of the endoparasitic population, respectively.

The results of the nematicidal treatments are summarized in terms of percentage reduction of the cumulative nematode populations in soil, roots and corm (for *R. similis*) during the first and second cycle (Table 1). Results vary greatly depending on species; the best results in terms of population reduction were obtained with the population of *H. multicinctus*, regardless of the cycle or of the localization of the infestation (soil, roots). There was a significant increase in the population of *H. pararobustus* during the second cycle with some chemicals. With the exception of aldicarb, the effects of chemicals on the endoparasitic population of *R. similis* decreased strongly with the time from the first to the second cycle.

Nematode population data observed during the first and second cycle were analysed by the Friedman two-way analysis of variance (Table 2). Classifications of the treatments according to the sum of the ranks were almost identical for each nematode species as for each localization of the infestation (soil, roots or corm). There is only one exception with *H. pararobustus* in the roots during the second cycle which is an almost reverse classification. No significant differences between treatments were found on the control of the population of *R. similis* during the second cycle but treatment with aldicarb seemed to be most effective. According to this classification during the two cycles, two groups of treatments differ significantly from one to the other, and for the combined endoparasites, the best control of nematode populations was obtained after applications of aldicarb, DBCP/EDB, or isazophos.

Site 2, Monet 12

At this site *H. multicinctus, R. similis, H. pararobustus* were 8.2 %, 52.0 %, and 23.0 % of the endoparasitic population, respectively.

Results observed at this site (Table 1) were very similar to those obtained at site 1. Once again, the best results, in terms of reduction of population, were obtained with the population of *H. multicinctus*. The effects of chemicals on the endoparasitic root infestation of *R. similis* decreased also strongly with the time from the first to the second cycle where they seemed to have only a slight effect excepted after treatment with aldicarb (based on the higher reduction percentage of nematode population of 90.7 %). In the corm, during the first cycle, the infestation by *R. similis* was also highly reduced after application of either aldicarb and DBCP.

Classifications according to the sum of the ranks (Table 2) were very different from one species to another as for each localization of the infestation (soil, roots or corm). There was a confirmation of the inverse efficacy of some chemicals (aldicarb, isazophos) on the endoparasitic population of *R. similis* when compared with their effects with the endoparasitic populations of *H. multicinctus* and *H. pararobustus*. According to this classification during the two cycles, the best control of nematode populations, for the combined endoparasites, were obtained after applications of either aldicarb, isazophos, fenamiphos or DBCP/EDB while carbofuran showed a strong decrease of its efficacy from cycle 1 to cycle 2.

Site 3, Bia 3-66

At this site, *H. multicinctus, R. similis, H. pararobustus* occurred for 2.2 %, 77.2 %, and 16.9 % of the endoparasitic population, respectively.

As previously observed at sites 1 and 2, the results varied greatly depending on species and the best results in terms of reduction of population were always obtained with the population of *H. multicinctus* (Table 3). Due to the very low endoparasitic infestation by *H. multicinctus* at this site, we will mainly consider the effect on the population of *R. similis*. The efficacy of the chemicals on the endoparasitic population of *R. similis* decreased again strongly from the first to the second cycle.

Classifications according to the sum of the ranks were again very different from one species to the other, as for each localization of the infestation (Table 4). All endoparasites combined, the best control of nematode populations, during the two cycles, were obtained after applications of either isazophos, DBCP/EDB or aldicarb. But considering the endoparasitic population of *R. similis*, the greatest results were obtained after application of aldicarb, whereas treatments with isofenphos were totally ineffective.

Site 4, Agbo 115

At this site, *H. multicinctus, R. similis, H. pararobustus* occurred for 87.6 %, 10.8 %, and 0.5 % of the endoparasitic population, respectively.

The greatest population reductions in soil, roots or corm, were obtained with *H. multicinctus* but differences were only significant during the second cycle (Tables 5, 6). Highest control was obtained with DBCP. The effects of chemicals on the endoparasitic population of *R. similis* were less clear and significant reduction occurred only for the important population sheltered in the corm (up to population maxima ranging from 150 to 350 nematodes par gram of corm). As observed previously on mineral soils, the efficacy of successive chemical applications declined during the second cycle where maximum control was just 45.7 % after treatment with isazophos.

The best control of nematode populations on the combined endoparasites during the second cycle was obtained after applications of either isazophos or EDB, while fenamiphos and aldicarb showed a strong decrease of their activity from cycle 1 to cycle 2.

Site 5, Yace 25

On this pure peat soil, *H. multicinctus, R. similis, H. pararobustus,* respectively comprised 92.1 %, 5.8 %, and 1.7 % of the endoparasitic population.

The greatest reductions of population, in soil or roots, were obtained with *H. multicinctus;* all treatments were

Table 5

Percentage reduction of the cumulative nematode populations in soil, roots and corm during the first and second vegetative cycle relative to treatments at site 4 (Agbo 115) and site 5 (Yace 25).

	Helicotylenchus			*Radopholus*		*Cephalenchus*	
	soil	roots	corm	soil	roots	corm	soil
SITE 4							
1st cycle							
Aldicarb (ALD)	50.2	23.2	48.1	54.1	− 21.8	82.4	25.7
Carbofuran (CAR)	42.5	16.6	57.8	− 189.2	− 19.7	30.6	− 4.9
DBCP (DB)	63.5	59.9	62.9	− 37.8	− 3.9	75.2	26.6
Fenamiphos (FEN)	26.8	44.9	68.3	− 127.0	− 39.5	55.0	36.7
Isazophos (ISA)	9.1	2.0	35.9	− 18.9	7.3	− 34.7	22.2
2nd cycle							
Aldicarb (ALD)	63.2	45.4	74.3	− 55.8	− 51.1	34.2	67.9
Carbofuran (CAR)	95.8	41.9	57.7	− 3.2	10.8	− 67.1	46.8
DBCP/EDB (DB)	93.0	88.3	92.1	− 3.2	− 28.6	25.3	89.4
Fenamiphos (FEN)	68.9	44.1	58.3	− 13.7	− 15.3	− 18.9	64.6
Isazophos (ISA)	50.2	52.3	64.2	− 64.2	− 22.5	45.7	30.9
SITE 5							
1st cycle							
Aldicarb (ALD)	46.9	55.6	− 55.56	− 19.2	67.9	41.8	25.3
Carbofuran (CAR)	60.1	85.1	− 33.33	17.75	− 28.6	44.8	57.6
EDB (DB)	83.7	78.5	77.78	12.32	− 214.3	− 16.4	23.9
Fenamiphos (FEN)	54.9	53.8	− 5.56	− 21.5	28.6	53.8	56.9
Isazophos (ISA)	49.0	37.9	61.11	25.97	− 100.0	4.0	− 5.8
Meth. bromide (MBR)	94.4	95.3	94.44	52.78	− 135.7	− 110.1	70.7
2nd cycle							
Aldicarb (ALD)	47.6	52.6	12.5	− 57.4	− 52.6	12.8	21.4
Carbofuran (CAR)	78.0	76.1	34.4	24.2	5.3	14.8	54.9
EDB (DB)	91.4	89.0	0.0	− 12.8	5.3	26.8	79.9
Fenamiphos (FEN)	11.3	40.1	− 18.8	− 25.2	10.5	− 0.5	21.4
Isazophos (ISA)	58.2	55.2	− 25.0	− 37.4	10.5	− 14.4	46.0
Meth. bromide (MBR)	78.2	68.56	37.5	27.73	− 152.63	− 101.36	22.77

Table 6

Classification of the treatments according to the sum of ranks at site 4 (Agbo 115) and site 5 (Yace 25) during the first and the second vegetative cycle (Friedman Two-way analysis of variance). Sums of ranks in a column followed by the same letter are not significantly different according to a multiple range test (P > 0.05).

Helicotylenchus			*Hoplolaimus*		*Radopholus*			*Cephal.*	Comb. Endo.
soil	roots	corm	soil	roots	soil	roots	corm	soil	
SITE 4									
1st cycle									
NS	p = 0.0308	NS			NS	NS	p = 0.0018	NS	p = 0.0001
	FEN (15.5) ALD (22.5) DB (28) CAR (28) ISA (36) CTR (37.5)						ALD (15) FEN (21) CAR (22.5) DB (31.5) ISA (39) CTR (39)		FEN (125) *a* ALD (136) *a* CAR (162.5) *ab* DB (176) *ab* ISA (200.5) *b* CTR (208) *b*
2nd cycle									
p = 0.0001	p = 0.0001	p = 0.0006			NS	NS	p = 0.0406	p = 0.0040	p = 0.0001
DB (11.5) CAR (12.5) ALD (30) FEN (32) ISA (34) CTR (48)	DB (8) ISA (25) ALD (28) FEN (29) CAR (32) CTR (46)	DB (9.5) ISA (24.5) ALD (26) CAR (32) FEN (34) CTR (42)					ISA (17) DB (23.5) ALD (24) FEN (32) CTR (34) CAR (39.5)	DB (12.5) ALD (23.5) FEN (26) CAR (32) ISA (33) CTR (41)	DB (108) *a* ISA (154) *ab* CAR (165) *b* ALD (177) *bc* FEN (182.5) *bc* CTR (221.5) *c*
SITE 5									
1st cycle									
p = 0.0136	p = 0.0001		NS	NS	p = 0.0023	p = 0.0382		NS	p = 0.0038
DB (19.5) ALD (29) FEN (29.5) ISA (30.5) CAR (32) CTR (48.5)	DB (18.5) CAR (18.5) FEN (28) ALD (33) ISA (40) CTR (51)				ALD (24) FEN (27) CTR (27.5) CAR (28) ISA (33) DB (49.5)	FEN (24.5) ALD (25) CAR (26) ISA (29) CTR (41.5) DB (43)			CAR (170) *a* DB (178.5) *a* ISA (181.5) *ab* FEN (182.5) *ab* ALD (184.5) *ab* CTR (237) *b*
2nd cycle									
p = 0.0011	p = 0.0001		NS	p = 0.0366	NS	NS		NS	p = 0.0002
DB (12) CAR (19) ALD (30) ISA (31) FEN (35) CTR (41)	DB (9) CAR (17) FEN (32) ALD (32) ISA (32) CTR (46)			CAR (18) CTR (21.5) DB (26.5) FEN (29) ISA (33) ALD (40)					CAR (133) *a* DB (133.5) *a* ALD (176) *ab* FEN (184.5) *ab* CTR (185) *ab* ISA (196) *b*

NS = not significant; Comb. Endo. = Combined endoparasites; *Cephal.* = *Cephalenchus;* the other abbreviations used for chemicals are defined in Table 5.

effective but the largest reductions were obtained after treatment with methyl bromide before planting (Table 5). The two other chemicals with strong and consistent efficacy against *Helicotylenchus* during the two cycles were EDB and the non-fumigant carbofuran.

The effects of these chemicals on the endoparasitic population of *R. similis* were very diverse. In fact, the population of *R. similis* increased strongly in the plots treated with methyl bromide before plantation when compared with the untreated plots. On the contrary, all the treatments with the non-fumigant nematicides were active against *R. similis,* with various degrees of effectiveness. The population reduction of *R. similis* was only significant during the first cycle (Table 6). All endoparasites combined, without considering the particular treatment with methyl bromide, the best control of nematode populations during the two cycles was obtained after applications of either carbofuran or EDB.

HORTICULTURAL RESULTS

Site 1, Dominique 1

During the first cycle, statistical analysis of the growth showed highly significant differences for each studied parameter (Table 7). The intervals between planting and flowering from plots treated were smaller (at least 59 days) than those from untreated controls, regardless the treatment. The intervals between flowering and harvest from plots treated with aldicarb and carbofuran were smaller (at least 10 days) than those from other treatments and untreated control. The intervals between planting and harvest showed a significant graduation between treatments in term of shortening from 94 days for treatments with aldicarb to 60 days for treatments with fenamiphos, in comparison with the untreated controls.

Differences in the average weight of the marketable bunches ranged from 20.8 to 16.0 kg for the treated plants compared to 13.0 kg for the untreated controls. The number of harvested marketable bunches increased at least 26.9 percentage points in treated plots.

Total harvest weight showed three significant groups of treatments. Treatment with aldicarb differed from all other treatments (increase at least of 6.1 t/ha). All the other treatments were at least 9.5 t/ha greater than the untreated controls.

During the second cycle it was impossible to calculate any interval between each harvest, planting and second harvest, and also bunch weight at 50 % of the harvest, except for plots treated with aldicarb. For all other treatments and untreated control, the number of marketable harvested bunches was strongly reduced below 50 %. The maximum (in the plots treated with isazophos) number of marketable harvested bunches only reached 35.4 %.

Therefore, the total harvest weight exhibited the same three significant groups between treatments as observed during the first cycle but differences here have tremendously increased within the treated plots (at least 13.7 t/ha between plots treated with aldicarb and other treatments).

Site 2, Monet 12

During the first cycle, there were treatment differences ($p < 0.0002$) in the interval between planting and

Table 7

Effects of nematicidal treatments on the growth and harvest of banana plants at site 1 (Dominique), respectively on first crop and second ratoon (means followed by a same letter are not different ($p = 0.05$) according to a Newman-Keuls test).

GROWTH				*HARVEST*		
IPF (days)	IFH (days)	IPH (days)		BW (kg)	HB (%)	THW (t/ha)
p = 0.0001	p = 0.0023	p = 0.0001		p = 0.0001	p = 0.0011	p = 0.0001
CAR (247) *a*	ALD (90) *a*	ALD (337) *a*		ALD (20.8) *a*	ALD (96.9) *a*	ALD (33.6) *a*
ALD (247) *a*	CAR (101) *ab*	CAR (348) *ab*		ISA (19.2) *ab*	DB (88.6) *a*	ISA (27.5) *b*
ISA (251) *a*	ISA (111) *b*	ISA (362) *ab*		CAR (17.5) *bc*	ISA (88.0) *a*	CAR (24.3) *b*
FEN (258) *a*	DB (111) *b*	DB (370) *b*		DB (16.4) *c*	CAR (87.0) *a*	DB (24.3) *b*
DB (259) *a*	FEN (113) *b*	FEN (371) *b*		FEN (16.0) *c*	FEN (83.2) *a*	FEN (22.1) *b*
CTR (318) *b*	CTR (113) *b*	CTR (431) *c*		CTR (13.0) *d*	CTR (56.3) *b*	FEN (12.6) *c*
IHF (days)	IFH (days)	IPH (days)	IHH (days)	BW (kg)	HB (%)	THW (t/ha)
					p = 0.0001	p = 0.0001
*	*	ALD (652)	ALD (315)	ALD (19.6)	ALD (66.3) *a*	ALD (23.6) *a*
*	*	**	**	**	ISA (35.4) *b*	ISA (9.9) *b*
*	*	**	**	**	CAR (24.7) *b*	CAR (8.2) *bc*
*	*	**	**	**	DB (16.4) *b*	DB (5.8) *bc*
*	*	**	**	**	FEN (13.7) *b*	FEN (5.3) *bc*
*	*	**	**	**	CTR (11.3) *b*	CTR (2.8) *c*

Asterisks indicate : (*) unavalaible data, (**) not calculable data. Abbreviations used : IPF : interval between planting and flowering; IPH : planting and harvest; IHH : harvest and harvest; IFH : flowering and harvest; THW : total harvest weight; BW : bunch weight; HB : harvested bunches; UP : uprooted plants. The other abbreviations used for chemicals are defined in Table 1.

harvest, with aldicarb and carbofuran resulting in the shortest intervals (Table 8). Treatment with aldicarb greatly reduced the number of uprooted plants, even when they were correctly propped with bamboo poles. In that case, there is little doubt of the relationship between the nematode root infestation and the anchoring function of the root system.

The average weight of the marketable bunches ranged from 22.5 kg for the plots treated with aldicarb, to weights ranging from 20.0 to 19.8 kg for the other treatments. As a combination of both number of uprooted plants and number of immature, deformed or smaller unharvestable bunches, the number of harvested marketable bunches was also significantly increased in treated plots from 55.1 percentage points (aldicarb) to 26.3 percentage points (isazophos) in comparison with the untreated control. As a result of these components, the total harvest weight showed three significant groups among treatments. In the first, treatment with aldicarb differed significantly from all other treatments (32.4 t/ha); in second all other treatments (20.2 to 26.1 t/ha) differed significantly from untreated control (10.6 t/ha).

It was not possible to follow a second crop due to a local hurricane in the early flowering period of the ratoon.

Site 3, Bia 3-66

During the first cycle, statistical analysis of the growth showed treatment differences ($p < 0.0001$) in the interval between planting and harvest (Table 9) with two separate groups within the treatments in terms of shortening (with a minimum of 28 days between treatment with fenamiphos and treatment with DBCP).

The average weight of the marketable bunches ranged from 24.6 to 20.8 kg on the treated plots and 17.7 kg on the untreated control. The number of harvested marketable bunches was also significantly reduced (at least 40.5 percentage points from plots treated with non-fumigant nematicide to untreated control and a reduction of 10.1 percentage points from plots treated with fumigant nematicide to untreated control). As a result, the total harvest weight showed four significant groups of treatments with increase ranging from 22.7 t/ha (aldicarb) to 6.4 t/ha (DBCP).

During the second cycle, the interval between harvests was also lengthened ($p < 0.0062$). There was no significant differences between treatments on the average weight of the bunches. The number of harvested marketable bunches was again significantly affected with reductions ranging from 41.5 percentage points (aldicarb) to 13 percentage points (fenamiphos) from treated to untreated control.

Thus, the total harvest weight showed three significant groups between treatments with increase ranging from 24.1 t/ha (aldicarb) to 7.1 t/ha (fenamiphos) when compared to the untreated plots.

Site 4, Agbo 115

No significant treatment effects occurred on growth during the first cycle in the interval between planting and harvest (Table 10). There were only treatment differences ($p < 0.00026$) on the weight of the marketable bunches which ranged from 30.1 kg (DBCP) to 26.6 kg after treatment whith carbofuran.

During the second cycle, the number of marketable harvested bunches was strongly reduced to only 36.9 % on the untreated control. Therefore, analyses of variance were only completed on the results of the treated plots, both on the growth and the average bunch weight. The interval between the first and second harvest was only significant at $p < 0.10$. The average weight of the bunches from plants treated with EDB (26.8 kg) were different from those from plants treated with fenamiphos or carbofuran (23.9 and 23.6 kg respectively). The number of harvested marketable bunches was also significantly increased in treated plots from 36.9 percentage points (isazophos) to 15.2 percentage points (fenamiphos) in comparison with the untreated control.

Increased yield weight ranged from 18.6 t/ha (aldicarb) to 10.1 t/ha (fenamiphos) when compared with the untreated control.

Site 5, Yace 25

During the first cycle, due to heavy rainfall two months after planting, at least 24 hours of flooding occurred on the whole surface of the trial. This impaired severely a great number of banana plants which did not produce marketable bunches (due to small and deformed bunches). Therefore the statistical analysis was not performed on the results of the growth and of the average bunch weight for this first cycle (Table 11). The number of harvested bunches and the total weight of the harvest were much higher in all treatments, although differences were non significant.

At this site, a large number of plants, even propped with bamboo after fructification, were uprooted and the data analysis indicated treatment differences ($p < 0.0001$). The maximum uprooting of plants occurred among controls and after treatments with fumigants (methyl bromide or EDB), while no uprooting occurred after treatment with carbofuran.

During the second cycle, all the statistical analysis conducted on all the horticultural parameters measured indicated treatment differences. The interval between planting and second harvest was significantly lengthened and treatments were classified in nearly the same order as previously observed for the uprooted plants during the first cycle. The average bunch weight showed significant differences between treatments (24.5 kg after treatment with isazophos, significantly different from all other treatments, with a minimum of 2.2 kg per bunch). The number of harvested marketable bunches was also significantly affected with a fairly similar classification

Table 8

Effects of nematicidal treatments on the growth and harvest of banana plants at site 2 (Monet 12), on first crop (means followed by a same letter are not different (p = 0.05) according to a Newman-Keuls test).

GROWTH				*HARVEST*		
IPF (days)	IFH (days)	IPH (days)	UP (%)	BW (kg)	HB (%)	THW (t/ha)
		p = 0.0002	p = 0.0001	p = 0.0024	p = 0.0001	p = 0.0001
*	*	ALD (323) *a*	ALD (1.8) *a*	ALD (22.5) *a*	ALD (87.5) *a*	ALD (32.4) *a*
*	*	CAR (333) *a*	CAR (9.0) *b*	CAR (20.0) *b*	CAR (75.9) *ab*	CAR (26.1) *b*
*	*	FEN (376) *b*	DB (10.9) *b*	ISA (19.8) *b*	FEN (61.1) *b*	DB (21.2) *b*
*	*	ISA (377) *b*	ISA (14.5) *bc*	DB (19.8) *b*	DB (59.0) *b*	ISA (20.6) *b*
*	*	DB (390) *b*	FEN (23.8) *c*	FEN (19.8) *b*	ISA (58.7) *b*	FEN (20.2) *b*
*	*	**	CTR (24.1) *c*	**	CTR (32.4) *c*	CTR (10.6) *c*

Asterisks indicate : (*) unavalaible data; (**) not calculable data. Abbreviations used : IPF : interval between planting and flowering; IPH : planting and harvest; IHH : harvest and harvest; IFH : flowering and harvest; THW : total harvest weight; BW : bunch weight; HB : harvested bunches; UP : uprooted plants. The other abbreviations used for chemicals are defined in Table 1.

Table 9

Effects of nematicidal treatments on growth and harvest of banana plants on site 3 (Bia 3-66), respectively on first crop and second ratoon (means followed by a same letter are not different (p = 0.05) according to a Newman-Keuls test).

GROWTH				*HARVEST*		
IPF (days)	IFH (days)	IPH (days)		BW (kg)	HB (%)	THW (t/ha)
		p = 0.0001		p = 0.0001	p = 0.0001	p = 0.0001
*	*	CAR (378) *a*		ISA (24.6) *a*	CAR (99.9) *a*	ALD (40.9) *a*
*	*	ISA (381) *a*		ISO (23.8) *ab*	ALD (99.6) *a*	ISO (40.7) *a*
*	*	ALD (388) *a*		ALD (22.6) *abc*	ISO (99.5) *a*	ISA (40.0) *a*
*	*	ISO (389) *a*		CAR (22.4) *abc*	ISA (99.1) *ab*	CAR (38.1) *a*
*	*	FEN (398) *a*		FEN (21.8) *bc*	FEN (90.4) *b*	FEN (32.0) *b*
*	*	DB (426) *b*		DB (20.8) *c*	CTR (69.1) *c*	DB (24.6) *c*
*	*	CTR (458) *c*		CTR (17.7) *d*	FEN (58.6) *c*	CTR (18.2) *d*
IHF (days)	IFH (days)	IPH (days)	IHH (days)	BW (kg)	HB (%)	TWH (t/ha)
		p = 0.0001	p = 0.0062	p = 0.1007	p = 0.0024	p = 0.0008
*	*	ISA (606) *a*	ISA (214) *a*	ALD (27.9)	ALD (99.5) *a*	ALD (49.3) *a*
*	*	CAR (607) *a*	DB (219) *a*	ISA (27.4)	ISA (91.4) *ab*	ISA (43.1) *ab*
*	*	ALD (610) *a*	ALD (221) *a*	CAR (26.5)	ISO (90.3) *ab*	ISO (43.0) *ab*
*	*	ISO (630) *ab*	CAR (229) *ab*	ISO (25.7)	CAR (89.0) *ab*	CAR (41.6) *ab*
*	*	DB (646) *b*	CTR (232) *ab*	DB (25.7)	DB (80.1) *abc*	DB (35.0) *abc*
*	*	FEN (647) *b*	ISO (241) *ab*	FEN (25.2)	FEN (71.0) *bc*	FEN (32.3) *bc*
*	*	CTR (691) *c*	FEN (249) *b*	CTR (25.2)	CTR (58.0) *c*	CTR (25.2) *c*

Asterisks indicate (*) unavalaible date. Abbreviations used : IPF : interval between planting and flowering; IPH : planting and harvest; IHH : harvest and harvest; IFH : flowering and harvest; THW : total harvest weight; BW : bunch weight; HB : harvested bunches; UP : uprooted plants. The other abbreviations used for chemicals are defined in Table 3.

Table 10

Effects of nematicidal treatments on the growth and harvest of banana plants at site 1 (Agbo 115), on first crop and second ratoon (means followed by a same letter are not different (p = 0.05) according to a Newman-Keuls test).

GROWTH				*HARVEST*		
IPF (days)	IFH (days)	IPH (days)		BW (kg)	HB (%)	THW (t/ha)
		NS		p = 0.0026	NS	p = 0.1015
*	*	CAR (312)		DB (33.6) *a*	CAR (87.2)	DB (43.3)
*	*	FEN (313)		FEN (29.3) *ab*	ALD (85.1)	FEN (43.2)
*	*	ALD (313)		ALD (28.0) *abc*	FEN (84.2)	ALD (42.1)
*	*	ISA (313)		ISA (27.9) *abc*	ISA (82.9)	ISA (41.0)
*	*	DB (314)		CTR (27.1) *bc*	DB (81.6)	CAR (39.4)
*	*	CTR (329)		CAR (26.6) *c*	CTR (65.4)	CTR (31.0)
IHF (days)	IFH (days)	IPH (days)	IHH (days)	BW (kg)	HB (%)	TWH (t/ha)
		NS	p = 0.0627	p = 0.0001	p = 0.0011	p = 0.0005
*	*	ISA (576)	ISA (263)	DB (26.8) *a*	ISA (73.8) *a*	ALD (33.3) *a*
*	*	ALD (577)	ALD (264)	ALD (26.0) *ab*	ALD (73.5) *a*	ISA (33.3) *a*
*	*	CAR (585)	DB (271)	ISA (25.9) *ab*	CAR (70.8) *a*	DB (29.9) *a*
*	*	DB (587)	CAR (272)	FEN (23.9) *b*	DB (67.3) *a*	CAR (26.1) *a*
*	*	FEN (595)	FEN (282)	CAR (23.6) *b*	FEN (58.6) *a*	FEN (24.7) *a*
*	*	**	**	**	CTR (36.9) *b*	CTR (14.7) *b*

Asterisks indicate : (*) unavalaible data; (**) not calculable data. Abbreviations used : IPF : interval between planting and flowering; IPH : planting and harvest; IHH : harvest and harvest; IFH : flowering and harvest; THW : total harvest weight; BW : bunch weight; HB : harvested bunches. The other abbreviations used for chemicals are defined in Table 5.

Table 11

Effects of nematicidal treatments on the growth and harvest of banana plants at site 2 (Yace 25), respectively on first crop and second ratoon (means followed by a same letter are not different (p = 0.05) according to a Newman-Keuls test).

GROWTH				*HARVEST*		
IPF (days)	IFH (days)	IPH (days)	UP (%)	BW (kg)	HB (%)	THW (t/ha)
			p = 0.0001		NS	NS
*	*	**	CAR (0) *a*	**	DB (51.0)	ISA (20.7)
*	*	**	ISA (0.5) *ab*	**	CAR (48.4)	CAR (20.3)
*	*	**	FEN (1.7) *ab*	**	ALD (46.3)	DB (20.0)
*	*	**	ALD (4.1) *b*	**	ISA (46.2)	ALD (17.9)
*	*	**	MBR (10.7) *c*	**	MBR (42.5)	MBR (16.9)
*	*	**	DB (14.5) *c*	**	FEN (39.4)	FEN (15.4)
*	*	**	CTR (16.4) *c*	**	CTR (29.5)	CTR (11.5)
IPH (days)	IHH (days)		UP (%)	BW (kg)	HB (%)	TWH (t/ha)
p = 0.0001			p = 0.0107	p = 0.0088	p = 0.0001	p = 0.0125
CAR (528) *a*	**		CAR (3.1) *a*	ISA (24.5) *a*	ALD (96.3) *a*	ISA (38.7) *a*
ISA (536) *a*	**		ALD (3.6) *ab*	ALD (22.3) *b*	CAR (95.7) *ab*	ALD (37.4) *ab*
FEN (545) *a*	**		FEN (5.1) *ab*	DB (22.2) *b*	ISA (94.6) *ab*	CAR (35.0) *ab*
ALD (547) *a*	**		ISA (5.3) *ab*	FEN (21.7) *b*	FEN (88.0) *bc*	FEN (33.6) *ab*
MBR (569) *b*	**		DB (7.7) *ab*	CAR (21.4) *b*	MBR (79.7) *c*	MBR (31.6) *ab*
CTR (574) *b*	**		MBR (9.3) *b*	MBR (21.3) *b*	CTR (78.7) *c*	CTR (31.4) *ab*
DB (581) *b*	**		CTR (10.0) *b*	CTR (21.1) *b*	DB (76.4) *c*	DB (30.3) *b*

Asterisks indicate : (*) unavalaible data; (**) not calculable data. Abbreviations used : IPF : interval between planting and flowering; IPH : planting and harvest; IHH : harvest and harvest; IFH : flowering and harvest; THW : total harvest weight; BW : bunch weight; HB : harvested bunches; UP : uprooted plants. The other abbreviations used for chemicals are defined in Table 5.

of the treatment. This was due to uprooted plants and to small, deformed or immature bunches.

The total harvest weight showed significant groups between treated plots and untreated plots but here there was an increase of only 7.3 t/ha (isazophos) when compared with the untreated control. Treatment with EDB resulted in some slight evidences of phytotoxicity when considering some horticultural parameters (lengthening of the vegetative cycle and reduction of the number of marketable bunches when compared with the untreated control).

REGRESSION ANALYSIS

Site 1, Dominique 1

In each cycle, horticultural results showed numerous correlations with nematode infestations (Tab. 12). The strongest relationships occurred when horticultural results were regressed on nematode infestations :

During the first cycle, when considering the combined species in the roots of the entire root system or in the corm of the main sucker and followers during the interval from planting to flowering (except for the bunch weight, negatively correlated with the combined species in the roots of the entire root system during the interval from planting to harvest).

During the second cycle, when considering the combined species in the roots of the main sucker during the interval from flowering to flowering.

Site 2, Monet 12

At this site (Table 13), the strongest relationships occurred when horticultural results were regressed on nematode infestations during the first cycle :

i) when considering *H. pararobustus* in the roots of the main sucker during the interval between planting and flowering;

ii) when considering *R. similis* in the corm of the main sucker during the interval between planting and flowering (except with the number of uprooted plant, positively correlated with the corm infestation by *R. similis* in the main sucker and followers during the interval between planting and harvest).

Site 3, Bia 3-66

At this site (Table 14), the strongest relationships occurred when horticultural results were regressed on nematode infestations :

during the first cycle, when considering the combined species in the roots of the entire root system or in the corm of the main sucker and followers during the interval between planting and flowering (except with the number of harvested bunches and total harvest weight,

Table 12

Most significant correlations and linear regression equations for relationships between horticultural results and nematode infestations at site 1 (Dominique 1).

Dep. var. *(y)*	Cycle	Independent. var. *(x)*	Coeff. r^2	Linear regression equation
IPH	1	comb. sp. [IPF; R-grs]	0.888*	y = 8.22 + 139.14 x
	1	comb. sp. [IPF; C-msf]	0.659	—
BW	1	comb. sp. [IPH; R-grs]	0.940**	y = 49.7 — 11.4 x
	1	comb. sp. [IPF; C-msf]	0.948**	y = 43.7 — 11.8 x
	2	NS		
HB	1	comb. sp. [IPF; R-grs]	0.981**	y = 184.38 — 45.33 x
	1	comb. sp. [IPF; C-msf]	0.769	—
	2	comb. sp. [IFF; R-ms]	0.999***	y = 178.28 — 50.60 x
THW	1	comb. sp. [IPF; R-grs]	0.972**	y = 103.73 — 30.67 x
	1	comb. sp. [IPF; C-msf]	0.874*	y = 89.05 — 29.24 x
	2	comb. sp. [IFF; R-ms]	0.971**	y = 92.7 — 28.70 x
THW/IPH	1	comb. sp. [IPF; R-grs]	0.987***	y = 0.33 — 0.10 x
	1	comb. sp. [IPF; C-msf]	0.852*	y = 0.28 — 0.09 x
	2	not available		

Abbreviations used : Dep. var. : Dependent variable; IPF : interval between planting and flowering; IPH : planting and harvest; IHH : harvest and harvest; IFH : flowering and harvest; THW : total harvest weight; BW : bunch weight; HB : harvested bunches; UP : uprooted plants; comb. sp. : combined species; R : roots; C : corm; ms : main sucker; msf : main sucker and followers; grs : global root system. Asterisks indicate significance at $p < 0.05$ (*), $P < 0.01$ (**), and $P < 0.001$ (***). Coefficients significant at $P < 0.10$ are unmarked. NS : not significant. Regression equations were computed only for relationships having significant ($P < 0.05$) correlation coefficients. Dashes indicate no equations.

Table 13

Most significant correlations and linear regression equations for relationships between horticultural results and nematode infestations at site 2 (Monet 12).

Dep. var. *(y)*	Cycle	Independent var. *(x)*	Coeff. r^2	Linear regression equation
IPH	1	*Hoplolaimus* [IPF; R-ms]	0.749	—
UP	1	*Hoplolaimus* [IPF; R-ms]	0.693*	y = — 77.93 + 52.05 x
	1	*Radopholus* [IPH; C-msf]	0.714*	y = — 22.61 + 20.65 x
BW	1	NS		
HB	1	*Hoplolaimus* [IPF; R-ms]	0.827*	y = 206.97 — 81.24 x
	1	*Radopholus* [IPF; C-ms]	0.756*	y = 84.59 — 21.91 x
THW	1	*Hoplolaimus* [IPF; R-ms]	0.832*	y = 117.83 — 50.55 x
	1	*Radopholus* [IPF; C-ms]	0.714*	y = 41.08 — 13.20 x
THW/IPH	1	NS		

The abbreviations used are defined in Table 12. Asterisks indicate significance at p < 0.05 (*), P < 0.01 (**), and P < 0.001 (***). Coefficients significant at P < 0.10 are unmarked. NS : not significant. Regression equations were computed only for relationships having significant (P < 0.05) correlation coefficients. Dashes indicate no equations.

Table 14

Most significant correlations and linear regression equations for relationships between horticultural results and nematode infestations at site 3 (Bia 3-66).

Dep. var. *(y)*	Cycle	Independent var. *(x)*	Coeff. r^2	Linear regression equation
IPH	1	comb. sp. [IPF; R-grs]	0.876**	y = — 33.85 + 153.75 x
IHH	2	NS		
BW	1	comb. sp. [IPF; R-msf]	0.720*	y = 48.63 — 9.57 x
	2	comb. sp. [IFH; R-grs]	0.775*	y = 44.74 — 5.96 x
HB	1	comb. sp. [IPF; R-msf]	0.869**	y = 313.46 — 84.04 x
	2	comb. sp. [IFH; R-grs]	0.696*	y = 264.23 — 63.54 x
THW	1	*Radopholus* [IPF; R-msf]	0.876**	y = 143.12 — 40.56 x
	2	comb. sp. [IFH; R-grs]	0.683*	y = 171.56 — 42.91 x
THW/IPH	1	*Radopholus* [IPF; R-msf]	0.871**	y = 0.41 — 0.12 x
	2	comb. sp. [IFH; R-grs]	0.754*	y = 0.86 — 0.23 x

The abbreviations used are defined in Table 12. Asterisks indicate significance at p < 0.05 (*), P < 0.01 (**), and P < 0.001 (***). Coefficients significant at P < 0.10 are unmarked. NS : not significant. Regression equations were computed only for relationships having significant (P < 0.05) correlation coefficients. Dashes indicate no equations.

negatively correlated with the infestation by *R. similis* in the roots main sucker and followers during the interval between planting and harvest);

during the first cycle, when considering the combined species in the roots of the entire root system during the interval between flowering (1st crop) and harvest (2nd crop).

Site 4, Agbo 115

At this site (Table 15), the strongest relationships occurred when horticultural results were regressed on nematode infestations :

during the first cycle, when considering the combined species in the corm of the main sucker and followers

Table 15

Most significant correlations and linear regression equations for relationships between horticultural results and nematode infestations at site 4 (Agbo 115).

Dep. var. *(y)*	Cycle	Independent var. *(x)*	Coeff. r^2	Linear regression equation
IPH	1	NS		
IHH	2	comb. sp. [IFH; C-ms]	0.846*	y = 195.90 + 28.10 x
BW	1	comb. sp. [IPF; R-grs]	0.783*	y = 62.30 — 10.96 x
	2	comb. sp. [IFH; C-ms]	0.678	—
HB	1	NS		
	2	comb. sp. [IFH; C-msf]	0.558	—
THW	1	comb. sp. [IPF; C-msf]	0.818*	y = 81.28 — 18.75 x
	2	comb. sp. [IFH; C-msf]	0.807*	y = 86.58 — 22.34 x
THW/IPH	1	comb. sp. [IPF; C-msf]	0.794*	y = 0.27 — 0.066 x
	2	comb. sp. [IFH; C-ms]	0.957**	y = 0.29 — 0.068 x

The abbreviations used are defined in Table 12. Asterisks indicate significance at $p < 0.05$ (*), $P < 0.01$ (**), and $P < 0.001$ (***). Coefficients significant at $P < 0.10$ are unmarked. NS : not significant. Regression equations were computed only for relationships having significant ($P < 0.05$) correlation coefficients. Dashes indicate no equations.

during the interval between planting and flowering); (except with the bunch weight negatively correlated with the infestation in the roots of the entire root system during the interval between planting and flowering);

during the second cycle when considering the combined species in the corm of the main sucker or main sucker and followers during the interval between flowering (1st crop) and harvest (2nd crop).

Site 5, Yace 25

At this site no relationships were found between horticultural results and nematode infestations.

Discussion

The burrowing nematode, *Radopholus similis,* causes severe losses throughout the world in banana and plantain production. Chemical control has been commonly used to prevent nematode damages in commercial plantations (Vilardebò *et al.,* 1984; Pinochet, 1986; Gowen & Quénéhervé, 1990).

The result of applying a chemical is a balance between the direct stimulative and depressive effects on both vegetative and reproductive phases of plant development and the stimulative but indirect effect by reduction of the pest stress.

In the analysis of field trials conducted with chemicals on bananas, the simple results on yield do not delineate these specific effects. It is more useful to consider the effects of the chemicals separately on the growth and on the harvest. The study of the effect on growth needs to have a consistent method of measurement which can be used on a comparative basis from trial to trial. In these experiments on bananas in which the harvest is spread over a long period of time, use of the median over the arithmetic mean has been proved very useful, as in the characterization of the growth of perennials (Wisiol, 1987). In the same manner, there is generally a significant correlation between the length of production (IPH or IHH) and the average bunch weight; the slope of this regression depends on the stresses not only due to pests but also to environmental factors. Under these conditions, the use of the average bunch weight at 50 % of harvest is a way to minimize uncontrolled factors in comparing different treatments, in addition to the total harvest weight.

Specific effects of nematicides according to the nematode species

In each of these trials, whatever the nematicide used, the response varied according to the nematode species and the soil type and was always higher during the first cycle than during the second. These products did not show an equal range of activity over the different nematodes species encountered, and some nematicides seemed to fail in reducing certain species of nematode (*e.g., R. similis, H. pararobustus* at sites 1, 2 and 3).

In fact the nematicidal activity of these products is related to their application conditions. An application by incorporation into the soil is better than a surface application in vegetation. Reasons are various, such as loss of chemicals by runnoff during heavy rainfall or overhead irrigation, especially on sloping terrains and problems of leaching linked to the mobility of these chemicals in relation to the soil types in these tropical regions (Fritsch, unpubl.).

Another component of this decrease of activity may be attributed to the nematode biology. *R. similis* infection originates with the planting material, while infection by the other species comes mainly from the soil. In the early settlement of the population of *R. similis,* these chemicals may have a good both contact and systemic activity, due to the limited dispersion of both parasites and root system. However after several months, due to the infestation of the corm by this parasite, only chemicals with effective systemic activity will reduce nematodes in this primary site. As the banana plant ages, the rhizome increases in size with continuous inoculum growing parts which are directly infected without the need of a soil phase by *R. similis* (Quénéhervé & Cadet, 1985).

Therefore, the greater the endoparasitic nature of the species (e.g. *Radopholus similis*), the more the nematicidal activity of the applied fumigants and non-fumigants decreases. It is interesting to note that this nematicidal activity on populations of *H. pararobustus* in the roots was also less important and sometimes conflicting with results obtained on endoparasitic populations of *R. similis;* particularly after treatment with aldicarb. This situation could be the consequence of two phenomena : *i)* an evident competition with other nematode species, here mainly *R. similis; ii)* a differential sensitivity to chemicals between nematode species.

From a nematological point of view, on mineral soils (Sites 1, 2 and 3), the fumigants (DBCP and EDB) and the non-fumigant nematicides, aldicarb and isazophos, were the most effective chemicals in reducing nematode populations in the three experiments. Aldicarb was the most effective on the population of *R. similis,* even when sheltered in the corm. Other chemical (fenamiphos), commonly used on banana plantations of the Ivory Coast and applied here at its recommended dosage, was less consistently effective in the control of nematode populations than expected from previous works (Melin & Vilardebò, 1973; Guérout, 1974; Sarah & Vilardebò, 1979). Natural biodegradation may be responsible for poor control, since that phenomenon is well recognized after repeated use of fenamiphos on some banana plantations of the Ivory Coast (Anderson & Wibou, 1987).

On organic soils (Sites 4 and 5), the main endoparasitic species, in terms of density, was *H. multicinctus.* In both trials, the relative control was always greatest with *H. multicinctus* than with *R. similis.* And, regardless of which nematicide was used, it was always higher during the first cycle than during the second cycle. The fumigants (DBCP and EDB) and the non-fumigant nematicides, isazophos (on clay soil) and carbofuran (on peat soil), were the most effective chemicals in reducing nematode populations in the two experiments.

It is noteworthy that even when *H. multicinctus* outnumbered *R. similis* in the soil and the roots, the corm infestation was dominated by *R. similis,* as long as that corm belonged to a sucker with a rhizogenic activity (after fructification, *H. multicinctus* outnumbers *R. similis* even in the corm).

On peat soil, the use of fumigants (methyl bromide or EDB before planting) was very effective against the population of *H. multicinctus* but stimulated the root and corm infestation by *R. similis.* This phenomenon suggests competition between these species in natural conditions. Due to this competitive effect, it was difficult to evaluate the real effect of the different chemicals on *R. similis.*

The efficacy of all chemicals against *R. similis* ranged from poor to none either on clay or peat soil. The influence on efficacy of the soil type was evident on these organic soil problably due to the loss of chemicals by runnoff or vertical leaching during heavy rainfall or overhead irrigation (Fritsch, unpubl.), but also due to adsorption related to the high amount of organic matter in these soil (Hague & Gowen, 1987).

Specific effects of nematicides on growth and harvest

As a general trend, all tested chemicals reduced the length of the phenological phases (IPF, IFH, IHH, IPH_n) in comparison with the control. These effects on the growth did not always result directly in significant differences in terms of harvest. The duration of each phenological phase is so long that many environmental factors can vary during the period covering vegetative and reproductive phases.

A principal component of the harvest is the number of harvested bunches. Reasons for a decrease in the number of harvested bunches may be evident when banana plants are uprooted as observed at site 2, due to wind and poor anchorage. Other reasons may be more insidious, such as delayed flowering or small or deformed fingers resulting in non-exportable bunches, even if the plants are bearing bunches in controls and treated plots. Without propping, most of these banana plants would most likely have been uprooted. The total harvest weight takes into account all these components, but in the analysis of the global yield, results on the growth must also be considered.

In these three experiments on mineral soil, the treatments with aldicarb were always effective in reducing the intervals of the vegetative phases, increasing the number of harvested bunches and therefore the total harvest weight. The effect of the other chemicals were similar, but not as consistent.

On the peat soil the largest number of uprooted plants occurred in two cases *i)* after treatments with fumigants (EDB and methyl bromide) and *ii)* on untreated control (Table 11). In the first case, population levels of *H.*

multicinctus remained so low that *R. similis* was allowed to build populations higher than those observed in natural conditions. It was a long-term effect after treatment with methyl bromide, as it lasted almost two cycles. The effect could be interpreted as a difference in susceptibility to uprooting with respect to different nematode communities. Even at a lower level of root infestation, the plant anchorage was more heavily impaired by *R. similis* than by *H. multicinctus*. This function was not the only one to be impaired, similarly *R. similis* lengthened the interval between planting and harvest of the second fruit.

As a general trend on organic soil, all these chemicals significantly increased the average weight of bunch, the number of harvested plants and the total weight of the harvest during the second cycle. However there was no significant difference among the chemicals tested. The comparison of the results obtained on the nematode infestations and the growth and the harvest parameters showed some interesting discrepancies. Carbofuran was one of the most active compounds against nematode populations found in these organic soils, and gave very good results in terms of reduction of the growth length and number of uprooted plants. However the average bunch weight was also reduced most of the time. In fact, this product showed a phytotoxic effect only on the reproductive phase. There are also discrepancies in the horticultural results obtained after applications of EDB. Even with a good nematicidal activity, the vegetative phase was lengthened, as were reduced the number of harvestable (and/or unmarketable) bunches leading to a lower total yield.

The best and most consistent horticultural results on these soils were obtained after applications of either aldicarb or isazophos. In these experiments (both on mineral and organic soils) we used a higher dosage for aldicarb and carbofuran than now recommended in order to clearly separate the activity of these chemicals. Others studies have confirmed the efficacy of aldicarb even at lower dosage (Vilardebò *et al.*, 1988; Sarah *et al.*, 1989).

Results of this study revealed certain components of nematode damage in banana plantations in the Ivory Coast :

i) lengthening of the vegetative cycle. Some of the different phenological intervals (IPF, IFH, IHF, IHH) are lengthened without significant reduction of the total harvest (*e.g.* Tab. 10). This type of damage often occurs during the first vegetative cycle;

ii) lengthening of the vegetative cycle and reduction of the total harvest. There are two sub-components to this effect, the reduction of the number of harvested bunches (non exportable bunches because of immaturity or bad quality) and the reduction of the average bunch weight (*e.g.* Tabs 7, 9, 10);

iii) reduction of the longevity of the plantation. This response is the same as *ii)* above but irreversible due to the loss of plants which are uprooted (*e.g.* Tabs 8, 11).

In fact all these types of damage are mixed in a commercial plantation and are not specific to nematodes. If the most evident damage is the toppling plants, the most insidious remains the lenghtening of the vegetative cycle.

Severity of damage in respect to the soil type

From these experiments, it appears that nematode damage is more important on the ferralitic soils of the region of Azaguié than on the alluvial soil of Aboisso. On the ferralitic soils nematode damage did not permit a second harvest without nematicidal treatment. Even the first harvest after planting is greatly delayed and the number and the average weight of the harvested bunches are reduced. On the alluvial soil of Aboisso, the situation is not so acute; however, the benefit of the nematicide treatments is very important since the total harvest doubled in each cycle when nematicides are used.

Soil factors are undoubtedly of major importance in the nematode damage expressions. The soils of the region of Azaguié were very shallow due to soil texture and erosion of the sloping terrain at site 1, Dominique 1 and due to a high water table at site 2, Monet 12. Both these situations resulted in a restricted layer of soil for anchorage and adsorption of solutes, and also concentrated the nematode activity. On the other hand, the alluvial soil at site 3 was very deep with excellent water holding capacity and drainage (Fritsch, unpubl.) which is favourable for the development of the banana root system. Without correct propping, differences would certainly have been even more important.

From the experiments conducted on organic soil, it appears that on peat soil, nematode damage is lower than observed on clay soil or mineral soil. Increase in the content of organic matter seems to favor the infestation in *H. multicinctus* (Quénéhervé, 1988). This observation was supported on the organic soil where *H. multicinctus* restricts the development of *R. similis* (Quénéhervé, 1989*b*). At the same time, yield reduction on the control on peat soil are less important than observed on the other soil types. A possible natural control of *R. similis* by *H. multicinctus* must also be considered.

Control of nematode populations on these organic soils is very difficult because at similar density *H. multicinctus* appears far less damageable to the banana plant than *R. similis*. Even if lower than on mineral soils, nematode damage must be controlled and application of nematicides must be done in order to decrease the infestation by *H. multicinctus* without allowing a correlative increase of the infestation by *R. similis,* such as observed after treatments with fumigants.

RELATIONSHIPS BETWEEN HORTICULTURAL RESULTS AND NEMATODE INFESTATIONS

Numerous varied relationships were found between nematode species in portion of the root system and horticultural parameters. Over all these experiments several trends emerge : *i)* relationships were found between either plant growth or harvest and either root or corm nematode infestation; *ii)* the best regressions were obtained using nematode infestation in the roots or corm of the main and following suckers, or of the entire root or corm system of the banana plant; *iii)* except some cases, the best regressions were obtained using the infestation of all species combined.

One of the most interesting results of this study was to obtain significant regressions between nematode infestation of the corm and some horticultural assessments during the second cycle in the experiment conducted in clay soil. The predominant species (> 90 %) in the infestation of the corm was *R. similis* which supports the greater pathogenicity of *R. similis* compared to that of *H. multicinctus*. Unfortunately, corm sampling was not done on a regular basis during the trial in peat soil. The infestation period (from planting to flowering or harvest; from flowering to flowering or harvest) providing strongest correlations depends on both the horticultural parameter and nematode species.

Guérout (1972) demonstrated the existence of a non-linear relationship between the growth of the banana plant and the logarithm of the root infestation in *R. similis*, and concluded that the threshold level was in the range of 1 000 nematodes per 100 g of roots. Usually, regression analysis are performed in order to predict losses and to define threshold levels. It appears that for each of the horticultural parameters measured (from the growth and from the harvest) we may be able to calculate a threshold level. But, from our experiments, it appears also that those threshold levels may vary greatly from site to site, according to : the horticultural parameter considered; the soil type (texture and structure); the nematode community structure; the period of infestation (vegetative or reproductive phase); the cultural practices (quality of drainage system, propping, etc.); and other environmental factors (climate, etc.). This important topic needs further research and numerous data to be useful in a pest management process.

In conclusion, this study has shown, how difficult and necessary it is to control nematodes in the mineral soils on the Ivory Coast in order to obtain a reasonable yield and that in organic soils the species *R. similis*, although outnumbered by *H. multicinctus* in the soil and the banana root system, remains the « key species » with a special ability to infest the banana corm and to impair the anchorage system.

Measurement of the effects of these chemicals separately on the vegetative phase and on the reproductive phase of the banana plant should allow researchers to select compounds according to the local situation. Compounds which are known to have phytotoxic effects on the reproductive phase, while having a very good nematicidal activity, should be considered for use at times other than during the reproductive phase. So many factors affect chemical efficacy, at planting and particularly during vegetative growth, that each application must be optimized to control nematodes and increase yields. While choosing the correct chemical is important, it is only one of the conditions required to succeed.

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