Indian J. Genet., 74(1): 56-63 (2014)

Breeding and evaluation of *Musa* hybrids to the spiral nematode, *Helicotylenchus multicinctus*

Sukhen Chandra Das[1]*, T. N. Balamohan, K. Poornima, R. Velalazan[2] and N. Seenivasan

Department of Fruit Crops, Horticultural College and Research Institute, [2]Department of Pathology, Tamil Nadu Agricultural University, Coimbatore 641 001

(Received: January 2013; Revised: December 2013; Accepted: January 2014)

Abstract

Twenty four banana (*Musa*) hybrids developed by crossing nematode resistant male parents *viz.,* Pisang lilin, Anaikomban, Pisang Jari Buaya, Ambalakadali, Rose, H-56, H-201 and Yangambi KM5 with commercial triploid bananas *viz.,* Karpooravalli, Poovan, Hill banana, Manoranjitham and Rasthali were screened for their reaction to spiral nematode *Helicotylenchus multicinctus* under field and pot conditions. The hybrids H 516 and H 531 were resistant, while the hybrids H 511, H 534, H 537, H 571, H 572 and H 589 were tolerant. Among the resistant hybrids, H 516 and H 531 produce good bunch weights. H 504, H 515, H 529, H 530, H 532, H 540, H 542, H 547, H 548, H 556, H 563, H 564, H 573 and H 576 were susceptible and H 508 was highly susceptible. The resistant hybrids had enhanced contents of total phenol, peroxidase, polyphenol oxidase and phenylalanine ammonia lyase. The overall evaluation of 24 parthenocarpic *Musa* hybrids led to identification of the hybrid H 531 with high yield potential as well as increased resistance to *H. multicinctus*.

Key words: Musa, plant breeding, hybrids, *Helicotylenchus multicinctus*

Introduction

Banana (*Musa* spp.) is one of the most important fruit crops grown in India and ranks second in area and production. Nematodes are a serious constraint of banana production world-wide and crop losses caused by nematodes to bananas are very high, with an average annual yield losses estimated at about 20 per cent world wide [1]. The spiral nematode (*Helicotylenchus multicinctus*) is considered to be a serious nematode parasite of banana in several banana growing regions of the world and is responsible for a 33 per cent reduction in fruit yield [2]. *Helicotylenchus multicinctus* is considered to be an endoparasite in banana which is able to complete its life cycle within the root cortex where both the sexes, all juvenile stages and eggs can be found. *Helicotylenchus multicinctus* feeds within the outer layers of the root cortex, causing characteristic lesions, progressive root deterioration, toppling and reduced yields, which ultimately results in the rapid decline of banana plantations [2]. Management of this nematode relies mainly on the repeated use of chemical nematicides which maintain yields 50% greater than in untreated plantations [3]. However, the use of chemical nematicides has many drawbacks among which are the potential residue in fruits, ground water contamination, effect on non target organisms and toxicity to applicators. This necessitates efforts to find alternative methods of nematode control in banana.

Breeding hybrid bananas with nematode resistance is an alternate strategy of controlling these pest simultaneously ensuring environmental safety. Traditional genetic improvements must come from potential and improved diploids, which can be further crossed with commercial variety/hybrids to develop new hybrids [4]. In India, diploid breeding was initiated by hybridizing Matti (AA) as a female parent with diploid male parents like Anaikomban, Pisang Lilin, Tonget and Namarai, as they possessed resistance to nematodes. This study was conducted, therefore, to develop nematode resistant banana hybrids by hybridization of crossing nematode resistant male

*Corresponding author's e-mails: sukhenchandra@rediffmail.com
[1]Present address: College of Agriculture, Tripura
Published by the Indian Society of Genetics & Plant Breeding, F2, First Floor, NASC Complex, PB#11312, IARI, New Delhi 110 012
Online management by indianjournals.com

parents namely, Pisang lilin, Anaikomban, Pisang Jari Buaya, Ambalakadali, Rose, H-56, H-201 and Yangambi KM5 with commercial triploid bananas *viz*., Karpooravalli, Poovan, Hill banana, Manoranjitham and Rasthali. The results obtained are presented in this communication.

Materials and methods

Unopened anthers, just prior to dehiscence, were collected from the inflorescence and pollen smeared over the surface of receptive stigma of female flowers for production of new hybrids [5]. Hybridization was attempted using Manoranjitham, Anaikomban, H 201, H-03-09, H-02-34, H-03-16, H-03-13, Poovan, H-03-13, H-02-34, H-02-23, H-04-06, H-04-05, H-03-35, H-03-12 and H-03-19 as female parent and resistant male parents like Pisang Lilin, Anaikomban, H 201, Ykm-5 and Rose. Breeding work carried out at Horticultural College and Research Institute, Tamil Nadu Agricultural University, Coimbatore, during the year 2005-2008, resulted in development of twenty four elite banana hybrids, out of which hybrids H 516 and H 531 were found as resistant to *H. multicinctus*. The new *Musa* hybrids obtained and some earlier developed ones were assessed for ploidy level using stomatal density and flow cytometry analysis [6]. The hybrids were screened against spiral nematode, *Helicotylenchus multicinctus* infestation. The hybrid Rasthali (AAB, Syn. Silk) was taken as the susceptible reference cultivar and Pisang Lilin (AA) as the resistant cultivar in field and pot studies.

Field screening

The experiment was laid out in a randomized block design with three replicate blocks in *H. multicinctus* sick plot. The initial nematode population in the field was 98 ± 6 /200 cm^3 soil. Other nematodes were negligible. Nematode free suckers of twenty four hybrids and two reference cultivars were planted. Five plants of each accession were planted next to one another in each replicate block. No nematicide was applied. Other standard agronomic practices were followed to raise the crop. At the time of harvest, nematode population in soil/root, root/corm damage was assessed. To assess nematode population roots were collected from a standard size excavation of 20 x 20 x 20 cm extending outward from the corm of the plant, a sub sample of 5 g was taken. Then the roots were macerated 3 times for 10 seconds (separated by 5 second intervals). The suspension was poured through 300 and 40 µm sieves and rinsed with tap water. The nematodes were collected from 40 µm sieve with 200 ml distilled water and the nematodes were counted using a stereomicroscope. Soil from standard excavation size 20 x 20 x 20 cm was collected and a sub sample of 200 cm^3 was processed by Cobb's sieving and modified Baermann funnel method [7].

The extent of nematode damage to roots and corms was assessed following the technical guidelines prescribed by INIBAP [8]. Root damage assessment was done after harvest. Roots were collected from a standard size excavation of 20 x 20 x 20 cm extending outward from the corm and were divided into dead roots and functional roots. Five functional primary roots at least 10 cm long were selected at random from each genotype in each replication. Scoring of feeder roots assigned a score of 1 if the roots were all healthy, 2 for mostly healthy roots, 3 if roots were mostly dead and 4 if all roots were dead. The lengths of the five selected functional roots were all reduced to 10 cm and the roots sliced lengthwise. The percentage of root lesions was assessed in one half of each of the five roots. The maximum root lesion index given per root half was 20, giving a maximum root lesion index of 100 (per cent) for all five together.

Corm damage assessment was done after harvest and after thoroughly shaking off all soil and washing the corms with water. The outward half of the corm was assessed for damage after trimming the roots off. The number of roots showing shallow superficial lesions around their bases on the selected outward half of the corm was counted. The oriental scale of plant response to lesion-forming nematodes used earlier by Pinochet [9] was adapted to the hybrids as tolerant, susceptible or resistant and reaction of banana to spiral nematode according to Pinochet [9].

Pot screening

Screening experiment executed in pots (30 x 20 x 18 cm) filled with sterilized pot mixture (red soil : sand : FYM in the ratio of 2 : 1 : 1 v/v). Each hybrid was replicated three times according to completely randomized design with each replicate consisting of four suckers. *Helicotylenchus multicinctus* multiplied by carrot disc culture technique [10] and plants were inoculated in the rhizosphere of the hybrids by soil injection method @10,000 nematodes/pot. Same set of replicated banana hybrids were also maintained as un-inoculated check. The plants were fertilized with Hoagland's No. 2 nutrient solution fortnightly. The plants were allowed to grow for 90 days in glass house

at 25-27^{o}C. Then the lesion index for five selected functional roots, corm grade and nematode population in 200 cm^{3} sub samples and in 5 g of root sub samples were assessed as described earlier.

The activity of defence-related enzymes *viz*., peroxidase (PO), polyphenol oxidase (PPO) and phenylalanine ammonia lyase (PAL) and phenols in the roots were determined for each replicate after three months, just before root samples were scored for nematode damage. The total phenol in the roots was estimated using Folin Ciocalteau reagent and measuring absorption at 660 nm in a spectrophotometer [11]. For enzyme extraction, one gram of root sample per replicate was homogenized with 2 ml of 0.1 M sodium phosphate buffer (pH 7.0) at 4°C. The supernatant was used as crude enzyme extract for assaying peroxidase and polyphenol oxidase. Enzyme extracted in borate buffer was used for estimation of phenylalanine ammonia lyase. The PO activity was assessed according to Hammer-schmidt *et al.* [12] and the PPO activity was assessed using the modified method of Mayer *et al.* [13].

Results and discussion

Development of nematode resistant hybrids

A total of 7550 crosses were attempted and 2026 seeds were obtained, of which 271 seeds had germinated. Twenty four hybrids were selected for further evaluation because of their parthenocarpic nature (Table 1), while non- parthenocarpic hybrids were discarded. Screening of 24 hybrids showed that two hybrids (H 516 and H 531) were found resistant, six (H 511, H 534, H 537, H 571, H 572 and H 589) tolerant, while remaining hybrids were susceptible and highly susceptible under field

Table 1. Ploidy, genome and yield of twenty-four selected hybrids

S.No.	Hybrids	Parentage	Genome	Ploidy	Yield (kg/plant)
1	H 504***	H-03-09 x Pisang Lilin	AAABB	Pentaploid	4.50
2	H 508	Anaikomban x Pisang Lilin	AA	Diploid	2.50
3	H 511**	H-02-34 x Ykm-5	AABB	Tetraploid	9.50
4	H 515	Manoranjitham x Anaikomban	AAA	Triploid	6.00
5	H 516	Anaikomban x Pisang Lilin	AA	Diploid	7.50
6	H 529	H-03-16 x Anaikomban	AABB	Tetraploid	4.00
7	H 530	H-03-13 (Open pollinated)	AABB	Tetraploid	8.00
8	H 531	Poovan x Pisang Lilin	AAB	Triploid	12.50
9	H 532	H-201 x Manoranjitham	AAB	Triploid	1.50
10	H 534*	H-03-13 x Rose	AAB	Triploid	8.50
11	H 537**	(H-201x Peykunnan) x Rose	AABB	Tetraploid	11.00
12	H 540***	(H-201 x Peykunnan) x Rose	AAABB	Pentaploid	7.00
13	H 542	H-02-34 x Anaikomban	AABB	Tetraploid	8.50
14	H 547	H-02-23 (Open pollinated)	AABB	Tetraploid	5.00
15	H 548	H-02-23 (Open pollinated)	AABB	Tetraploid	5.00
16	H 556	H-04-06 x Ykm-5	AABB	Tetraploid	6.50
17	H 563	H-201 x Pisang Lilin	AB	Diploid	1.50
18	H 564	H-201 x Pisang Lilin	AB	Diploid	2.00
19	H 571**	H-04-05 x Ykm-5	AABB	Tetraploid	8.00
20	H 572	H-03-35 (Open pollinated)	AAB	Triploid	7.00
21	H 573***	H-03-12 x Rose	AAABB	Pentaploid	6.50
22	H 576	H-201 (Open pollinated)	AB	Diploid	1.50
23	H 579	Mano x Rose	AA	Diploid	6.00
24	H 589	H-03-19 (Open pollinated)	AABB	Tetraploid	15.00

* = Triploid; ** = Tetraploid; *** = Pentaploid (All flow cytometry tested)

and pot culture conditions (Tables 2, 3 and 4). Hybridization was taken up between commercial and synthetic triploids with the select potential diploids. Poor fertility and poor viability of the seeds are very common in banana due to ploidy and ascribed to the presence of structural hybridity and chromosomal aberrations [14]. A critical perusal of the genomic constitution of these crosses could reveal that most of them had *balbisiana* genes in their pedigree. The presence of 'BB' genome might be the plausible factor for high female fertility in these crosses. Sathiamoorthy [15] also observed poor seed set in Poovan (AAB) but not in Karpooravalli (ABB) in the earlier studies.

Bunch weight varied among the hybrids. Tetraploid hybrid, H 589 registered the maximum bunch weight of 15 kg followed by the triploid hybrid H 531 with a bunch weight of 12.50 kg while the minimum bunch weight of 1.50 kg was recorded by the triploid hybrid H 532 and diploid hybrids H 563 and H 576 (Table 1). The maximum bunch weight of 15.0 kg/ plant recorded by H 589 (AABB) may be attributed to heterotic vigour, which indicated that parents with wider genetic base as well as geographical diversity might be the important factors to get hybrid vigour in banana. Similar results on heterotic vigour were earlier reported in banana. The nematode resistant hybrid H 531 also recorded relatively higher yield of 12.5 kg/plant.

Significant differences were observed in the number of nematodes in soil and roots from various banana hybrids (Table 2) under field conditions. The nematode population in the soil was low in H 516 and H 531. The highest soil population was observed in H 573. The root population was lowest in H 511 (114/5 g root). H 516 and H 531 had comparatively low root populations (119 and 119, respectively). Root lesion index varied from 3% in H 537 and 46% in H 508. H 531 and H 516 recorded relatively lower root lesion index (4 and 5%, respectively). The corm grade ranged between 1 and 5 among the various accessions and hybrids. H 516 and H 531 rated as resistant, while H 511, H 534, H 537, H 571, H 572 and H 589 were identified as tolerant.

Significant difference was found among the hybrids for root population, soil population and total final population at 90th DAI for *H. multicinctus* (Table 3) under pot conditions . The root population was found to be the lowest in hybrid H 516 (85 per 5 g) and the highest in H 548 (276 per 5 g). The soil population also varied among the hybrids and the hybrid H 516 recorded the lowest 102 per 200 cm^3 of soil while the highest 386 nematodes per 200 cm^3 of soil nematodes was recorded in H 548. Total nematode population was the lowest in H 516 (6,112) and the highest in H 548 (16,596). Based on the intensity of lesion on roots and corm, the hybrids were assessed for their levels of nematode resistance. The root lesion index was the maximum in H 508 (45%) and minimum in H 531 (4%). The hybrid H 508 registered the highest corm grade of 4, whereas H 516, H 531 and H 589 registered the lowest grade of 1. Resistance/tolerance to nematodes can be clearly established by studying the damage caused to the root and corms of the sucker. The INIBAP method largely encompasses the ability of the genotype to resist nematode infection based on root and corm damage assessment besides its ability to tolerate more population of nematodes. The nematode though can live in the soils, it cannot enter into the roots of resistant hybrids and multiply at a faster rate [16]. As the nematode population directly inflicts damage to the root system by causing lesions, assessment of root and corm damage becomes important. Field and pot screening showed that the resistant hybrids *viz*., H 516 and H 531 and tolerant hybrids *viz*., H 511, H 534, H 537, H 571, H 572, and H 589 had lesser number of nematodes in roots and soil resulting in minimum root lesion index and corm. According to Fogain (17) good root development potential favours resistance.

Biochemical contents

Significant variation was observed among the hybrids for peroxidase activity (Table 4) assessed under pot culture conditions. The highest peroxidase activity of 2.26 abs/min/g in control and 2.65 abs/min/g in inoculated banana plants were recorded in H 531. The lowest peroxidase activity of 0.75 abs/min/g in control and 0.81 abs/min/g in inoculated pseudostem was recorded in H 579. However, the per cent increase was the highest in H 572 (18.13%) and the lowest in H 530 (3.33%). The polyphenol oxidase activity varied significantly among the hybrids (Table 3). The hybrid H 531 expressed the maximum activity of 0.096 abs/ min/g in control and 0.120 abs/min/g in inoculated. The minimum of 0.026 abs/min/g was registered by H 563 under control and 0.030 abs/min/g under inoculated. Per cent increase in polyphenol activity was the highest in H 589 (29.41 per cent) and the lowest in H 515(6.06 per cent). The phenylalanine ammonia lyase activity was found to be highly significant among the hybrids (Table 4).The hybrid H 531 expressed the maximum activity of 17.55 nmol/ min/ml under control and 21.10 nmol/min/ml under

Table 2. Root and Corm damage assessment of banana hybrids under field condition infected by *Helicotylenchus multicinctus*

Hybrids	Parents	Genome	Soil population in 200 cm^3	Root population (5g)	Root lesion index(%)	Corm grade	Reaction status	Bunch weight (kg)
H 504	H-03-09 x PL	AAABB	313	350	23	2	S	4.50
H 508	ANK x PL	AA	291	384	46	5	HS	2.50
H 511	H-02-34 x Ykm-5	AABB	183	114	9	1	T	9.50
H 515	Mano x ANK	AAA	293	385	18	2	S	6.00
H 516	ANK x PL	AA	196	119	5	1	R	7.50
H 529	H-03-16 x ANK	AABB	197	271	31	2	S	4.00
H 530	H-03-13 (OP)	AABB	174	146	33	2	S	8.00
H 531	Poovan x PL	AAB	176	119	4	1	R	13.50
H 532	H-201 x Mano	AAB	312	337	20	2	S	1.50
H 534	H-03- 13 x Rose	AAB	218	137	9	1	T	8.50
H 537	(H-201x PK) x Rose	AABB	194	137	3	1	T	11.00
H 540	(H-201 x PK) x Rose	AAABB	301	267	25	2	S	7.00
H 542	H-02-34 x ANK	AABB	251	302	32	2	S	8.50
H 547	H-02-23(OP)	AABB	277	351	27	3	S	5.00
H 548	H-02-23(OP)	AABB	320	362	29	3	S	5.00
H 556	H-04-06 x Ykm-5	AABB	319	351	34	3	S	6.50
H 563	H-201 x PL	AB	319	370	23	2	S	1.50
H 564	H-201 x PL	AB	307	379	22	2	S	2.00
H 571	H-04-05 x Ykm-5	AABB	200	155	9	2	T	8.00
H 572	H-03-35 (OP)	AAB	298	184	7	1	T	7.00
H 573	H-03-12 x Rose	AAABB	340	385	30	2	S	6.50
H 576	H-201(OP)	AB	319	358	20	2	S	1.50
H 579	Mano x Rose	AA	280	345	17	2	S	6.00
H 589	H-03-19 (OP)	AABB	326	214	9	1	T	15.00
Pisang Lilin			145	81	4	1	R	3.50
Rasthali			441	352	44	4	HS	9.50
SEd			4.94	6.81				
CD(.05 %)			9.93	13.69				
CD(.01%)			13.25	18.26				

PL=Pisang Lilin; ANK=Anaikomban; PK=Paykunnan; Mano=Manoranjitham, OP=Open pollinated; R=resistant; T=tolerant; S=susceptible; HS=Highly susceptible

inoculated. The minimum of 9.20 nmol/min/ml under control and 10.05 nmol/min/ml under inoculated was registered by the hybrids H 540. Per cent increase in polyphenol activity was the highest in H 537 (21.85%) and the lowest in H 576 (3.01%). Significant difference was observed in total phenol content among the hybrids (Table 4). The hybrid H 531 registered the highest total phenol content of 332.65 and 383.71µg/g under control and inoculated respectively. However, the lowest phenol content of 120.48 µg/g under controlled and 131.55 µg/g under inoculated conditions was recorded by the hybrid H 579. Per cent increase in total phenol

Table 3. Root and Corm damage assessment of banana hybrids under pot culture conditions infected by *Helicotylenchus multicinctus* at 90th DAI

Hybrids	Root lesion index (%)	Corm grade	Soil population ($200cm^3$)	Root population (5g)	Total population	Reaction status
H 504	27	2	310	245	12,399	S
H 508	45	4	329	237	11,988	HS
H 511	7	2	118	106	7,477	T
H 515	34	2	269	232	11,588	S
H 516	6	1	102	85	6,112	R
H 529	36	2	298	234	15,701	S
H 530	37	2	263	198	13,723	S
H 531	4	1	106	80	6,249	R
H 532	25	2	337	249	12,783	S
H 534	5	2	120	111	7123	T
H 537	5	2	124	103	7168	T
H 540	18	2	301	256	16,534	S
H 542	40	2	325	236	13,872	S
H 547	32	3	335	217	12,963	S
H 548	30	3	386	276	16,596	S
H 556	39	3	365	232	14,609	S
H 563	28	2	285	196	10,897	S
H 564	29	2	293	201	11,022	S
H 571	6	2	117	101	6,509	T
H 572	5	2	121	112	6,850	T
H 573	28	2	364	237	13,592	S
H 576	25	2	348	226	12,905	S
H 579	15	2	295	257	15,941	S
H 589	6	1	119	102	7,721	T
Pisang Lilin	5	1	105	82	4051	R
Rasthali	48	4	432	298	13606	HS
SEd			15.271	11.160	656.419	
CD(.05 %)			30.643	22.395	1317.205	
CD(.01%)			40.831	29.840	1755.151	

R=Resistant; T=Tolerant; S=Susceptible; HS=Highly susceptible

content over control was the maximum in H 571 (19.29%) and the minimum in H 504 (2.77%) than control among the hybrids.

Enzyme activity is one of the important tools to confirm the resistance to root pathogenic nematodes. When a nematode infects the host tissue, a small number of specific genes are induced to produce mRNA's that permit synthesis of similar number of specific proteins [18]. Many of these proteins are enzymes such as phenylalanine ammonia lyase, polyphenol oxidase, peroxidase and b-1-3 glucanase [19]. These are involved in the synthesis of low molecular weight substances such as phytoalexins, phenols and lignin, which are inhibitory to the invading nematodes [19]. Hence, estimation of these biochemical markers, which provide mechanism for resistance to nematodes, is highly essential. Among the various enzymes, peroxidase is considered as one of the important defense related enzymes due to its role in catalyzing the condensation of phenolic compounds into lignin. Estimation of peroxidase activity in the current study elicits that all the resistant genotypes possessed higher peroxidase activity than the susceptible ones. Enhanced peroxidase activity has been associated with hybrids resistant to nematodes [20].

Polyphenol oxidase (PPO) oxidises the phenols to highly toxic quinones and hence is considered to play an important role in disease resistance, particularly those affecting the tissues [21]. Thus, the overall analysis of estimation of these enzymes in resistant and susceptible hybrids indicated the role of these enzymes in conferring resistance to nematodes. A critical analysis of their activity within hybrids reveals that nematode resistant and tolerent hybrids *viz*., H 531, H 516, H 511, H 534, H 537, H 571, H 572 and H 589 recorded higher peroxidase and polyphenol oxidase activity than the susceptible ones. Similar findings were earlier reported in banana by Das *et al.* [20]. Total phenols play a unique role in response to nematode invasion. The results of the present study revealed a significant increase in phenol content in above described hybrids *vis-a-vis* in others. The accumulation of phenol may be due to the excess production of hydrogen peroxide by increased respiration or due to the activation of hexose monophosphate (HMP) shunt pathway, acetate pathway and release of bound phenols by hydrolytic enzymes [22]. In conclusion, the overall evaluation of 24 parthenocarpic *Musa* hybrids led to identification of the hybrid H 531 with high yield potential as well as increased resistance to *H. multicinctus*.

Table 4. Enzyme activity and phenol content in hybrids inoculated with *Helicotylenchus multicinctus* at 90th DAI under pot culture

Hybrids	Peroxidase (abs/min/g)			Polyphenol oxidase (abs/min/g)			PAL (nmol/min/ml)			Total phenol(µg/g)		
	C	I	%	C	I	%	C	I	%	C	I	%
H 504	1.52	1.60	5.26	0.031	0.034	9.68	12.35	13.40	8.50	255.65	262.72	2.77
H 508	1.22	1.28	4.92	0.042	0.046	9.52	11.25	12.33	9.60	220.70	228.80	3.67
H 511	1.93	2.22	17.10	0.081	0.092	13.58	15.85	17.96	13.31	293.55	333.61	13.99
H 515	1.15	1.22	6.09	0.033	0.035	6.06	12.68	13.70	8.04	210.30	224.50	6.75
H 516	1.95	2.21	13.33	0.090	0.099	10.00	16.82	19.90	18.31	329.45	361.82	9.83
H 529	1.23	1.29	4.88	0.040	0.043	7.50	12.20	13.27	8.77	201.30	216.55	7.58
H 530	1.20	1.24	3.33	0.035	0.038	8.57	13.15	14.20	7.98	215.80	222.92	3.30
H 531	1.98	2.26	12.12	0.096	0. 120	25.00	17.55	21.10	20.23	332.65	383.71	15.35
H 532	1.16	1.21	4.31	0.036	0.039	8.33	12.25	12.95	5.71	140.35	145.73	3.62
H 534	1.82	2.16	18.68	0.082	0.098	19.51	15.46	18.55	19.99	285.50	320.56	12.28
H 537	1.85	2.19	18.38	0.080	0.097	21.25	16.25	19.80	21.85	290.40	326.44	12.41
H 540	1.05	1.11	5.71	0.029	0.033	13.79	9.20	10.05	6.91	210.75	221.84	5.26
H 542	1.01	1.08	6.94	0.035	0.038	8.57	10.64	10.96	3.01	205.60	218.69	6.37
H 547	0.96	1.02	6.25	0.038	0.041	7.89	10.26	11.35	10.62	204.30	222.50	8.91
H 548	0.99	1.04	5.05	0.042	0.045	7.14	11.30	12.42	9.92	185.80	196.93	5.99
H 556	0.92	0.98	6.52	0.046	0.050	8.70	12.15	13.26	9.14	180.65	192.76	6.70
H 563	0.87	0.92	5.75	0.026	0.030	19.23	9.40	10.35	12.50	160.70	172.79	7.52
H 564	0.89	0.94	5.62	0.027	0.031	11.11	10.15	10.85	6.89	165.80	174.93	5.51
H 571	1.86	2.18	17.20	0.081	0.096	18.52	16.20	19.32	19.26	275.60	328.75	19.29
H 572	1.82	2.15	18.13	0.080	0.098	22.50	17.15	20.20	17.78	282.95	333.96	18.03
H 573	0.90	0.94	4.44	0.033	0.036	9.09	11.65	12.76	9.53	135.32	142.43	5.25
H 576	0.84	0.89	5.95	0.034	0.038	11.76	10.28	10.81	5.16	130.76	140.80	7.68
H 579	0.75	0.81	8.00	0.039	0.043	10.26	12.25	13.32	8.73	120.48	131.55	9.16
H 589	1.79	2.12	18.44	0.085	0.110	29.41	17.20	20.28	17.91	310.84	356.95	14.83
Pisang Lilin	1.82	2.24	23.08	0.12	0.147	22.50	17.75	21.92	23.49	338.56	381.65	12.73
Rasthali	0.50	0.54	8.00	0.026	0.027	3.85	9.20	9.95	8.15	110.72	116.87	5.35
SEd	0.121	0.145	0.641	0.005	0.006	0.838	0.753	0.861	0.764	13.021	13.993	0.577
CD(0.05%)	0.245	0.290	1.286	0.010	0.012	1.681	1.511	1.728	1.533	26.128	28.080	1.157
CD(0.01%)	0.326	0.387	1.711	0.012	0.017	2.240	2.014	2.303	2.042	34.815	37.416	1.542

DAI=Days after inoculation; C=Control; I=Inoculated; %=Per cent difference over control; PAL=Phenylalanine Ammonia Lyase

Acknowledgements

The authors wish to thank and acknowledge the financial support of the Flemish office for Development Cooperation and Technical Assistance (VVOB), Belgium and the International Network for the Improvement of Banana and Plantain (INIBAP) obtained through NRC for banana.

References

1. **Sasser J. N. and Freckman D. W.** 1987. A world perspective on Nematology: The role of the society. Pp. 7-14. *In* : Vistas on Nematology (Veech, J.A. and Dickson, D.W., eds). Society of Nematologists , Inc, Hyattsville, USA.
2. **Rajendran G. and Sivakumar C. V.** 1996.

Pathogenicity of the spiral nematode *Helicotylenchus multicinctus* (Cobb, 1893) Golden, 1956 and effect on yield and nutrient status of banana. Pest Manag. Hort. Ecosyst., **2**: 23-27.

3. **Sundararaju P. and Kumar V.** 2003. Management of root-lesion nematode, *Pratylenchus coffeae* in six commercial cultivars of banana through organic and inorganic amendments. Infomusa, **12**: 21-25.
4. **Rowe P. R. and Rosales F. E.** 1993. Bananas and plantains. *In*: Advances in Fruit Breeding. Janick J. and J. N. Moore (eds.). John Wiley & Sons Inc., New York.
5. **Rowe P. R. and Richardson D. L.** 1975. Breeding bananas for disease resistance, quality and yield. Tech. Bull. No.2. Trop. Agrl. Res. Ser., La Lima, Honduras. p. 25.
6. **Damodaran T., Kumar N., Dolezel J., Suchankova P. and Kavino M.** 2006. Hybridization and ploidy determination in new banana hybrids, Phytomorphology, **56**: 1-6.
7. **Southey J. F.** 1986. Laboratory methods for work with plant and soil nematodes. Ministry of Agriculture, Fisheries and Food, Her majesty's Stationary Office, London, pp. 202.
8. **Speijer P. R. and De Waele D.** 2002. INIBAP Technical guideline.
9. **Pinochet J.** 1988. A method for screening bananas and plantains to lesion forming nematodes. In: Nematodes and borer weevil in bananas, INIBAP Montpellier, France, pp. 62-65.
10. **Pinochet J., C. Fernandez and Sarah J. L.** 1995. Influence of temperature on *in vitro* reproduction of *Pratylenchus coffeae*, *P. goodeyi*, and *Radopholus similis*. Fund. Appl. Nematol., **18**: 391-392.
11. **Spies J. R.** 1955. Methods in enzymology. S. P. Colowick and W. O. Kaplan (eds.). Academic press, pp. 467-468.
12. **Hammerschmidt R., Nuckles E. M. and Kuc J.** 1982. Association of enhanced peroxidase activity with induced systemic resistance of cucumber to *Colletotrichum lagenarium*. Physiol. Plant Pathol., **20**: 73-82.
13. **Mayer A. M., Haul E. and Shaul R. B.** 1965. Assay of catechol oxidase, a critical comparison of method. Phytochemistry, **5**: 783-789.
14. **Dodds K. S.** 1945. Genetical and cytological studies of *Musa*. VI. The development of female cells of certain edible diploids. J. Genet., **46**: 161-179.
15. **Sathiamoorthy S.** 1987. Studies on male breeding potential and certain aspects of breeding bananas. Ph.D. (Hort.) Thesis, Tamil Nadu Agriculture University, Coimbatore.
16. **Gowen S. R.** 1994. Burrowing nematode and root rot. *In*: Compendium of tropical fruit diseases, Ploetz., R.C., G.A. Zentmyer, W. T. Nishijima, K.G. Rohrsach, and H.D.Ohr, (Eds.). APS press, St plant MN. USA, pp. 21.
17. **Fogain R.** 1995. Study of resistance of *Musa* spp. to nematodes (*Radopholus similis* and *Pratylenchus goodeyi*). Ph.D. Thesis, University of Reading, Berkshire, U.K.
18. **Vera P. and Conejero V.** 1989. The induction and accumulation of pathogenesis -related P69 proteinase in tomato during citrus exocortis viroid infection and after chemical treatments. Physiol. Mol. Plant Pathol., **34**: 323-334.
19. **Vidhyasekaran P.** 1993. Defense genes for crop disease management, Genetic Engineering, Tissue Culture and Molecular Biology for Crop Pest and Disease Management (P. Vidhyasekaran ed.) Daya Publishing House, New Delhi, pp.17-30.
20. **Das S. C., Balamohan T. N., Poornima K., Velalazan R. and Seenivasan N.** 2011. Reaction of *Musa* Hybrids Resistantance to *Meloidogyne incognita*. Indian J. Nematol., **41**: 189-196.
21. **Farkas G. L. and Kirlay Z.** 1962. Role of phenolic compounds in the physiology of plant disease resistance. Phytopathology, **44**:105-150.
22. **Goodman R. N., Kiraly E. and Ziatlin M.** 1967. The biochemistry and physiology of infectious plant diseases. D. Van. Nosti and Co., Princeton, New Jersey, pp. 354.