ISSN 0115-463x

CSSP 1970

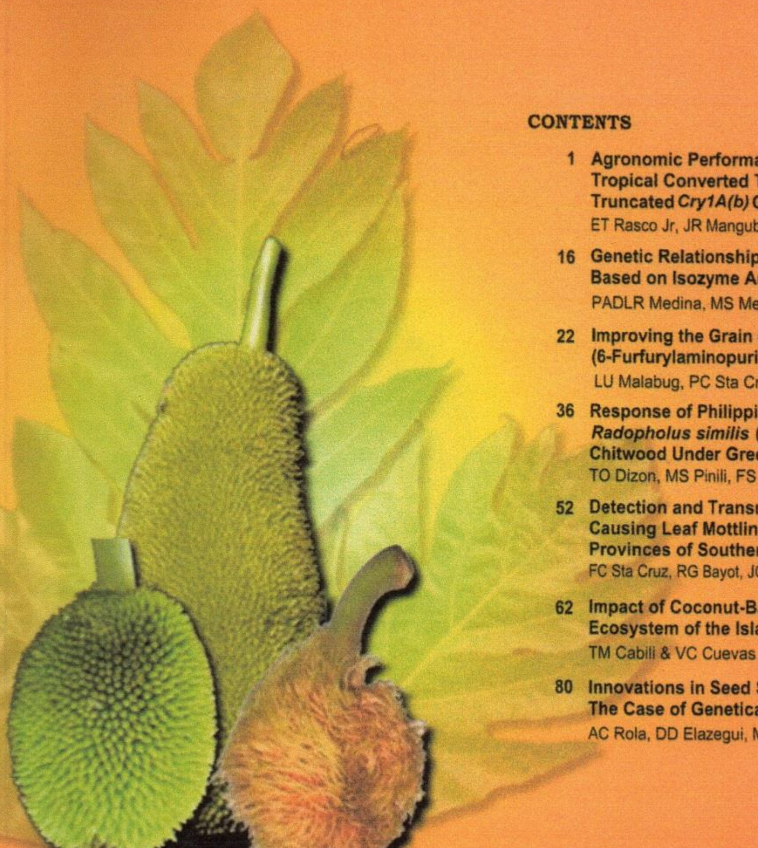
THE PHILIPPINE JOURNAL OF CROP SCIENCE

Published by the Crop Science Society of the Philippines

Volume 35 No. 1 April 2010

"... that whoever could make two ears of corn, or two blades of grass, to grow on a spot of ground where one grew before, would deserve better of mankind and do more essential service to his country..."

-- Jonathan Swift



Some *Artocarpus* species in the Philippines

CONTENTS

PJCS is an ISI journal listed in the 15th of January 2007 'CABI Full Text Journals' accepted. Check url: http://bg.au.poznan.pl/dzialy/download/CABI%20Full%20Text%20journals.pdf. PJCS is being indexed and abstracted in Science Citation Index Expanded (Sci Research) and Journal Citation Reports / Science Edition.

Philippine Journal of Crop Science (PJCS) April 2010, 35 (1):36-51

Response of Philippine Banana (*Musa* spp.) Cultivars to *Radopholus similis* (Thorne) and *Meloidogyne incognita* Chitwood Under Greenhouse Conditions

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A total of 32 Philippine banana cultivars of varying genotypes including two collections of wild *Musa balbisiana* were evaluated for resistance to burrowing nematode, *Radopholus similis*, and root-knot nematode, *Meloidogyne incognita*, under greenhouse conditions. Resistance was evaluated based on plant growth parameters, root damage and nematode reproduction.

Cultivars Ambon (AAA), Cuarenta Dias (AA), Carbada (BBB), Katali (ABB), Kinamay Dalaga (AA), Morong Princesa (AA), Tanggung (AAA) and wild *Musa balbisiana* (BBw) collection 98-085 were identified to be resistant and/or tolerant to *R. similis*. On the other hand, cultivars Ambon (AAA), Pandili (unclassified) and Sulay Baguio (AAA) were found resistant to *M. incognita*, whereas Cardaba (BBB), Datu (AAA), Katali (ABB), Kinamay Dalaga (AA), Laknau (AAB), Manang (AA) and Matavia (ABB) were tolerant.

Key words: banana cultivars, *Meloidogyne incognita, Radopholus similis,* resistance

INTRODUCTION

Bananas (*Musa* spp.) are one of the most important crops in the Philippines. The crop is grown in a wide range of environments. Majority of the local producers are small scale farmers who grow bananas for home consumption or for the local market as a source of income. But there are also some multi-national companies that contribute to the world's supply of export bananas (Frison and Sharrock 1999). Bananas are a popular fruit because they easily grow under Philippine conditions with minimum cultural management. They are short-season crops which produce fruits year round and have multiple uses.

The Philippines contributed 9.38% to world's production of banana in 2005, with corresponding production of 6,298.23 M mt. Our country ranked second exporter of banana with a net export of 1.9047 M mt (FAO 2006 as cited by Maghirang 2007). The reported export volume in 2005 was 1,964,396.65 mt, equivalent to 16.5% of the total world's export market. The country's major varieties being exported were Cavendish, as fresh bananas and Saba or Cardaba as chips. In 2005, exported as fresh banana was 2,304,180,085 mt, and as chips, 37,754,368 mt. Most of the country's banana varieties are being exported to Japan (41%) as fresh, and to USA (20%), China (17%) and Germany (14%) as chips (Maghirang 2007).

In 2006, the total area planted to banana was 428,800 ha, and the volume of production was 6,794,564 mt valued at PhP 47.97M. The largest production of banana, mainly Cavendish variety, was located in Region 11, which constituted 43.35% of the total banana production (Maghirang 2007).

Like other crops, banana is infested by insect pests and diseases including black leaf streak, *Fusarium* wilt, banana bunchy top and plant parasitic nematodes, corm weevil, aphids and mealybugs. Among its pests, nematode is the most significant. Nematodes are recognized as one the major constraints to banana production worldwide. In a nationwide survey conducted in Luzon, Visayas and Mindanao from 1974 to 1977, the common species of nematodes associated with some native cultivars of banana were *Meloidogyne, Radopholus similis, Helicotylenchus, Pratylenchus, Rotylenchus, Tylenchorynchus, Hoplolaimus* and *Rotylenchulus* (Davide and Gargantiel 1974; Davide and Zarate 1977). Recent study by Erana (2005) reported the occurrence of *Hemicycliophora* and *Xiphinema* in banana growing area. Both *R. similis* and *Meloidogyne* are major problems not only in banana but in almost all crops since they are most common and has wide host range (Castillo et al 1974; Boncato and Davide 1980).

Radopholus similis (Thorne) or the burrowing nematode is one of the most damaging and widespread nematodes attacking bananas (Stover and Simmonds 1987). It was the most destructive species found in introduced Cavendish variety grown in Davao province followed by *Helicotylenchus* *multicinctus* and *Meloidogyne* spp. (Boncato and Davide 1980). Several years later, *R. similis* was found to infect not only the Cavendish variety but also the native or local varieties and introduced or foreign banana varieties (Erana 2005). It is a migratory endo-parasite that enters the roots and spends its life cycle inside the roots. It destroys the roots by feeding on the cytoplasm of the cortical parenchyma cells (Blake 1961). As the nematode grows, it continually feeds causing tunnels towards the endodermis. At this stage, reddish brown lesions are observed throughout the cortex. In most cases, the stele remains healthy (Stover 1972). Once the roots are destroyed, water and nutrient uptake are hindered and anchorage of the roots to the soil is affected. It causes blackhead and rotting of the whole root system and corm. Severely infected plants tend to topple down due to uprooting (Ohm Williams and Siddiqi 1973). Besides root rotting, other aboveground symptoms that can be observed due to *R. similis* include wilting, leaf yellowing, premature defoliation, reduction in leaf size and number, reduction in growth and development.

Meloidogyne spp. or the root-knot nematode attacks almost all economically important crops. The most common species *Meloidogyne* affecting bananas *are M. incognita* Chit., *M. javanica* Chit. and *M. arenaria* Chit. It is also endo-parasitic but sedentary. Once inside the roots, they induce production of multi-nucleate giant cells and multiplication of cortical cells resulting to gall formation. These giant cells block the surrounding xylem vessels (dos Santos and Sharma 1978). Symptoms of *Meloidogyne* infection are formation of galls on primary, secondary and tertiary roots, cessation of growth of root tips and root proliferation above infected roots. Other aboveground symptoms are leaf yellowing and stunted growth. Davide and Marasigan (1985) reported that an inoculums level of 1,000 larva per plant of Cavendish variety resulted in 27.40% yield loss, and at 10,000 larva per plant, yield loss increased to 45.4%.

Pratylenchus is another migratory endo-parasitic nematode and causes similar root damage as *R. similis*. Two species have been reported in banana viz. *P. coffeae* and *P. goodeyi* Sher & Allen (Speijer 1993, Pinochet et al 1995). However, they do not cause serious damage in banana since they are not widely distributed. *Helicotylenchus multicinctus* is another nematode problem in Davao province in early 1990 (RA Zorilla, Personal Communication). However, it is not causing serious damage in banana since it is an ecto-parasite. Larva only feed on the surface of the roots.

Nematodes can be managed by cultural practices like: crop rotation, fallowing and flooding; physical means such as hot water treatment of corms, solar or soil sterilization; application of botanical pesticides such as Marigold; biological control using *Paecilomyces lilacinus* (BIOACT) and *Penicillium oxalicum* (Tandingan and Davide 1992); and through the application of nematicides. However, these management strategies are often not very effective, reliable, not practical, highly expensive and unaffordable for small scale farmers. The chemicals used as nematicides are extremely toxic and hazardous to humans and the environment.

Host-plant resistance can offer an alternative means of managing, if not totally eliminating, nematodes. It remains the most practical approach in dealing with banana nematode problems (Fogain and Gowen 1996; Pinochet et al 1998). Many studies were done to develop and standardize screening procedure for nematode resistance in banana worldwide (Pinochet et al 1995; Pinochet 1996; Speijer and De Waele 1997; De Schutter et al 2001). In screening for *R. simils* and *Pratylenchus* resistance, *in vitro* culture using carrot discs was developed for rapid multiplication of larvae for inoculation (Pinochet et al 1995). For *Meloidogyne* screening, multiplication of the larvae is being done on susceptible host. Single root inoculation was developed by De Schutter and co-workers (2001). Nematodes from carrot discs and live plants were extracted using a modified Baermann funnel technique (Speijer and De Waele 1997). Evaluation of resistance can be done on mature banana plants under field condition and on tissue cultured plantlets under greenhouse condition. For the current work, the protocol developed by Carlier and co-workers as indicated in the INIBAP Technical Guidelines (2003) was followed. Determination of the nematode reproduction for *R. similis* was done first by determining the root fresh weight, extracting the nematode from the soil and assessing the nematode population or number of nematodes per root unit and per root system. For *Meloidogyne*, nematode reproduction was assessed by determining the root fresh weight, number of egg-laying females and larva and eggs per root unit and per root system. Assessing the root damage caused by *R. similis* was done by counting the number of dead roots and the functional roots and by taking the percentage root necrosis on five 10-cm root segments. For *Meloidogyne*, the root galling of the whole root system was rated. Aside from the nematode reproduction and root damage assessment, plant growth parameters like plant height, girth of the pseudostem at the base, shoot fresh weight and root fresh weight were taken to determine the effects of nematodes. Sources of resistance to *R. similis* in banana have been identified in Yangambi Km 5 (AAA) (Sarah et al 1992), Pisang Jari Buaya (AA) (Wehunt et al 1978) and wild *Musa balbisiana* (BBw) (Fogain et al 1996). In the Philippines, Davide and Marasigan (1985) reported that cultivars Inambak (unclassified), Pastilan (AAA), Pugpogan (AA) and Maia Maoli (AAB) are resistant to *R. similis*. They also identified some sources of resistance to *M. incognita*: Alaswe (AA), Paa-Dalaga (BBB), Dakdakan (AAA) and Viente Cohol (AA).

The objective of this study is to screen Philippine banana cultivars for resistance to *R. simiis* and *M. incognita* under greenhouse condition.

MATERIALS AND METHODS

The experiment was conducted at the Nematology Laboratory of the Plant Pathology Section of the Institute of Plant Breeding (IPB), Crop Science Cluster, College of Agriculture, University of the Philippines Los Baños (UPLB), College, Laguna from July 2002 to June 2008. Planting of banana and inoculation with nematodes were done at the greenhouse while *in vitro* culturing of *R. similis* and evaluation of inoculated and un-inoculated plants were done at the Nematology Laboratory of the IPB.

Materials

The names and genomes of the tested banana cultivars used for both nematodes were indicated in Table 1. Five pot experiments were done for *R. similis*, whereas, six for *M. incognita* (Table 2). The duration for each experiment was 3 to 3.5 months from potting out of the tissue cultured plantlets to collection of data and evaluation of results.

Methods

***In Vitro* Propagation of Banana Plantlets.** All the local banana cultivars evaluated for resistance to *R. similis* and *M. incognita* were collections of the National Plant Genetic Resources Laboratory of the Institute of Plant Breeding (NPGRL-IPB), UPLB. Bananas were grown in Murashige & Skoog proliferating medium (Murashige and Skoog 1962). After which plantlets were transferred to rooting medium and incubated for one month. Healthy plantlets were then acclimatized at room temperature and then individually removed from vials and planted in plastic bag containing sterile mixture of garden soil, river sand and coir dust at 1:1:0.5 ratio. Prior to planting, the mixture was drenched with Mancozeb R (1 T per gallon of water) to prevent fungal contamination. Eight to ten plantlets per cultivar were inoculated with the nematodes while the same number of plantlets were not inoculated to serve as control. Plastic pots were placed over the plastic plates. For *R. similis*, the resistant check cultivars were Yangambi Km 5 and Pisang Jari Buaya, while the susceptible check cultivar was Grand Naine. For *Meloidogyne incognita,* only Grand Naine was used as the susceptible check. No resistant check cultivar has been provided. Cultivars Yangambi Km 5, Pisang Jari Buaya and Gand Naine are being used in global evaluation of *Musa* germplasm for nematode resistance.

***In Vitro* Culturing of *Radopholus similis*.** *Radopholus similis* were extracted from infected roots obtained from Davao City, Philippines. Infected ro samples were cut into small pieces and macerate using Waring blendor for 30 s (three 10-s perio separated by 5-s intervals). The suspension an macerated roots were passed through 250, 106 an 40-µm pore sieves, rinsed with water after each pass The suspension at 40-µm pore sieve was collected i a beaker. To separate the dead nematodes from th living ones, the suspension was collected and poure in modified Baerman funnel and incubated overnigh The suspension was examined under th Stereomicroscope. The gravid females of *R. simili* were picked up using thin bamboo midrib and place in sterile distilled water. The suspension wa transferred in 10-µm pore sieve placed in 0.01% $HgCl_2$ for 2 min and rinsed with sterile distilled water The sterile nematodes was transferred to sterile tes tube with 2,000 ppm streptomycin sulfate and incubated overnight. The solution was sucked and rinsed with sterile distilled water twice. Approximately 25 gravid females of *R. similis* were placed at the margin of the carrot (*Daucus carota* L.) discs under the Laminar flow hood.

Preparation of the carrot discs was done following the method of O'Bannon and Taylor (1968). Blemish-free, healthy fresh carrots with foliage were washed thoroughly with water and blotted dry. They were surface sterilized with ethanol prior to peeling in a Laminar flow hood. The procedure was done 3 times. Using flame sterile sharp knife, the carrot was cut into discs, about 4-5 mm thick, and placed in sterile Petri dish. The number of discs per plate depended on their size. Using sterile Pasteur pipet, drops of nematode suspension were placed at the margin of the disc. The Petri dish was sealed with parafilm, placed in the Incubator (Binder) having a temperature of 28°C for 7-8 wk. The inoculum was examined regularly to determine the presence of contaminations. Discs contaminated with bacteria or fungi were discarded. For series of inoculation of *R. similis*, the procedure was repeated except the use of $HgCl_2$.

***In Vivo* Culturing of *Meloidogyne incognita*.** *M. incognita* population was obtained from banana plants grown at the UPLB. Galled roots were collected, cleansed and processed using sieving method. Roots were macerated in Waring bender and then passed through three series of mesh sieves as described above. Suspension from the 40-µm sieve was poured into pots with 1.5 month-old okra plants. Inoculum was maintained continuously from those plants to ensure availability for screening.

Extraction of *Radopholus similis* and *Meloidogyne incognita*. For inoculation with *R. similis*, carrot discs were macerated in Waring blender as described earlier. The suspension from the 40-µm sieve was collected in a beaker and diluted with water. The number of living *R. similis* was counted under the Stereomicroscope (Motic), and further diluted to

Table [illegible]. Philippine *Musa* genotypes tested for resistance to *Radopholus similis* (Davao population) and *Meloidogyne incognita* (UPLB population).

Musa genotype	Local synonym	Genomic group	Subgroup/ Related type	Type
[illegible]				
[illegible]		AAA	cavendish	Dessert
[illegible]	Tudlo Datu	AA		Dessert
[illegible]	-	AAA	Ibota	Dessert
[illegible]				
[illegible]	Nelam, Gros Michel	AAA		Dessert
[illegible]	Taripan	AA		Dessert/cooking
[illegible]	-	AAB	plantain	Cooking
[illegible]	Burunguran, Buluñgan, Balingan	AAA	Ibota	Dessert
[illegible]	Calisnon	BBB		Cooking
[illegible]	-	AA		Cooking/dessert
[illegible]	-	AA		Cooking/dessert
[illegible]	-	AAA		Cooking
[illegible]	Turdang panarii	AAB		Dessert
[illegible]	Gaddatu, Padilat	BBB		Cooking
[illegible]	-	AA		Dessert
[illegible]	-	AAB		Dessert
[illegible]	-	Unclassified		Cooking
[illegible]	Lagkitan, Botolan	ABB	Pisang awak	Cooking/dessert
[illegible]	Candy banana	AA		Dessert
[illegible]	Mapang	AA		Dessert
[illegible]	Darayan, Cuhaman, Puguran, Kalaykay, Maybag, Dukka	AAB	Plantain	Cooking
[illegible]	Tundan, Turdan, Cantong	AAB	Silk	Dessert
[illegible]	-	ABB	Monthan	Cooking
[illegible]	Sapnay	AA		Dessert
[illegible]	Batana, Dacosta, Galangan, Sabang Iloco	ABB		Cooking
[illegible]	-	AAB		
[illegible]	-	AA	Pisang raja	Cooking/dessert
[illegible]	-	AAA		Cooking
[illegible]	-	Unclassified		
[illegible]	Aguila	AAA		Dessert
[illegible]	-	AAB	Plantain	Cooking
[illegible]	-	AA		Dessert
[illegible]	Tigbao	ABB		Cooking/dessert
[illegible]	Sale Baguio, Chinese Dwarf, Dwarf Cavendish, Tampuhin,	AAA	Cavendish	Dessert
[illegible]	Amas manado, Siañgil	AAA		Dessert
[illegible]	Ondoc	AAB	Plantain	Cooking
[illegible]	Balongkare	ABBB		Cooking
[illegible]	Tuduk, Todoc, Tuldoc	AAA		Dessert
[illegible]	-	AAA		Dessert
[illegible]	Pik-iw	BBw		Wild
[illegible]	Pik-iw	BBw		Wild

Table 2. Local banana cultivars and species evaluated for resistance to *Radopholus similis* (Davao population) and *Meloidogyne incognita* (UPLB population).

Genotype	*Radopholus similis* Pot Experiment					*Meloiodgyne incognita* Pot Experiment					
	1	2	3	4	5	1	2	3	4	5	6
Grand Naine (S)	/	/	/	/	/	/	/	/	/	/	/
Pisang Jari Buaya (R)	/					/	/				
Yangambi Km 5 (R)	/	/	/		/	/	/				
Ambon		/					/				
Alaswe		/							/		
Bungaoisan				/	/	/					
Bungulan		/								/	
Cardaba			/						/		/
Cuarenta Dias		/							/		
Dakdakan						/					
Datu								/			
Galamay Señora	/							/			
Gubao						/					
Guyod	/							/			
Hilao-hinog				/		/					
Inambak				/				/			
Katali				/							/
Kinamay Dalaga					/					/	
Lakatan		/			/		/		/		
Laknau				/						/	/
Latundan				/							
Madurangga					/						/
Manang			/								/
Matavia											/
Morado							/	/			
Muracho											/
Morong Princesa			/						/		
Oma				/							/
Pandili			/			/		/			
Pastilan	/					/					
Patag							/				
Rawari	/					/					
Suisok			/							/	
Sulay Baguio	/							/			
Tanggung			/							/	
Tindok					/			/			
Tiparot							/	/			
Tudok			/					/			
Umalag					/					/	
Wild *Musa balbisiana* (98-085)				/							
Wild *Musa balbisiana* (98-617)				/							

R – resistant check, S – susceptible check deliver approximately 1,000 juveniles and eggs per plant.

For *M. incognita*, okra plants were uprooted. The roots were thoroughly cleansed with water and cut from the shoots. Galled roots were cut into small pieces and macerated in Waring blender as described earlier. The suspension from 40-µm sieve was collected and diluted with water. The number of juveniles and eggs were counted and further diluted to deliver approximately 5,000 each per plant.

Inoculation of Banana with Radopholus similis and Meloidogyne incognita. Prior to inoculation, three holes around the base of the banana plant were made. The nematode suspension was mixed and air was blown into the suspension to equally distribute the nematodes. Suspension was sucked using pipetor and poured evenly into the holes. After which, the holes were covered with the soil. To mask the effect of the growth of the different cultivars, individual plants were placed at random in a bench.

Maintenance of Inoculated Plant. After inoculation, plants were maintained by regular watering of plastic plates placed under each pot. Application of compete fertilizer (14-14-14) was done every 2 weeks. As necessary, plants were sprayed with Methomyl R to kill insects. Due to the large number of local cultivars evaluated, the cultivars were grouped into pot experiments. Each pot experiment contained local cultivars to be tested and check or reference cultivars. The cultivars for each pot experiment were selected based on the availability of the tissue cultured plantlets during the conduct of the experiment. In all pot experiments, the methodology was standardized, such as soil mixture, age of the plant at inoculation and during evaluation, number and population of nematodes, watering, fertilization and time of data collection. The only factor that was not consistent was the environmental factors particularly temperature in the greenhouse during the conduct of the study.

Assessment of Nematode Damage. Two to three months after inoculation, plants were collected and processed following the methodology of Speijer and De Waele (1997). Plants were carefully removed from the pots and the roots were thoroughly washed with tap water. Whole plants were brought to the Nematology Laboratory for evaluation. The following plant parameters were recorded: plant height (cm), pseudostem girth at base (cm), shoot fresh weight (g) and root fresh weight (g). After weighing the whole roots, damages due to *R. similis* and *M. incognita* were taken. To determine the effect of nematode per individual plant, percent difference, computed as un-inoculated minus the inoculated divided by the un-inoculated multiplied by 100, was taken.

The same parameters were used to evaluate un-inoculated banana cultivars. For *R. similis*, percentage dead roots (number of dead roots divided by the total number of roots multiplied by 100) and the percentage root necrosis were taken. Percentage root necrosis was taken by selecting at random 5 roots and cut into 10-cm length. The roots were cut into half lengthwise and necrotic cortical tissues were assessed. For *M. incognita*, whole root system was examined for the presence of root galls. Root galling index, base on the percentage of roots, was taken as follows: 0 – no galling; 1 – trace infection with few small galls; 2 - <25 of roots galled; 3 – 25 to 50% roots galled; 4 – 50 to 75% of roots galled; and 5 - >75% of roots galled.

Determination of Nematode Reproduction. The number of *R. similis* and *M. incognita* in fresh roots was evaluated. One-gram roots were cut into small pieces and macerated in Waring blender as described earlier. The suspension from 40-µm sieve was placed in beaker of known volume and counted. In addition to the number of juveniles and adults on fresh roots, the number of egg-laying females of *M. incognita* on roots was determined. One-gram of galled roots was cut into 1-cm pieces and placed in small vial. Boiled modified acid fuchsin stain was poured into the vial enough to cover the roots. After 24-48 h, stained roots were placed in clean Petri dish, crushed with clean scalpel and forceps and the number of egg laying females was counted under the Stereomicroscope. The number of nematodes per gram of roots and whole root system was determined.

Data Analysis

Statistical analyses of the results of each pot experiment were performed using software Package SPSS 13 for Windows. Significant differences on plant parameters between inoculated and uninoculated plants were determined at $p<0.05$, $p<0.01$ and $p<0.001$ using t-test. Mean comparison among the inoculated cultivars was done by Tukey's Least Significance at 5% level. Data on nematode count were transformed using $\log_{10}$ transformation before statistical analysis.

RESULTS

Radopholus similis

The effect of *R. similis* on plant growth, root damage and reproduction on different *Musa* genotypes is shown in Table 3.

Pot Experiment 1. Eight cultivars namely Galamay Señora, Grand Naine, Guyod, Pastilan, Pisang Jari Buaya, Rawari, Sulay Baguio and Yangambi Km 5, were used. Yangambi Km 5 and Pisang Jari Buaya were the resistant cultivars while Grand Naine, the susceptible cultivar. Most of the cultivars inoculated with *R. similis* had reduced plant height, shoot weight and root weight. Pseudostem girth was not affected by

Table 3. Growth parameters, nematode damage and reproduction of different *Musa* cultivars, 8-10 weeks after inoculation with *Radopholus similis* (Davao population).

Musa genotype	Plant height (cm)		Pseudostem girth at base (cm)		Shoot weight (g)		Root weight (g)		Number of nematodes		Percent dead roots[A]	Percent root necrosis[B]
	Un-ino-culated	Percent difference	Un-ino-culated	Percent difference	Un-ino-culated	Percent difference	Un-ino-culated	Percent difference	Root system	Per gram root		
Pot Experiment 1	March 8, 2005 – May 9, 2005[C]											
Pastilan	36.4	- 3.3	3.8	-7.9	205.8	-29.0 *	59.8	-57.2	4,131 c	190 bc	38.8 a	72.5 bc
Galamay Señora	41.6	- 23.6 *	3.4	-8.8	171.3	-33.6 *	48.3	-57.8 *	3,583 bc	247 c	30.7 a	68.8 abc
Rawari	40.9	- 20.8 ***	3.5	0.0	178.7	-36.8 **	60.6	-57.3 **	3,453 bc	114 ab	43.8 ab	67.5 abc
Sulay Baguio	24.9	- 6.4 *	3.0	0.0	116.3	-25.6	32.6	-48.1 *	3,006 bc	232 bc	47.8 ab	73.6 bc
Guyod	42.8	- 16.6 **	2.7	+3.7	131.9	-21.8	36.5	-29.6	1,502 ab	59 ab	40.7 a	72.2 bc
Yangambi Km 5 (R)	44.4	+ 4.5	3.3	-3.0	162.3	-4.7	36.2	-34.3	991 a	36 a	12.1 a	43.5 a
Pisang Jari Buaya R)	47.0	- 29.4 *	3.5	0.0	186.2	-46.7	53.7	-59.2	989 a	45 ab	37.2 a	57.9 ab
Grand Naine (S)	31.4	- 9.6	3.3	+3.0	156.6	-17.0	40.1	-45.9	2,786 ab	104 ab	51.8 ab	92.5 c
Pot Experiment 2	December 8, 2005-February 6, 2006[C]											
Lakatan-Cavite	24.8	-21.4 *	2.4	-25.0	92.3	-35.4 **	26.2	-51.9 *	33,479 b	2,789	13.0	61.6 ab
Lakatan-Palawan	24.4	-38.1 ***	2.6	-19.2	95.1	-68.9 ***	28.5	-73.7 ***	17,022 b	2,317	41.5	73.4 b
Bungulan	24.9	-17.3	2.1	-13.6	65.1	-27.2 *	15.9	-37.7	16,720 b	2,282	27.2	68.0 b
Lakatan-Mindoro	22.0	-39.5 **	2.3	-21.7	69.4	-47.6 *	21.4	-73.4 **	11.343 ab	1,598	25.0	77.5 b
Lakatan-Davao	23.8	-28.6 **	2.0	-10.0	65.8	-39.7 *	15.7	-53.5 *	11,286 ab	1,545	28.5	69.7 b
Alaswe	21.1	-39.8	1.5	- 6.7	37.9	-52.2	7.8	-38.5	4,281 ab	1,478	24.1	57.7 ab
Ambon	25.6	-43.0 **	1.9	-15.8	65.0	-72.1 ***	17.1	-78.4 **	4,255 ab	1,301	19.8	77.0 b
Cuarenta Dias	19.0	- 7.4	1.9	+10.5	56.7	-17.8	7.8	-38.5	3,966 ab	766	4.2	29.6 a
Yangambi Km 5 (R)	18.6	+70.0	1.6	+ 6.2	37.5	-42.7 *	9.7	- 1.7 *	798 a	225	0.0	28.8 a
Grand Naine (S)	22.4	-48.2 ***	2.0	-30.0	67.8	-72.3 **	17.5	-86.3 **	2,278 ab	987	32.4	67.2 b
Pot Experiment 3	March 5, 2006-May 7, 2006[C]											
Tudok	21.4	-19.1 **	2.3	-13.0	69.5	-28.2 *	14.3	-49.9 **	16,876 c	2,662 c	0.6	46.9 bc
Suisok	22.6	- 4.4	2.4	-16.7	67.7	-21.7	18.9	-26.4	13,051 bc	903 ab	16.6	41.2 abc
Cardaba	25.4	+ 1.2	1.9	+10.5	66.3	- 0.4	15.3	+18.3	9,064 bc	632 a	0.0	24.0 ab
Matavia	-	-	-	-	-	-	-	-	7,202 ab	1,721 bc	0.0	29.5 abc
Pandili	28.2	-34.0 *	2.1	-25.6	81.6	-67.4 *	18.3	-52.4	6,144 a	579 a	13.3	35.5 abc
Morong Princesa	14.4	+65..3 ***	1.9	+106.5 ***	9.2	+45.3**	0.7	+14.8***	5,706 a	498 a	0.0	33.7 abc
Tanggung	22.8	+ 6.1	2.0	0.0	56.9	+ 1.8	11.7	- 9.4	4,650 a	508 a	0.0	29.0 abc
Yangambi Km 5 (R)	29.1	- 3.8	2.8	0.0	89.0	-11.0	25.9	-24.7	7,815 ab	354 a	0.0	19.0 a
Grand Naine (S)	24.7	-13.4	2.4	- 8.3	78.1	-18.4	15.7	-21.0	5,332 a	658 a	8.5	49.7 c

Table 3. Continued

Musa genotype	Plant height (cm)		Pseudostem girth at base (cm)		Shoot weight (g)		Root weght (g)		Number of nematodes		Percent dead roots[A]	Percent root necrosis[B]
	Un-ino-culated	Percent difference	Un-ino-culated	Percent difference	Un-ino-culated	Percent difference	Un-ino-culated	Percent difference	Root system	Per gram root		
Pot Experiment 4	November 17, 2007-January 17, 2008[C]											
Bungaoisan	58.4	- 19.8	3.1	- 9.7	247.1	-20.6	31.9	- 19.4	68,586 c	2,802 c	4.2 ab	29.8 abc
Inambak	40.3	+ 3.0	2.2	+ 9.5	105.8	+23.0	11.3	- 5.8	33,243 c	3,129 c	9.5 ab	43.7 c
Latundan	38.0	- 2.1	2.1	+ 9.5	105.8	+23.0	13.4	+ 47.8	31,519 c	1,367 c	0.0 a	27.0 abc
Wild *Musa balbisiana* (98-617)	28.9	- 4.8	2.2	- 4.5	88.8	+ 6.0	10.5	- 16.2	20,356 c	2,066 c	6.8 ab	43.7 bc
Madurangga	23.7	- 10.1	1.7	0	75.3	-15.8	10.5	+ 15.2	13,170 bc	479 bc	8.6 ab	30.1 abc
Katali	45.1	- 33.9 ***	2.4	-33.3 ***	156.3	-60.2 ***	22.5	- 64.4 ***	7,565 bc	603 bc	0.0 a	13.2 ab
Oma	44.1	- 30.8 **	3.1	-35.5 **	195.8	-58.2 **	29.0	- 71.0 **	6,907 bc	707 c	1.4 ab	19.5 abc
Wild *Musa balbisiana* (98-085)	19.6	- 7.1	1.4	-21.4 *	31.8	-35.5	7.3	- 38.3	474 a	90 ab	6.8 a	37.0 abc
Yangambi Km 5 (R)	24.8	+14.1	1.7	0	65.0	- 1.5	24.5	- 18.4	1,917 ab	75 a	0.0 a	7.3 a
Grand Naine (S)	27.2	-10.1	1.7	0	75.3	- 15.8	8.3	- 7.3	20,047 bc	8,125 c	12.8 b	45.8 c
Pot Experiment 5	January 11, 2008-March 12, 2008[C]											
Tindok	24.9	- 3.2	1.9	-31.6	51.6	- 2.1	11.2	- 13.4	11,800 bc	955 bc	6.6 ab	36.8 ab
Umalag	18.7	- 14.4	1.6	-37.5	42.5	- 25.9	6.8	- 20.6	6,005 bc	1,194 c	25.5 bc	56.0 b
Laknau	22.2	- 26.6	1.5	-53.3	39.1	- 49.6	6.9	- 52.2	5,038 b	1,407 c	15.3 abc	54.8 b
Kinamay Dalaga	18.1	+19.3	1.4	-14.3	29.7	+35.0	6.9	+ 31.9	3,680 b	378 b	0.0 a	17.5 a
Manang	16.6	- 1.2	1.4	-21.4	26.3	- 9.9	7.2	- 12.5	2,986 b	471 bc	8.6 ab	36.1 ab
Yangambi Km 5 (R)	21.4	+ 4.7	1.6	-18.8	35.2	+ 6.8	6.8	- 8.8	215 a	35 a	3.2 ab	15.9 a
Grand Naine (S)	18.8	- 2.6	1.7	-29.4	47.7	-12.4	6.4	- 4.7	20,924 c	3,583 d	42.2 c	66.4 b

[A]Percent difference is equal to uninoculated minus inoculated divided by uninoculated multiplied by 100 at * ($P<0.05$), ** ($P<0.01$) or *** ($P<0.001$) according to the *t*-test.
[B]Means in columns followed by the same letter do not differ significantly according to Tukey's LSD at 5% level of significance.
R – resistant check, S – susceptible check, C – date from inoculation of *Radopholus similis* to gathering of data

R. similis in Rawari, Sulay Baguio and Pisang Jari Buaya. Reduction in root weight was significant in Galamay Señora, Rawari and Sulay Baguio. Likewise, significant differences were observed among the cultivars in terms of percentage root necrosis and number of nematodes per 1 g root samples and root system. Roots of Dakdakan were totally destroyed due to *R. similis*. Among the cultivars tested, Galamay Señora has the lowest percentage dead roots (30.7%) but was not significantly different from other cultivars. Among the test cultivars, Rawari had the lowest (67.5%) percentage root necrosis, but differences were not significant with other cultivars. On nematode count, no significant differences were observed among the cultivars. Guyod had the least number of nematodes, i.e. 59 and 1,502 on a per gram and roots system, respectively. The two resistant checks, Yangambi Km 5 and Pisang Jari Buaya, supported the least number of nematodes and percentage root necrosis.

Pot Experiment 2. Four collections of Lakatan, namely Lakatan-Cavite, Lakatan-Palawan, Lakatan-Mindoro and Lakatan-Davao, and cultivars Alaswe, Ambon, Bungulan, Cuarenta Dias, Grand Naine and Yangambi Km 5 were evaluated. Yangambi Km 5 and Grand Naine were used as the resistant and susceptible cultivars, respectively. Reduction in plant height, shoot weight and root weight in the four collections of Lakatan, Ambon and the susceptible, Grand Naine, was significantly different. Pseudostem girth did not differ among cultivars. Compared with other cultivars, Cuarenta Dias was least affected by *R. similis* in terms of plant height (7.4%) and shoot weight (17.8%). It has the lowest percentage dead roots (4.2%) but not significantly different from other cultivars including the two checks. On percentage root necrosis, Cuarenta Dias had the lowest percentage root necrosis (29.6%) and was significantly different from Ambon, Bungulan and three collections of Lakatan and Grand Naine. Cuarenta Dias had the least number of nematode per gram root samples (766) and root system (3,966) among the cultivars tested, however, it was not significantly different with other cultivars including the resistant and susceptible checks.

Pot Experiment 3. Nine cultivars, namely Cardaba, Grand Naine, Matavia, Morong Princesa, Pandili, Suisok, Tanggung, Tudok and Yangambi Km 5, were used. Grand Naine was used as susceptible cultivar, while Yangambi Km 5, resistant cultivar. Among the cultivars tested, only Morong Princesa had apparent increase in plant height, pseudostem girth, shoot and root weight despite the inoculation with *R. similis*. The percentage dead roots did not cause significant reduction in growth parameters of inoculated plants. Percent root necrosis in all cultivars were not as severe as the susceptible check (Grand Naine), except those with Cardaba (24.0%). Tanggung had the least number of juveniles on per gram root system (4,650). Counts in Tanggung were significantly different from Tudok, Suisok and Cardaba. The resistant check, Yangambi Km 5, had the lowest percentage root necrosis (19%) and number of nematodes per gram root sample (354).

Pot experiment 4. Eight cultivars, namely Bungaoisan, Grand Naine, Inambak, Madurangga, Katali, Latundan, Oma and Yangambi Km 5; and two wild *Musa balbisiana* accessions (98-085 and 98-617) were used. Grand Naine and Yangambi Km 5 were used as susceptible and resistant cultivars, respectively. An increase in plant height, pseudostem girth and shoot weight of *R. similis*-inoculated Inambak was observed. However, Latundan, despite the *R. similis* infection caused an increased pseudostem girth, shoot and root weight. Among the cultivars, significant differences were noted in Katali and Oma. Both cultivars had the highest percentage reduction in four plant growth parameters. Roots of Latundan, Katali and Yangambi Km 5 were not affected by *R. similis* (0% dead roots). Katali had lower percentage root necrosis (13.2%), and it was significantly different from Grand Naine and Inambak. The number of *R. similis* recovered from root samples of *M. balbisiana* (98-085), were the least among the test cultivars and were significantly different from the susceptible check, Grand Naine.

Pot Experiment 5. Cultivars Grand Naine, Kinamay Dalaga, Laknau, Manang, Tindok, Umalag and Yangambi Km 5 were used. Grand Naine was used as susceptible cultivar, while Yangambi Km 5 as resistant cultivar. Differences between inoculated and un-inoculated plants in all cultivars tested did not differ in all growth parameters. Kinamay Dalaga inoculated with *R. similis* was taller and had higher shoot and root weights than the other cultivars. On percentage root necrosis and percentage dead roots, Kinamay Dalaga had the lowest, with 17.5 and 0%, respectively. On nematode count, Kinamay Dalaga and Manang had lower count based on 1-g and root system than other cultivars. The resistant check, Yangambi Km 5 had the lowest nematode count and percentage root necrosis, while the susceptible check, Grand Naine, had the highest.

Meloidogyne incognita

Table 4 shows the effect of *M. incognita* on the growth, root damage and reproduction of different local banana cultivars.

Pot Experiment 1. Ten cultivars were used in the study. These were Bungaoisan, Dakdakan, Grand Naine, Gubao, Hilao hinog, Pandili, Pastilan, Pisang Jari Buaya, Rawari and Yangambi Km 5. Grand Naine was used as susceptible cultivar. Except for Pandili, all the cultivars tested had increased shoot and root weight when inoculated with *M. incognita*. Reduction in root weight was significant in Bungaoisan, Rawari,

Table 4. Growth parameter, nematode damage and reproduction of different *Musa* cultivars 8-10 weeks after inoculation with *Meloidogyne incognita* (UPLB population)

Musa genotype	Plant height (cm)		Pseudostem girth at base (cm)		Shoot weight (g)		Root weight (g)		Number of nematodes		Root galling index
	Un-ino-culated	Percent difference	Un-ino-culated	Percent difference	Un-ino-culated	Percent difference	Un-ino-culated	Percent difference	Root system	Per gram root	
Pot Experiment 1	October 6, 2004-December 8, 2004[c]										
Bungaoisan	29.9	- 1.0	2.4	+12.5	107.3	+ 6.5	11.6	+ 63.6 ***	12,505 b	663 b	5.0 d
Rawari	22.6	+ 4.0 *	4.0	+ 4.2	69.0	+ 6.4	13.5	+ 28.4 **	8,561 ab	425 ab	3.6 bc
Pastilan	23.8	+26.9	1.9	-32.3	63.4	+46.4	10.3	+101.9	5,785 ab	265 ab	4.0 bcd
Gubao	25.8	+ 3.9	2.4	0	75.4	+10.5	12.2	+ 22.9	3,600 ab	179 a	3.6 bc
Dakdakan	27.4	- 4.7	1.9	+10.5	54.3	+11.0	5.7	+101.8 *	3,274 a	237 a	4.8 cd
Hilao hinog	22.8	+32.4	1.9	+15.8	52.6	+46.5	6.6	+ 90.9	2,465 a	234 a	4.0 bcd
Pandili	29.2	- 0.7	3.1	0	77.2	-13.5	19.4	- 12.4	919 a	36 a	2.0 a
Yangambi Km 5	27.5	- 0.4	2.2	+16.7	66.4	+39.3	14.2	+ 65.8 *	4,775 ab	233 a	4.1 bcd
Pisang Jari Buaya	30.5	+ 6.6	2.2	+13.6	72.1	+ 5.3	10.9	+104.5 ***	3,664 ab	151 a	3.0 ab
Grand Naine (S)	19.7	-18.3	1.9	-15.8	54.0	+15.2	9.0	+ 51.5	5,680 ab	316 ab	4.0 bcd
Pot Experiment 2	April 19, 2005-July 20, 2005[c]										
Lakatan-Batangas	33.5	+22.4 ***	3.5	2.8	159.0	+ 3.1	60.9	- 1.7	91,428 c	1,564 c	4.4 d
Lakatan 1882a	42.5	- 4.9	3.2	0	144.0	- 1.5	52.2	-22.8	74,898 bc	1,174 c	3.6 bcd
Patag	36.7	- 9.0	3.2	0	149.1	-11.0	40.1	+21.4	47,347 bc	1,585 c	3.0 bcd
Tiparot	-	-	-	-	-	-	-	-	8,089 ab	155 a	2.8 abc
Lakatan 2201a	-	-	-	-	-	-	-	-	6,892 ab	214 abc	4.7 d
Morado	-	-	-	-	-	-	-	-	5,298 a	100 a	2.7abc
Ambon	25.8	+17.4 ***	2.1	+23.8 **	52.6	+71.3 ***	21.4	+97.2 ***	4,411 a	105 a	1.4 a
Yangambi Km 5	29.6	+35.1 ***	2.4	+25.0 *	76.3	+54.6 *	35.0	+20.8	6,702 a	150 ab	2.0 ab
Pisang Jari Buaya	35.0	- 8.6	2.3	+26.1 *	92.5	-13.3	35.1	+43.9	25,980 abc	537 bc	2.4 ab
Grand Naine (S)	32.4	-11.7 ***	3.4	0	147.5	-14.2	53.7	- 3.7	47,301 bc	873 c	4.0 cd
Pot Experiment 3	September 16, 2005-November 23, 2005[c]										
Morado	37.3 *	-13.9	2.9	-10.3	153.8	-20.7 *	42.1	- 9.0	12,300 c	312 d	4.8 d
Tiparot	38.6	- 0.8	2.8	0	164.4	-17.6 *	54.1	-33.3 **	7,366 ab	210 bcd	3.0 bc
Pandili	40.1	-15.0	2.7	-11.1	102.0	+ 2.4	47.1	-51.8	4,103 ab	193 cd	2.0 ab
Datu	39.0	- 8.5	2.6	- 7.7	130.5	-26.5	45.3	-54.7	4,057 ab	210 cd	1.8 ab
Galamay Señora	35.9	0	2.8	0	124.6	- 0.6	35.5	0	3,467 ab	122 abcd	2.6 abc
Guyod	21.0	- 3.8	2.6	-38.0	104.2	-10.9	29.5	-33.6	2,943 ab	153 bcd	2.6 abc
Tindok	38.9	- 9.1	2.6	- 7.1	123.3	-13.7	39.1	- 9.5	2,757 ab	71 ab	2.7 abc
Tudok	18.8	- 1.1 *	2.5	- 8.0	98.8	-24.0 *	12.9	-15.5	1,673 ab	187 bcd	2.7 abc
Inambak	44.6	+16.7	3.1	+ 7.1	156.4	+24.9	29.3	-36.6	1,019 b	47 ab	3.0 bc
Sulay Baguio	18.4	+32.1	1.1	+36.4	18.1	+79.6	3.2	+43.8	210 a	43 a	1.0 a
Grand Naine (S)	30.1	-15.6	2.8	-10.7	115.2	-16.0	30.0	-30.3	1,150 b	66 abc	4.1 cd

Table 4. Continued...

Musa genotype	Plant height (cm)		Pseudostem girth at base (cm)		Shoot weight (g)		Root weight (g)		Number of nematodes		Root galling index
	Un-ino-culated	Percent difference	Un-ino-culated	Percent difference	Un-ino-culated	Percent difference	Un-ino-culated	Percent difference	Root system	Per gram root	
Pot Experiment 4	February 17, 2006-April 17, 2006[C]										
Alaswe	44.4	+ 2.9	2.9	0	142.2	+ 4.1	51.1	+12.3	46,918 b	795 c	3.0 bc
Cuarenta Dias	44.8	-13.4	3.2	0	144.7	- 3.6	57.4	+ 1.2	20,512 ab	347 abc	3.3 cde
Lakatan-Palawan	42.7	-15.2	3.0	- 6.2	166.9	2.9	64.1	- 8.0	14,328 ab	203 a	4.7 e
Lakatan-Mindoro	51.2	-14.8 *	3.0	0	194.6	-20.6 *	35.6	-43.0	11,506 ab	581 bc	3.0 bc
Lakatan-Davao	45.1	-10.2	3.1	+ 6.4	175.4	+ 7.8	34.5	+38.6	10,758 ab	230 abc	4.5 de
Cardaba	48.2	+ 7.5	3.0	+ 6.7	203.3	- 4.9	60.1	-17.8	10,324 ab	211 ab	2.0 ab
Morong Princesa	48.1	-12.7	3.2	-15.6	183.0	-17.3	45.2	-61.7	7,934 a	193 a	3.5 bcde
Yangambi Km 5	50.8	- 1.6	2.6	0	123.7	-10.0	21.2	-17.0	6,544 a	289 abc	1.0 a
Lakatan-Cavite	47.1	+ 3.8	3.1	- 9.6	177.2	- 9.9	36.5	- 38.6	5,506 a	258 abc	4.4 de
Grand Naine (S)	36.0	- 7.2	3.1	-12.9	159.6	-14.5	40.6	-53.9 *	12,529 ab	596 bc	3.9 cde
Pot Experiment 5	August 28, 2006-October 30, 2006[C]										
Bungulan	32.8	-16.1	2.7	-22.2	145.0	-48.8 *	18.9	- 3.7	18,655 c	977 b	4.0 c
Kinamay Dalaga	34.3	-22.2 *	2.6	-26.9 *	115.2	-58.2 **	24.6	-48.4 **	8,914 b	708 ab	2.0 a
Suisok	27.6	-17.8	2.4	-16.7	104.9	-40.3	17.6	-17.0	6,892 ab	464 ab	4.0 c
Tanggung	36.3	-17.9 **	2.4	-20.8 **	138.1	-48.3 ***	15.7	-18.5	3,435 ab	269 a	3.0 ab
Umalag	21.7	-24.0 *	2.3	-40.0 *	92.0	-65.2 *	11.8	-58.2 *	2,696 a	339 a	3.0 bc
Laknau	-	-	-	-	-	-	-	-	2,608 a	289 a	2.0 a
Grand Naine (S)	23.1	-12.6 *	2.6	-15.4 **	108.1	-28.7 **	15.0	-41.3 **	4,464 ab	493 ab	4.0 c
Pot Experiment 6	September 14, 2007-November 14, 2007[C]										
Oma	41.5	0	2.7	+ 7.4	142.1	+ 6.9	22.6	+24.8	45,764 c	1,586 c	3.0
Latundan	49.2	- 3.2	2.6	-11.5	156.2	- 23.8	28.0	-29.3	28,326 cd	1,440 c	2.8
Manang	29.6	+11.4	1.9	+ 9.5	63.8	+14.0	18.3	- 1.1	10,530 bcd	584 bc	2.0
Katali	27.5	+31.2	1.7	+15.0	65.0	+12.0	12.2	-18.4	10,332 bcd	826 c	2.0
Madurangga	28.1	- 3.2	2.1	- 4.8	79.3	-11.0	11.0	-13.6	7,253 ab	235 a	2.5
Muracho	31.4	- 4.1	1.8	+ 5.3	73.5	-23.4	15.2	-18.4	4,492 b	537 bc	2.6
Cardaba	40.0	+ 4.7	2.6	- 7.7	141.7	-24.7	24.2	-25.3	3,282 ab	197 a	3.0
Matavia	12.7	+10.2	1.2	0	20.5	-17.6	4.6	-60.9	668 a	375 b	3.0
Grand Naine (S)	27.1	-17.0	2.0	+ 4.8	83.7	-40.4	12.3	-33.3	11,221 bcd	680 bc	3.0

[A]Percent difference is equal to uninoculated minus inoculated divided by uninoculated multiplied by 100 at * ($P<0.05$), ** ($P<0.01$) or *** ($P<0.001$) according to the *t*-test.
[B]Means in columns followed by the same letter do not differ significantly according to Tukey's LSD at 5 level of significance.
S – susceptible check. C – date from inoculaton of M. incognita to gathering of data

...an, Pisang Jabi Buaya and Yangambi Km 5. ...t damage, expressed as root galling index, was ...st in Pandili (2.0), and was significantly different ...m most of the cultivars, except Pisang Jari Buaya. ...ngaoisan had the highest root galling index (5.0), ...d was significantly different from Rawari, Gubao, ...ndili and Pisang Jari Buaya. Pandili had the lowest ...mber of M. incognita per 1-gram roots (36) and root ...stem (919), but was not significantly different from ...cultivars except Bungaoisan.

Experiment 2. Three collections of Lakatan, ...ely Lakatan-Batangas, Lakatan 1882a and ...atan 2201a, and cultivars Ambon, Grand Naine, ...ado, Patag, Pisang Jari Buaya, Tiparot and ...gambi Km 5 were used in the experiment. Grand ...ne was used as susceptible cultivar. There was an ...ease in plant height, pseudostem girth and shoot ...ht in Lakatan-Batangas, Ambon and Yangambi ...5. Among the cultivars tested, *M. incognita* ...ed an increase in four parameters in Ambon and ...gambi Km 5. Reduction in growth parameters was ...d in Lakatan 188 2a and susceptible check, ...d Naine. Ambon had the lowest (1.4) root galling ..., which was significantly different with other ...ars except Morado, Tiparot, Yangambi Km 5 and ...g Jari Buaya. The three collections of Lakatan, ...ly, Lakatan-Batangas, Lakatan 188 2a and ...an 220 1a, had high root galling index, 4.4, 4.7, ...espectively. Morado, Ambon, Tiparot, Lakatan ...a and Yangambi Km 5 had lower number of ...iles and egg laying females per gram of roots ...root system compared with the other test ...ars.

Experiment 3. Eleven cultivars, namely Datu, ...nay Señora, Grand Naine, Guyod, Inambak, ...do, Pandili, Sulay Baguio, Tindok, Tiparot and ...k were used. Grand Naine was the susceptible .... Except for Inambak and Sulay Baguio, all the ...*cognita*-inoculated cultivars had reduced plant ...t, pseudostem girth, shoot and root weights. ...ction in root weight was significant only in ...ot. Sulay Baguio had the lowest root galling (1.0), but differed with other test cultivars except ...do, Tiparot, Inambak and Grand Naine. Sulay ...o had the lowest nematode count on 1-gram root ...les (43) and root system (210), while Morado ...ne highest (12,300 and 312, respectively).

Experiment 4. Four collections of Lakatan such ...akatan-Cavite, Lakatan-Davao, Lakatan-Mindoro Lakatan-Palawan, and 7 cultivars, namely ...e, Cardaba, Cuarenta Dias, Grand Naine, ...ng Princesa and Yangambi Km 5 were used. ...d Naine was used as susceptible cultivar. ...*dogyne incognita* supported the growth of ...e, Cuarenta Dias and Lakatan-Davao. Morong ...esa had the highest percent reduction (61.7%) in weight while Palawan-Lakawan, the lowest .... On root galling index, Yangambi Km 5 had the lowest (1.0) but not significantly different from Cardaba (2.0). The three collections of Lakatan, namely Lakatan-Palawan, Lakatan-Davao and Lakatan-Cavite were highly infected with *M. incognita* since they have the higher root galling index than other cultivars including the susceptible check, Grand Naine. Morong Princesa had the lowest nematode count per 1-gram root sample (193), while Lakatan-Cavite, the lowest on root system (5,506). Differences among cultivars did not differ at root system basis except in Alaswe.

Pot Experiment 5. Cultivars Bungulan, Grand Naine, Kinamay Dalaga, Laknau, Suisok, Tanggung and Umalag were tested, with Grand Naine as the susceptible cultivar. All of the test cultivars had reduced plant height, pseudostem girth, shoot and root weight with *M. incognita* inoculation. Significant differences in the four growth parameters were observed in Kinamay Dalaga, Umalag and the susceptible check, Grand Naine. Among the cultivars, Umalag had the highest percentage reduction in plant height (24%), pseudostem girth (40%), shoot weight (65.2%) and root weight (58.2%). Kinamay Dalaga and Laknau had the lowest root galling index (2.0). Tanggung had the lowest nematode count per 1-gram root samples (269) but not significantly different with all other cultivars except Bungulan. On the other hand, Laknau had the lowest nematode count per root system (2,608), but did not differ with the other cultivars except Kinamay Dalaga and Bungulan.

Pot Experiment 6. Nine cultivars, namely Cardaba, Grand Naine, Katali, Latundan, Madurangga, Manang, Matavia, Muracho and Oma were used. Grand Naine was used as susceptible cultivar. The effect of *M. incognita* on growth and root damage of all test cultivars was not significant. Among the cultivars tested, plant height, pseudostem girth and shoot weight of Katali and Manang were enhanced by *M. incognita*. Except for Oma, all test cultivars had reduced root weight with *M. incognita* inoculation. Although Manang and Katali had relatively the lowest root galling index of 2.0, it was not significantly different from all cultivars tested. Cardaba had the lowest nematode count on per gram (197) basis, and significantly different with other cultivars except Madurangga. Based on root system, Matavia had the lowest *M. incognita* count (668) but did not differ with Madurangga and Cardaba.

DISCUSSION

Radopholus similis Evaluation

In the first pot experiment, the resistant checks, Yangambi Km 5 and Pisang Jari Buaya, showed similar reactions. The reaction of Yangambi Km 5 in the last four pot experiments was consistent. The susceptible check, Grand Naine had higher percent dead roots and percentage root necrosis in the first pot experiment as compared with the last four pot experiments. This is possibly due to the varying temperatures inside the greenhouse where the inoculated and un-inoculated were maintained.

Generally, there was a reduction in plant height, pseudostem girth at base, shoot weight and root weight in most of the cultivars tested that were inoculated with *R. similis*. Reduction in plant growth parameters could be attributed to the reduction in water and mineral uptake (Van den Bergh 2002) as a result of root damage brought about by the nematode. Since *R. similis* is a migratory endo-parasite, it is capable of destroying the cortical parenchyma by feeding on the cytoplasm of the neighboring cells and causing cavities to develop (Blake 1966), as observed during the early symptoms of the disease. In susceptible response, these cavities coalesce and continually enlarge by nematode's feeding and tunneling laterally towards the endodermis, producing the characteristic reddish brown lesions throughout the cortex and may extend into the rhizome cortex (Loos and Loos 1960). Under severe condition, the entire root system including the secondary, tertiary and root hairs may rot. Other symptoms observed were lack of vigour, leaf yellowing prior to evaluation, reduction in size and number of leaves, and wilting as observed in the first pot experiment with the susceptible check, Grand Naine. The destruction of the roots also resulted to the plant to topple (Ohm Williams and Siddiqi 1973).

It was noted that only Morong Princesa (Pot Experiment 3) showed a different response to *R. similis*. The inoculated plants of this cultivar were taller, with bigger pseudostem girth and heavier shoot and roots than the un-inoculated ones. Other cultivars were affected by *R. similis* in one, two or three growth parameters like Guyod (Pot Experiment 1), Cuarenta Dias (Pot Experiment 2), Cardaba (Pot Experiment 3), Inambak, Latundan and Madurangga (Pot Experiment 4) and Kinamay Dalaga (Pot Experiment 5). Among the four growth parameters, plant height was least affected by *R. similis*. Pseudostem girth was the least affected, with the highest reduction of 53.3% in Laknau (Pot Experiment 5). The highest reductions in plant height (43.0%) and in root weight (78.4%) were noted in Ambon (Pot Experiment 2), and in shoot weight, (73.7%) in Lakatan-Palawan (Pot Experiment 2). The resistant check, Yangambi Km 5 was less affected by *R. similis* in terms of plant height only. The susceptible check, Grand Naine, had reduced plant height, pseudostem girth and shoot and root weight in all pot experiments done confirming its susceptibility to *R. similis*.

Very wide range in percentage dead roots and percentage root necrosis was observed among test cultivars. Percentage dead roots ranged 0-47.8% in Sulay Baguio (Pot Experiment 1), while percentage root necrosis, 7.3% (Yangambi Km 5, resistant check in Pot Experiment 4) to 92.5% (Grand Naine, susceptible check in Pot Experiment 1). In all pot experiments, the resistant check, Yangambi Km 5, had the lowest percentage dead roots and root necrosis, confirming its resistance to root damage by *R. similis*. On the other hand, the susceptible check, Grand Naine, had higher percentage dead roots and root necrosis than the other cultivars as shown in Pot Experiments 1, 3, 4 and 5. Lakatan-Palawan, Bungulan, Lakatan-Mindoro, Lakatan-Davao and Ambon (Pot Experiment 2) had higher percentage root necrosis indicating their high susceptibility to *R. similis*.

The number of *R. similis* juveniles recovered from the inoculated roots varied among pot experiments and cultivars tested. It was observed that at higher percentage root necrosis (92.5%) as in Grand Naine, lower densities of nematodes were recovered from the roots as compared with the other test cultivars (Pot Experiments 1, 2 and 3. It was noted that roots were totally destroyed at 8 weeks of evaluation and some of the roots were cut off from the plant. The possibility that the nematodes had moved out of the roots due to lack of healthy tissues for feeding might explain this phenomenon. Damage due to nematodes can be a measure of tolerance or sensitivity of the genotype, while the nematode reproduction, of resistance or susceptibility of the genotype (Van den Bergh et al 2000). In all pot experiments conducted, the resistant check, Yangambi Km 5 had lower percentage dead roots and root necrosis than the susceptible check, Grand Naine. The results on Yangambi Km 5 confirmed its highly resistant response to *R. similar* as reported by previous workers (Wehunt et al 1978; Pinochet and Rowe 1979; Fogain and Gowen 1998) although the population of *R. similis* collected from Davao province, Mindanao region of the Philippines was found to be the most virulent (Pinili et al 2008), some local banana cultivars, including the resistant check, Yangambi Km 5, were able to resist or tolerate the effect of infection. Some of the cultivars that showed tolerance or resistance to *R. similis* were, Cuarenta Dias 'AA' (Pot Experiment 2), Cardaba 'BBB' (Pot Experiment 3), Katali 'ABB' and wild *Musa balbisiana* (98-085) 'BBB' (Pot Experiment 4) and Kinamay Dalaga "AA' (Pot Experiment 5). Davide and Marasigan (1985) reported that Inambak, Pastilan, Suisok, Cardaba, Galamay Señora, Katali, Lakatan, Manang, Tanggung and Tiparot are resistant or have intermediate reaction to *R. similis*. In the present study, however, only Carbaba, Katali, Manang and Tanggung showed some level of resistance to *R. similis*, based on percentage dead roots and total number of nematodes recovered. The rest of the test cultivars were found susceptible. The results obtained could be attributed to the differences in the isolates used, period of the conduct of the experiment, and rating parameter used.

Meloidogyne incognita Evaluation

The responses of local banana cultivars evaluated to *M. incognita* varied. Infection by *M. incognita* caused a reduction in plant height, pseudostem girth at base, shoot and root weights in all cultivars tested (Pot Experiment 5). Other cultivars in some pot experiments responded similarly as shown in Ambon (Pot Experiment 2), Sulay Baguio (Pot Experiment 3) and Alaswe (Pot Experiment 4). On the other hand, *M. incognita* resulted in an increase in shoot and root weight in all cultivars including the susceptible check, except in Pandili (Pot Experiment 1). The increase in root weight of the infected plants can be probably explained by the galls induced by *M. incognita*. In most cultivars, necrosis of roots were not associated with *M. incognita* infection. Of all the cultivars, Bungaoisan had the highest root galling index (RGI) (5.0) which was not significantly different with the susceptible check, Grand Naine. Conversely, Sulay Baguio had the lowest RGI, 1.0 (Pot Experiment 3), Ambon, 1.4 (Pot Experiment 2), Datu, 1.8 (Pot Experiment 3), Pandili, 2.0 (Pot Experiments 1 and 3) Cardaba, 2.0 (Pot Experiment 4), Kinamay Dalaga and Laknau, 2.0 (Pot Experiment 5), and Manang and Katali, 2.0 (Pot Experiment 6). Pandili was evaluated twice (Pot Experiments 1 and 3), and yet it had the same RGI. Nematodes recovered on per gram basis were very high in Lakatan-Batangas, Lakatan 188 2a, Patag (Pot Experiment 2), Alaswe (Pot Experiment 4) and Oma (Pot Experiment 6). The rate of reproduction may have increased twice or even as high as 14 times as in Lakatan 188 2a and 18 times as in Lakatan-Batangas. Nematodes recovered from the susceptible check varied. For example in Pot Experiments 1 and 4, there was no reproduction, in Pot Experiment 2, the rate was almost 9.47 times, in Pot Experiment 4, 2.5 times and in Pot Experiment 6, 2.2. times. However, in Pot Experiment 3, *M. incognita* did not reproduce although RGI was 4.1. This could probably be due to the number of egg laying females on the galls. Based on the result, the RGI did not have a direct relationship with the total number of nematodes recovered on the roots. Although the RGI was low in Lakatan 188 2a and Patag, RGI of 3.6 and 3.0, respectively, the nematode count was 74,898 and 47,347, respectively. In the case of Grand Naine with RGI 4.0, the nematode count was only 5,680 (Pot Experiment 1). This could be interpreted to mean that root galling may not predict the number of egg laying females. It was observed that even if there were no symptoms of galling in roots, the number of egg laying females was high. In screening for resistance to *Meloidogyne,* RGI is one of the parameters used globally since *Meloidogyne* causes galling on affected roots. However, since relationship between root galling and number of egg laying females on affected roots varied, both parameters should be considered to be a valid and concrete response of the plant/cultivar to *Meloidogyne*.

Response of Pandili, although had low RGI, was affected by *M. incognita* as shown in the reduction in growth parameters (Pot Experiment 1). This may indicate that this cultivar is resistant to *M. incognita* as shown in the low nematode recovered on the roots. The two cultivars, Ambon and Sulay Baguio were the least affected since their growth parameters were increased with *M. incognita* inoculation (Pot Experiments 2 and 3). As reported by Van den Bergh and co-workers (2000), no source of resistance to *M. incognita* was found. However, in this study, local banana cultivars had been identified as resistant to *M. incognita* under greenhouse condition. These were Pandili 'unclassified' (Pot Experiments 1 and 3), Ambon 'AAA' (Pot Experiment 2), Sulay Baguio 'AAA' (Pot Experiment 3), and Matavia 'ABB' (Pot Experiment 6). Tolerant cultivars that were identified are Datu 'AA' (Pot Experiment 3), Cardaba 'BBB' (Pot Experiment 4), Kinamay Dalaga 'AA' and Laknau 'AAB' (Pot Experiment 5), Manang "AA" and Katali 'ABB" (Pot Experiment 6). The low RGI and number of nematodes recovered in Sulay Baguio could be attributed to its scarse root system. There were very few roots where nematodes could feed. This could be a possible mechanism of resistance in *Meloidogyne*.

Previous study by Davide and Marasigan (1985) revealed that Alaswe, Dakdakan, Inambak and Pastilan were resistant to *M. incognita*. However, in the present study, these cultivars were susceptible to the UPLB population *of M. incognita*. Differences in isolate used, varying time of conducting pot experiments and rating parameters may have contributed to the results obtained.

The availability of the identified resistant or tolerant cultivars from the Philippine Banana Germplasm Collections to burrowing nematode, *R. similis* and root-knot nematode, *M. incognita* is valuable information to plant nematologists in the Philippines and other countries in their banana nematode management program and breeding for nematode resistance work on bananas. Furthermore, the local cultivars identified to be resistant to *M. incognita* could be utilized by plant nematologists from other countries for their screening work as resistant reference cultivar(s).

RECOMMENDATION

Since the response of banana cultivars and species to *R. similis* and *M. incognita* varied, it is recommended that screening, although done at the greenhouse, should be conducted under similar environmental conditions.

ACKNOWLEDGMENT

The authors would like to thank VLIR for the financial support of the project and Bioversity, formerly International Network for the Improvement of Banana and Plantain (INIBAP).

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