

## Resumen

Con base en los resultados de un estudio morfométrico de machos, hembras y juveniles en el segundo estadio, y en la respuesta de siete plantas diferenciales, se pudo diferenciar cinco especies de *Meloidogyne* entre 16 poblaciones colectadas en diferentes localidades de Costa Rica. Las especies identificadas fueron *M. arenaria*, *M. incognita*, *M. hapla*, *M. exigua* y *M. salasi*. La respuesta de las plantas diferenciales dio evidencia de que la población de *M. arenaria* pertenece a la raza 2 (no infecto mani) y que entre las poblaciones de *M. incognita* existían representantes de las razas 1 y 2 de esta especie. Se encontró evidencia de variación patogénica en dos poblaciones de *M. exigua*, por cuanto una de ellas se reprodujo fácilmente en tomate, mientras que la otra no. En forma similar, dos poblaciones de *M. hapla* se reprodujeron abundantemente en chile, mientras que una tercera lo hizo pero sólo levemente.

## Introduction

The broad geographical distribution, wide host range, severe pathogenic effects and synergistic interactions with many kinds of plant disease organisms, have placed root-knot nematodes (*Meloidogyne* Goeldi, 1887, Nematoda: Meloidogynidae) among the major plant pathogens affecting man's food supply (15)

Management strategies aimed at reducing the severity of the damage caused by *Meloidogyne* spp include the use of chemicals, crop rotation, resistant cultivars and other cultural practices (15). The last three tactics require extensive knowledge of the morphology, variability and ecology of the species causing the damage.

One of the problems associated with the implementation of nonchemical management tactics against root-knot nematodes is the correct identification of populations. Identification is complicated by

the variation in morphology and host range commonly present in species of this genus (9). Due to this variability, approaches other than classical morphology, such as the response of differential plants, have been used to identify species (15).

The identification and/or quantification of the variability within and among species of root-knot nematodes by these different approaches could provide the basis for a better understanding of the genus from different points of view. This understanding would enable recognition of those characters which are species specific and therefore reliable for distinguishing species, as well as recognition of characters with little or no value in the identification of fields populations due to their overlap among or between species or their instability.

Having these considerations in mind research was conducted to study the variability of some populations of root-knot nematodes from Costa Rica by a morphometric characterisation of males, females and second stage juveniles, and by the reaction of certain differential plants.

## Materials and methods

Sixteen populations of root-knot nematodes were collected from different localities in Costa Rica (Figure 1) and increased in a greenhouse at the Facultad de Agronomía, Universidad de Costa Rica, San

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Pedro. Some selected ecological characteristics of the collection sites of these populations, along with the hosts on which they were collected and their population designation, are presented in Table 1

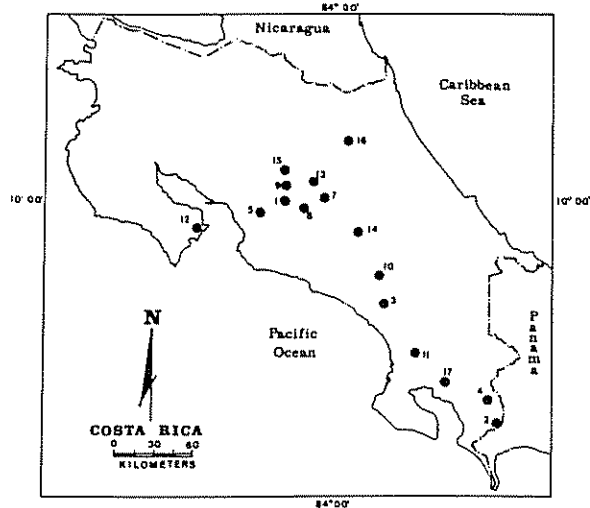


Fig. 1. Map of Costa Rica showing the approximate location of the collection sites of 16 populations of *Meloidogyne* spp

The inoculum for the propagation of each population consisted of several dozen egg masses collected from roots of the host from the original locality where the population was collected. Most population were increased on tomato, cv. Rutgers. Populations CR7 and 9 were maintained on coffee, cv. Caturra, whereas population CR2 was maintained on rice, cv. CR 1113. All plants were grown in 2 000 ml clay pots that contained 1 700 ml of an Andept soil (43.2% sand, 31.4% silt, 25.4% clay, 8.7% O.M. and 5.8 pH). The soil in all cases was treated with steam at 105°C for 24 hours prior to use. Each pot was fertilized twice a week during the first five weeks of plant growth with 150 ml of a 1% 20-20-20 fertilizer formula solution. Air temperatures varied between 17 and 31°C.

Twenty specimens were used for each character studied in the males, females and second-stage juveniles. All measurements were analyzed statistically with a one way classification model, and the mean values were compared using the Duncan's Multiple Range Test. The methodology used for the morphometric study, as well as that for the differential plants were the same as previously described (5), except that strawberry and sweetpotato plants were not included.

Table 1. Designations, sources and selected ecological characteristics of the collection sites of 16 populations of *Meloidogyne* spp. from Costa Rica.

Pop.	Host	Soil (%)				Soil pH	Elevation m.a.s.l.	Locality	Ecological zone
		Sand	Silt	Clay	O.M.				
CR1	<i>Lycopersicon esculentum</i> Mill.	50.2	29.7	20.1	8.8	6.1	810	La Guacima	Premontane moist forest
CR2	<i>Oryza sativa</i> L.	75.2	14.7	10.1	3.4	6.0	22	La Cuesta	Premontane wet forest, basal belt
CR3	<i>Nicotiana tabacum</i> L.	68.2	13.7	18.1	3.2	5.4	550	Repunta	Tropical moist forest
CR4	<i>Carica papaya</i> L.	55.2	26.7	18.1	2.4	6.2	42	Ciudad Neilly	Tropical wet forest
CR5	<i>Carica papaya</i> L.	30.1	31.8	38.1	5.6	6.0	220	Orotina	Tropical moist forest
CR6	<i>Lycopersicon esculentum</i> Mill.	35.1	46.8	18.1	2.7	6.1	905	Santa Ana	Premontane moist forest
CR7	<i>Coffea arabica</i> L.	44.8	32.7	23.5	8.7	6.1	1 360	San Luis	Premontane moist forest
CR9	<i>Coffea arabica</i> L.	32.1	34.8	33.1	11.6	6.2	1 020	Sarchí	Premontane wet forest
CR10	<i>Eupatorium subcordatum</i>	88.1	5.8	6.1	2.8	6.2	2 400	Division	Montane rain forest
CR11	<i>Musa acuminata</i> X <i>M. balbisiana</i> , AAB	52.1	12.7	35.2	4.3	6.0	60	Palmar Norte	Premontane wet forest
CR12	<i>Carica papaya</i> L.	26.1	31.8	42.1	5.3	6.1	10	Paquera	Premontane moist forest
CR13	<i>Bidens pilosa</i> L.	35.5	58.9	5.6	9.2	6.0	1 040	Porrosati	Lower montane rain forest
CR14	<i>Brassica oleracea</i> var. <i>capitata</i> L.	29.0	43.0	28.0	8.4	6.0	2 050	El Empalme	Lower montane wet forest
CR15	<i>Impatiens balsamina</i> L.	34.0	33.0	33.0	6.8	6.2	2 200	Palmira	Lower montane wet forest
CR16	<i>Musa acuminata</i> X <i>M. balbisiana</i> , AAB	80.6	8.0	11.4	5.6	5.8	75	Río Frio	Tropical wet forest
CR17	<i>Carludovica</i> sp.	55.1	25.8	19.1	8.6	6.1	10	Piedras Blancas	Tropical wet forest

Results

Five species of *Meloidogyne* were identified among the 16 populations studied. These species were *M. incognita* (populations CR1, 3, 5, 6, 11, 12, 16 and 17), *M. exigua* (populations CR7 and 9), *M. hapla* (populations CR10, 14 and 15), *M. arenaria* (population CR4), and *M. salasi* (population CR2). Population CR13 was identified as a mixture of *M. incognita* and *M. hapla*.

Morphology

The interpretation of the predominant type of perineal pattern for each species is presented in Table 2. Only specimens of *M. salasi* (CR2) and a few from

*M. exigua* (CR7 and 9) had a posterior protuberance. Populations CR16 and 17 of *M. incognita* had a few striae originating at the vulval lips and going out to the sides. *M. exigua* (CR7 and 9) had three striae in the perineum, whereas *M. hapla* (CR10, 14 and 15) and some specimens of CR13, a population consisting of a mixture of *M. incognita* and *M. hapla*, had one striae. The striae of *M. arenaria* (CR4), *M. exigua* (CR7, 9) and *M. hapla* (CR10, 14, 15) were interrupted where the lateral lines normally are, but they were not distinct enough to be considered lateral lines. The *M. incognita* populations CR1, 3, 5, 6, 11 and 17 had a few, wavy and broken striae in zones 2, 3 and 4, whereas CR12 and 16 had a moderate number of striae in these zones. In these same zones *M. exigua* (CR7, 9) had few, smooth, broken striae,

Table 2. Interpretation of the predominant type of perineal pattern of females of 16 populations of *Meloidogyne* spp. from Costa Rica.

Pop.	Posterior protuberance	Vulva lip striae	Perineum striae	Lateral incisures	Striae zone				
					1	2	3	4	
<i>M. incognita</i>									
CR1	A	A	A	A	F	FWB	FWB	FWB	
CR3	A	A	A	A	F	FWB	FWB	FWB	
CR5	A	A	A	A	F	FWB	FWB	FWB	
CR6	A	A	A	A	F	FWB	FWB	FWB	
CR11	A	A	A	A	F	FWB	FWB	FWB	
CR12	A	A	A	A	F	MWB	MWB	MWB	
CR16	A	I	A	A	M	MWB	MWB	MWB	
CR17	A	I	A	A	F	FWB	FWB	FWB	
<i>M. exigua</i>									
CR7	A	A	3	I	F	FSB	FSB	FSB	
CR9	A	A	3	I	F	FSB	FSB	FSB	
<i>M. hapla</i>									
CR10	A	A	I	I	F	FSU	FSU	FSU	
CR14	A	A	I	I	F	FSU	FSU	FSU	
CR15	A	A	I	I	F	FSU	FSU	FSU	
<i>M. arenaria</i>									
CR4	A	A	A	I	F	FSB	FSB	FSB	
<i>M. salasi</i>									
CR2	P	A	A	A	F	FSU	FSU	FSU	
<i>M. incognita</i> & <i>M. hapla</i>									
CR13	A	A	I & A	I & A	F	FSW & FWB	FSU & FWB	FSU & FWB	

A: absent; P: present; F: few; M: moderate in number; W: wavy; B: broken; U: unbroken; S: smooth; I: interrupted.

whereas *M. hapla* (CR10, 14, 15) had few, smooth, unbroken striae. *M. arenaria* (CR4) had few, smooth, broken striae in zones 2, 3 and 4. In the mixture of *M. incognita* and *M. hapla* (CR13) perineal patterns with few, smooth and unbroken striae, as well as perineals with few, wavy, broken striae in zones 2, 3 and 4 were found. *M. salasi* (CR2) had few, smooth, mostly unbroken striae in zones 2, 3 and 4. Striae of *M. salasi* and *M. hapla* were relatively fine whereas they were relatively coarse in the other species.

The shape of the perineal pattern varied with the species. In *M. incognita* the perineal patterns of all populations were mostly pyriform, with a trapezoidal dorsal arch. The perineal patterns of the two *M. exigua* populations were roughly rounded, with a low rounded dorsal arch; the striae were rather coarse and far apart. In *M. hapla* populations the perineal patterns were roughly rounded, with a low and wide dorsal arch. No wings were observed in the perineal patterns, but punctations on the tail terminus area were present. The striae were closely spaced. In *M. arenaria* the perineal patterns were mostly oval, with striae forming a shoulder on the low, flat to rounded dorsal arch. In the mixture of *M. incognita* and *M. hapla* both pyriform and roughly rounded perineal patterns were found. *M. salasi* (CR2) had oval shaped perineals, with high and wide rectangular dorsal arches; the striae were far apart. A photomicrograph of one perineal pattern from each population, except of the mixture of *M. incognita* and *M. hapla*, is presented in Figures 2 and 3.

The mean values of morphometric characters of the females are presented in Table 3. Highly significant differences among populations were found in stylet, DEGO, distance between the middle of the excretory pore and the head end (excretory pore), maximum body width, body length, vulva, anus-vulva and interphasmidial distances.

Average values for the characters measured in second-stage juveniles are presented in Table 4.

Highly significant differences among populations were found in total length, tail length, maximum body width, anal width, stylet base to head end, DEGO, and the a and c ratios. Undilated recta were present in *M. exigua* (CR7, 9) and *M. hapla* (CR10, 14, 15) whereas they were dilated in the other populations. In all juveniles the hemizonid was located anterior to the excretory pore.

Average values and observations of certain male characters are presented in Table 5.

All males had areolated lateral fields, although to a

variable degree. In most populations they had four lines in the lateral fields, although five were also observed in some specimens of CR14, a population of *M. hapla*. Only one gonad was observed in males of *M. salasi* (CR2), the *M. incognita* populations CR3 and 11, and the *M. hapla* population CR15; the others had a varying percentage of males with two gonads.

Highly significant differences were found among populations in the stylet, DEGO and spicules (chord of arch). The mean stylet length of *M. salasi* was the lowest, followed only by those of *M. exigua* (CR7, 9), which had stylets 2.4 and 2.8  $\mu\text{m}$  longer, respectively.

### Differential Plants

Similar responses were obtained in the four replicates of each differential plant-population combination, and the average values are presented in Table 6. The differential plant responses indicated that populations CR1, 5, 6 and 17 were *M. incognita* race 1, populations CR3, 11, 12 and 16 were *M. incognita* race 2, population CR4 was *M. arenaria* race 2, populations CR7 and 9 were *M. exigua*, populations CR10, 14 and 15 were *M. hapla*, population CR2 was *M. salasi*, and population CR13 was a mixture of *M. incognita* and *M. hapla*.

The responses to the differential plants gave evidence of pathogenic variation in *M. exigua*. The two populations of this species could be differentiated by their ability or inability to infect tomato, cv. Rutgers (Table 6). Population CR9 was able to reproduce well on this host but CR7 was not.

A major difference among populations of *M. hapla* was found in the reaction of pepper, cv. California Wonder. Populations CR14 and 15 reproduced abundantly on this host, but CR10 reproduced only to a limited extent.

Tomato was heavily infected and received the maximum rating value of 5 with all but *M. salasi* (CR2) and the *M. exigua* population CR7. Tobacco was not infected by *M. salasi* (CR2) and *M. exigua* (CR7, 9), only slightly by the *M. incognita* populations CR5, 6 and 17, and heavily by the remaining populations. Pepper was not a host for *M. salasi* (CR2), and was infected only slightly by CR10, a population of *M. hapla*, the other populations reproduced well on this host. Cotton was not infected, except slightly by CR6 and 16, two populations of *M. incognita*. Peanut was a good host for *M. hapla* (CR10, 14, 15), moderate for the mixture of *M. incognita* and *M. hapla* (CR13) and a poor host for CR6, a population of *M. incognita*. Watermelon was not infected by *M. salasi* (CR2), two populations of *M. ha-*

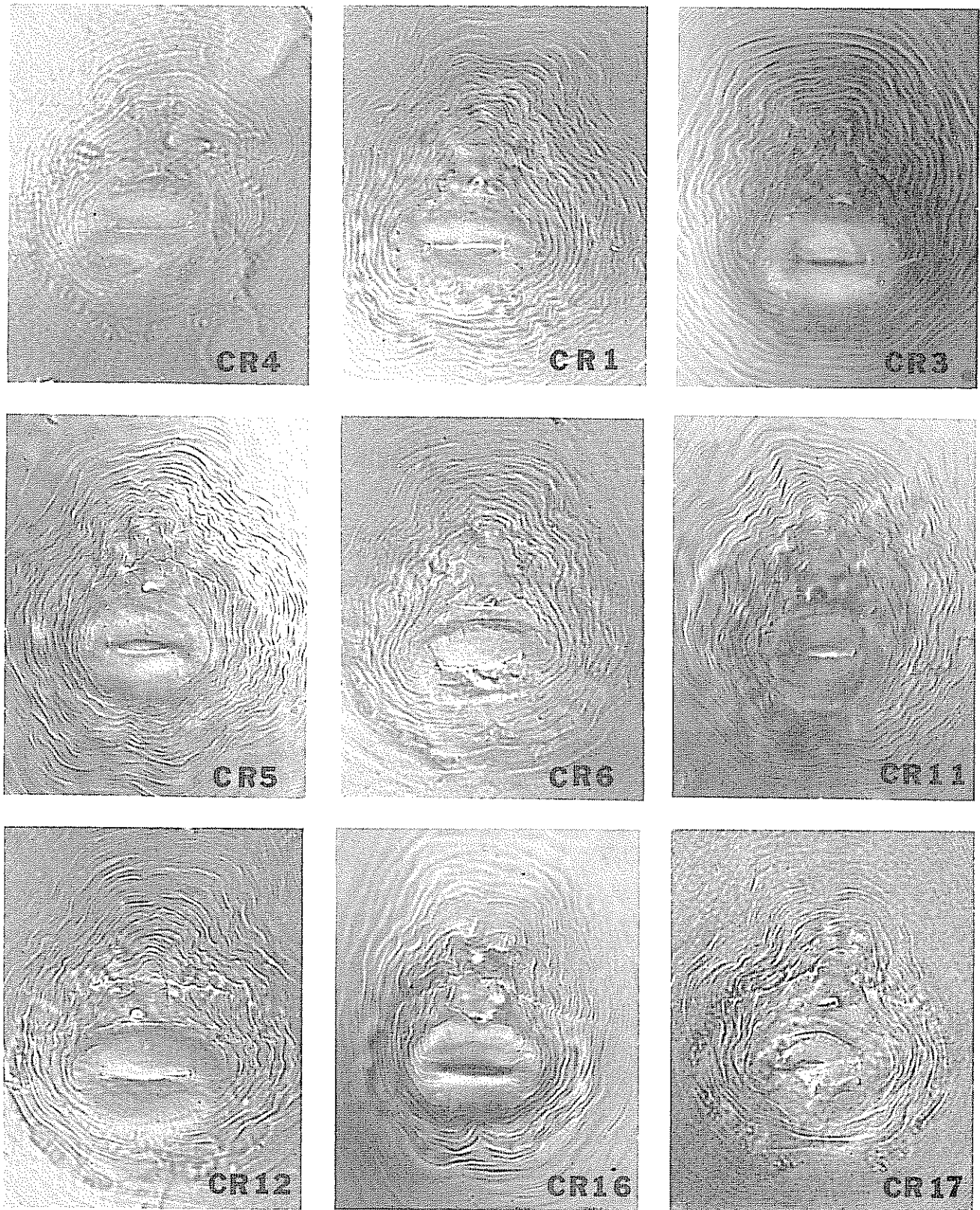


Fig. 2. Photomicrographs of female perineal patterns of nine populations of *Meloidogyne* spp from Costa Rica. CR4: *M. arcnaria* CR1, CR3, CR5, CR6, CR11, CR12, CR16 and CR17: *M. incognita*

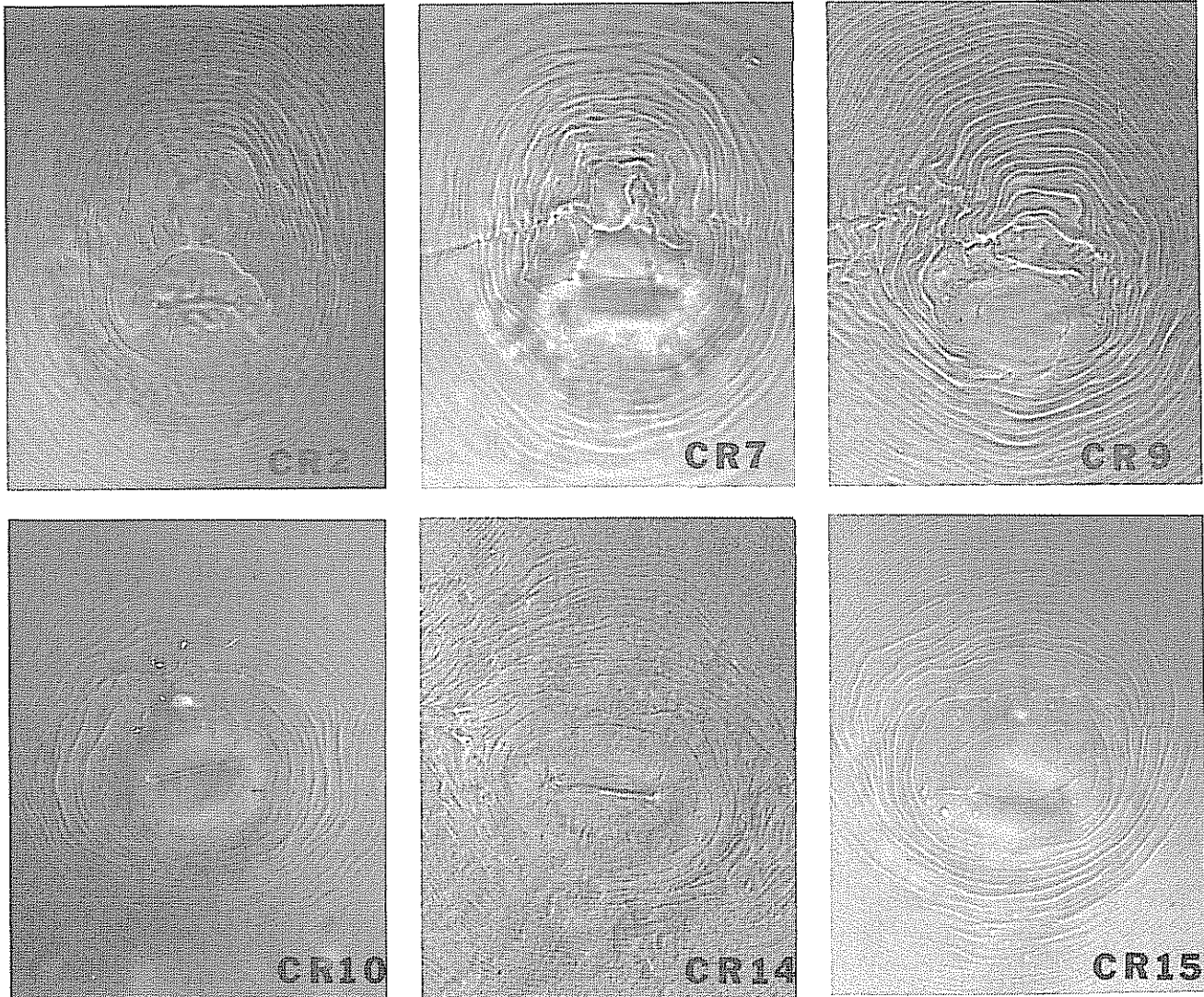


Fig 3 Photomicrographs of female perineal patterns of six populations of *Meloidogyne* spp from Costa Rica CR2: *M. salasi* CR7 and CR9: *M. exigua* CR10 CR14, and CR15: *M. hapla*

*pla* (CR14, 15), and only lightly by the third population of *M. hapla* (CR10) and by the mixture of *M. incognita* and *M. hapla*. This plant was a good host for the other populations. Finally, corn was not a host for *M. salasi* (CR2), *M. exigua* (CR7, 9), and for two populations of *M. hapla* (CR10, 14), a poor host for *M. arenaria* (CR4), the mixture of *M. incognita* and *M. hapla* (CR13), one population of *M. hapla* (CR15) and two of *M. incognita* (CR5, 17), and a good one for the other populations.

#### Discussion

##### Morphology

##### *M. incognita*

The general shape of the perineal patterns was similar among the populations studied and could be

used to distinguish this species from the others. The interpretation of the characteristics exhibited by the perineal patterns agreed with the reports by previous authors in Costa Rica (3, 13). Similarly, the absence of a posterior protuberance was noted. It was noticed that when the mean values of the morphometric characters of each population were compared to those previously reported from Costa Rica, the juvenile length and the female stylet in CR1 were greater. In CR3 the juveniles were wider; CR5 had juveniles with a greater length and females with a longer stylet; CR6 had longer juveniles, with longer tails and a greater ratio; population CR11 had longer juveniles, and the interphasmidial distance, tail length, stylet base to head end, DEGO and the ratio in the female were slightly greater. They also had a smaller anal width. In the females, the excretory pore was longer.

Males of all populations had mean values of their characteristics similar to those reported by these authors (3, 13)

*M. exigua*

There are no previous reports about the morphometrics of this species in Costa Rica, so comparisons were made to the data provided by Chitwood (1) and Lordello and Zamith (7). The general shape and characteristics of the striae of the perineal pattern agreed with previous descriptions. A few females of

each Costa Rican population had the neck region located on the ventral side of the body and a posterior protuberance

On the other hand, some males of the two populations from Costa Rica had twisted bodies and some untwisted bodies. This observation was in agreement with the previous report by Scotto la Massese (14), and contradicts the statement by Lordello and Zamith (7), that males of *M. exigua* did not have a twisted body, thus constituting an exception among the root-knot nematodes. Another contradiction with

Table 3. Morphometric characters of females of 16 populations of *Meloidogyn* spp. from Costa Rica.

Pop.	Exc. pore	Stylet	DEGO*	Body width	Body length
<i>M. incognita</i>					
CR1	23.7 a**	15.2 ede	4.1 bc	486 efg	634 bed
CR3	26.4 abcd	14.3 abcd	4.0 abc	538 g	764 gh
CR5	26.2 abcd	15.9 e	3.8 ab	459 def	679 cdef
CR6	23.4 a	15.6 de	4.0 abc	519 g	721 fg
CR11	25.5 abc	13.5 ab	3.9 ab	495 efg	784 h
CR12	26.4 bed	15.4 ede	3.4 a	439 de	656 bede
CR16	31.7 ede	15.4 ede	4.6 cd	371 bc	642 bede
CR17	24.7 ab	15.2 ede	4.3 bed	471 def	659 bede
<i>M. exigua</i>					
CR7	35.3 e	14.8 bede	6.1 e	272 a	493 a
CR9	32.6 bede	14.4 bed	4.8 c	325 ab	491 a
<i>M. hapla</i>					
CR10	34.8 e	12.9 a	5.7 e	472 def	697 ef
CR14	36.5 e	13.7 ab	5.7 e	423 cd	629 bc
CR15	33.3 de	14.2 abc	5.8 e	486 efg	728 fg
<i>M. arenaria</i>					
CR4	34.2 e	15.5 ede	4.6 d	508 fg	698 ef
<i>M. valasi</i>					
CR2	35.4 e	13.6 ab	3.9 ab	468 def	602 b
<i>M. incognita</i> & <i>M. hapla</i>					
CR13	25.2 abc	15.6 de	4.2 bc	495 efg	690 def
CV (%)	28.4	10.1	14.6	14.6	9.9

\* DEGO refers to the distance between the base of the stylet knobs and the dorsal esophageal gland orifice.

\*\* Mean of 20 observations. All measurements in  $\mu\text{m}$ . Means in the same column followed by the same letter do not differ significantly from one another according to Duncan's Multiple Range Test ( $P < 0.01$ )

Continuation Table 3.

Pop.	Vulva length	Anus-vulva	Interphasmidial distance
<i>M. incognita</i>			
CR1	22.1 bcde	17.8 cde	24.5 def
CR3	25.3 f	18.9 ef	28.6 h
CR5	25.0 f	18.6 def	27.2 gh
CR6	24.5 ef	17.0 abcde	27.5 gh
CR11	23.2 bcdef	19.8 f	26.2 fg
CR12	20.6 abcd	17.5 abcde	23.0 bcd
CR16	23.5 def	18.1 cdef	26.6 g
CR17	23.3 cdef	18.0 cde	26.9 gh
<i>M. exigua</i>			
CR7	18.9 a	17.2 abcde	24.8 ef
CR9	20.6 abcd	16.7 abed	22.6 bc
<i>M. hapla</i>			
CR10	20.7 abcd	15.7 ab	21.7 b
CR14	20.8 abcd	15.6 a	24.9 ef
CR15	20.4 abc	17.6 bcde	22.8 bcd
<i>M. arenaria</i>			
CR4	21.5 abcd	17.8 cde	27.6 gh
<i>M. salasi</i>			
CR2	23.2 bcde	16.3 abc	15.1 a
<i>M. incognita</i> & <i>M. hapla</i>			
CR13	20.3 ab	17.5 abcde	23.9 cde
CV (%)	14.2	11.7	7.9

\* DEGO refers to the distance between the base of the stylet knobs and the dorsal esophageal gland orifice.

\*\* Mean of 20 observations. All measurements in  $\mu\text{m}$ . Means in the same column followed by the same letter do not differ significantly from one another according to Duncan's Multiple Range Test ( $P = 0.01$ ).

the report by Lordello and Zamith (7) was the finding of only one testis in some males of both populations. Lordello and Zamith (7) reported that all males possessed two testes.

The two Costa Rican populations had longer second-stage juveniles and females with longer stylets than previously reported. Males of CR7 had greater DEGO values than those reported by Lordello and Zamith (7). All other values found in this investigation agreed with, and in some cases were identical to, those previously reported.

#### *M. hapla*

The finding of this species outside the Central Plateau and the Central Volcanic Range, the only areas

where it had been found previously (4, 6, 8, 13), widens its reported geographical distribution in Costa Rica. Both El Empalme and Division are high altitude areas with high precipitation and relatively cool temperatures all year round. This agrees with the observed tendency for the distribution of *M. hapla* in the rest of Costa Rica (6).

The shape of the perineal patterns and the characteristics of their striae were in close agreement with previous reports from Costa Rica (6, 13), except that no wings were observed in the perineal patterns. Females of the three populations had greater values for the excretory pore and the DEGO than those reported for other Costa Rican populations (6, 13). The population CR10 had greater values for the total length and tail length of the juveniles, and for the



stylet and spicules (chord of arch) of the males. The CR14 population had longer spicules than found by previous authors. The other characters had mean and range values similar to those reported earlier (6, 13)

The recta of all juveniles were undilated. When first found in Costa Rica, López and Salazar (6) observed some juveniles with dilated recta in a population collected from cabbage. Later, these authors (13) found *M. incognita* and *M. hapla* coexisting in cabbage in the same general area of their first finding. Since *M. incognita* juveniles have dilated recta (1), the possibility of a mixture of both species in the first re-

port seems likely, and therefore makes the report of dilated recta in *M. hapla* juveniles doubtful.

*M. arenaria*

The finding of a population of *M. arenaria* in Ciudad Neilly is the first report of this species in Costa Rica. Comparisons were made to the values and observations given by previous authors (1, 2). The general shape and characteristics of the striae of the perineal pattern were similar to those reported by these authors, but the second-stage juveniles were shorter than the value given by Eisenback *et al* (2),

Table 4. Morphometric characters of second-stage juveniles of 16 populations of *Meloidogynae* spp. from Costa Rica.

Pop.	Total length	Tail length	Maximum body width	Anal width
<i>M. incognita</i>				
CR1	414 cd**	53.3 b	14.9 abc	10.8 cde
CR3	402 c	49.8 a	16.1 e	11.1 de
CR5	426 d	53.9 bc	15.2 bcd	10.8 cde
CR6	449 e	57.5 d	14.9 abc	10.9 cde
CR11	420 d	52.8 b	15.1 bcd	11.1 de
CR12	419 d	49.8 a	15.6 cde	10.3 bcde
CR16	461 e	56.4 cd	14.9 abc	9.0 a
CR17	386 b	47.4 a	15.7 de	10.3 bcde
<i>M. exigua</i>				
CR7	373 ab	48.5 a	14.5 ab	9.4 ab
CR9	368 a	48.8 a	14.7 ab	9.4 ab
<i>M. hapla</i>				
CR10	464 f	61.2 e	14.7 ab	10.6 bcde
CR14	373 ab	47.4 a	14.6 ab	10.2 bcd
CR15	373 ab	48.1 a	14.5 ab	10.0 abcd
<i>M. arenaria</i>				
CR4	459 e	57.3 d	14.2 a	9.8 abc
<i>M. salasi</i>				
CR2	466 f	69.5 f	16.1 e	11.4 e
<i>M. incognita</i> & <i>M. hapla</i>				
CR13	418 d	54.7 bcd	14.9 abc	10.3 bcde
CV (%)	4.0	6.3	5.5	12.0

\* DEGO refers to the distance between the base of the stylet knobs and the dorsal esophageal gland orifice.

\*\* Mean of 20 observations. All measurements in  $\mu\text{m}$ . Means in the same column followed by the same letter do not differ significantly from one another according to Duncan's Multiple Range Test ( $P = 0.01$ ). All juveniles had the hemizonid anterior to the excretory pore. In CR7, 9, 10, 14 and 15 the recta were undilated, whereas in the remaining populations they were dilated.

Continuation Table 4.

Pop.	Stylet base to head end	DEGO*	a	c
<i>M. incognita</i>				
CR1	15.3 de	3.2 ab	27.9 bcd	7.8 bcde
CR3	15.6 ef	3.1 ab	26.2 abc	8.1 ef
CR5	15.7 ef	3.0 a	28.3 bcd	7.9 cdef
CR6	15.5 ef	3.1 ab	30.3 def	7.8 bcde
CR11	15.1 cd	3.1 ab	28.0 bcd	8.0 def
CR12	15.4 def	3.8 d	23.5 a	8.4 g
CR16	15.8 f	3.6 cd	31.2 def	8.2 fg
CR17	15.5 ef	3.2 ab	25.0 ab	8.2 fg
<i>M. exigua</i>				
CR7	13.6 a	3.2 ab	25.6 ab	7.7 bcd
CR9	13.6 a	3.5 bcd	25.2 ab	7.5 b
<i>M. hapla</i>				
CR10	14.8 c	4.5 e	31.7 ef	7.6 bc
CR14	14.2 b	4.2 e	25.7 ab	7.9 cdef
CR15	14.0 b	3.7 d	25.8 ab	7.8 bcde
<i>M. arenaria</i>				
CR4	15.4 def	3.5 bcd	32.6 f	8.0 def
<i>M. salasi</i>				
CR2	14.2 b	3.3 abc	29.2 cde	6.7 a
<i>M. incognita</i> & <i>M. hapla</i>				
CR13	15.3 de	3.1 ab	28.2 bcd	7.6 bc
CV (%)	3.2	12.7	13.5	4.7

\* DEGO refers to the distance between the base of the stylet knobs and the dorsal esophageal gland orifice

\*\* Mean of 20 observations. All measurements in  $\mu\text{m}$ . Means in the same column followed by the same letter do not differ significantly from one another according to Duncan's Multiple Range Test ( $P = 0.01$ ). All juveniles had the hemizonid anterior to the excretory pore. In CR7, 9, 10, 14 and 15 the recta were undilated, whereas in the remaining populations they were dilated.

although similar to the values given by Chitwood (1). All other morphometric values for females, males and juveniles were similar to the reports by the previously mentioned authors.

#### *M. salasi*

The females of this root-knot nematode could be differentiated from the other species by the presence of a posterior protuberance and the neck and head regions located on the ventral side of the body. The body was usually oval, in contrast to the pyriform shape found in *M. exigua*, some of which showed a posterior protuberance and the neck on the ventral side of the body. Some, but not all specimens of *M. exigua* exhibited these characters.

The shape of the perineal pattern of *M. salasi* was also unique. Other differentiating characters were the short interphasmidial distance in the females, the longer juvenile tails, the smaller c ratio of juveniles and the shorter male stylet. The phasmids of the females were also smaller than in other root-knot nematode species.

#### Differential Plants

As pointed out by Taylor and Sasser (15), differential plants 1) provide a preliminary or corroborative indication of the root-knot nematode species being evaluated, based on the usual response of the hosts, and 2) detect pathogenic variation of a population, as determined by host responses different from the

Table 5. Morphological characters of males of 16 populations of *Meloidogyne* spp. from Costa Rica.

Pop.	Stylet	Spicules (chord of arch)	DEGO*	Areolation	Number of lateral lines	% males with one gonad
<i>M. incognita</i>						
CR1	23.6 f***	35.0 hi	3.5 b	yes	4	95
CR3	25.1 hi	34.5 ghi	3.0 ab	yes	4	100
CR5	24.1 fg	32.6 efg	2.8 a	yes	4	65
CR6	25.0 ghi	34.2 fghi	2.9 a	yes	4	85
CR11	22.0 e	33.5 fghi	2.8 a	yes	4	100
CR12	22.6 e	31.1 de	3.0 ab	yes	4	80
CR16	24.4 fgh	32.3 ef	3.2 ab	yes	4	70
CR17	25.7 i	35.4 i	3.5 b	yes	4	95
<i>M. exigua</i>						
CR7	18.4 b	24.1 a	3.2 ab	yes	4	45
CR9	18.9 b	25.0 a	4.9 de	yes	4	85
<i>M. hapla</i>						
CR10	21.7 de	30.0 cd	5.0 e	yes	4	60
CR14	20.4 c	29.0 bc	4.1 c	yes	4-5	95
CR15	20.5 c	27.7 b	5.0 e	yes	4	100
<i>M. arenaria</i>						
CR4	24.3 fgh	33.0 efgh	3.1 ab	yes	4	95
<i>M. salasi</i>						
CR2	16.0 a	27.2 b	3.3 ab	yes	4	100
<i>M. incognita</i> & <i>M. hapla</i>						
CR13	21.0 cd	28.2 bc	4.4 cd	yes	4	85
CV (%)	6.8	9.3	16.9	-	-	-

\* DEGO refers to the distance between the base of the stylet knobs and the dorsal esophageal gland orifice

\*\* The rest of the males had two gonads.

\*\*\* Mean of 20 observations. All measurements in  $\mu\text{m}$ . Means in the same column followed by the same letter do not differ significantly from one another according to Duncan's Multiple Range Test ( $P = 0.01$ )

usual for the various species. However, differential plants cannot be relied upon entirely for identification, because the population being studied may be a mixture of species or a species for which no or limited host response data are available.

For example, *M. salasi* did not reproduce on any of the differential plants (Table 6). The reaction of the plants, however, was used to differentiate among the other species studied, and even for the determination of the host race among populations of *M. incognita* and *M. arenaria*.

Based on the scheme provided by Taylor and Sasser (15), the *M. incognita* populations CR1, 5, 6 and 17 were designated as race 1, whereas populations CR3, 11, 12 and 16 were designated as race 2. This is the first report of the presence of race 2 in Costa Rica. Salazar and Lopez (13) had previously reported race 1 only.

In spite of the evidence of pathogenic variation in the two populations of *M. exigua*, it seems premature at this time to call them races. This term was applied to populations of *Meloidogyne* species that were

Table 6. Response of seven differential plants to 16 populations of *Meloidogyne* spp. from Costa Rica.

Pop.	Tomato 'Rutgers'	Tobacco 'NC-95'	Pepper 'California Wonder'	Cotton 'Deltapine 16'	Peanut 'Florunner'	Watermelon 'Charleston Grey'	Corn 'Minnesota A-401'
<i>M. incognita</i>							
CR1	5*	3	5	0	0	5	5
CR3	5	5	5	0	0	4.5	5
CR5	5	1.5	4.5	0	0	3	3.2
CR6	5	1.5	5	1.5	0.2	5	4.7
CR11	5	5	5	0	0	5	5
CR12	5	4	3.5	0	0	5	1.5
CR16	5	5	5	0.5	0	5	5
CR17	5	2	5	0	0	5	3.7
<i>M. exigua</i>							
CR7	1.5	0	5	0	0	4	0
CR9	5	0	4.7	0	0	4	0
<i>M. hapla</i>							
CR10	5	5	1.7	0	5	5	0.2
CR14	5	4	5	0	5	0	0
CR15	5	5	5	0	5	0	1.6
<i>M. arenaria</i>							
CR4	5	5	5	0	0	5	3.2
<i>M. salasi</i>							
CR2	0**	0	0	0	0	0	0
<i>M. incognita</i> & <i>M. hapla</i>							
CR13	5	4.5	5	0	2.7	2	2.5

\* Mean of four replicates. Responses evaluated according to the number of egg masses/root system: 0 = 0 egg masses; 1 = 1-2; 2 = 3-10; 3 = 11-30; 4 = 31-100; and 5 = more than 100 egg masses.

\*\* Inoculum viability was evidenced by high reproduction on rice plants inoculated at the same time as the differential plants.

shown by numerous experiments to have unique host preferences, and that were named only after there was evidence of wide geographical distribution and/or sufficient significance for crop rotation and/or plant breeding programs (15). Most of the criteria used for the application of the term host were not fulfilled in this case. Future work could give the necessary proof that they indeed deserve to be designated as host races. From a practical point of view, this finding could be of value to farmers in the area of Sarchi, as some fields where coffee was grown were changed to tomato production.

Differences in the ability of *M. hapla* populations to reproduce on pepper were found. Reactions of the other differential plants to the three populations were

similar, and agreed with the usual response given by them to this species (15). As in the case of *M. exigua*, it seems premature at this time to apply the term host races to these populations.

The population of *M. arenaria*, similar to most of the populations in the world collection of the International *Meloidogyne* Project, did not reproduce on peanut, cv Florunner, and therefore was determined to be race 2 of this species.

The reaction given by the differential plants of CR13, the mixture of *M. incognita* and *M. hapla*, was different from the usual one given to each of the major species (15). Previous workers have found this same mixture of species in the Central Volcanic Ran-

ge of Costa Rica, on plants such as cabbage, carrot, lettuce and green peas (4, 10, 11, 12, 13) As pointed out by several of them, such mixture of species makes the management of root-knot nematodes by crop rotation and resistant cultivars even more difficult, and might require some long term studies for the development of profitable management schemes

#### Summary

Based on a morphometric study of males, females and second-stage juveniles, and on the responses of seven differential plants, five species of *Meloidogyne* (*M. arenaria*, *M. incognita*, *M. hapla*, *M. exigua* and *M. salasi*) were distinguished among 16 populations collected at different locations in Costa Rica. The responses of the differential hosts gave evidence that the *M. arenaria* population was host race 2, and that the *M. incognita* populations included host races 1 and 2. Evidence of pathogenic variation was found between the two *M. exigua* populations. One reproduced readily on tomato, whereas the second population did not. Similarly, two populations of *M. hapla* reproduced readily on pepper, whereas the third population reproduced only to a limited extent on that host.

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## Reseña de libros

TARO A review of *Colocasia esculenta* and its potentials ed by Jaw-Kai Wang University of Hawaii Press. 2840 Kolowalu Str Honolulu, Hawaii 96822 400 p. Price \$ 35.00

Taro is a very complete book about the species *Colocasia esculenta*, crop of first feeding importance through all the islands of the Pacific.

The investigation shown in this book have been realized, principally in the last 15 years, by a wide group of scientifics (botanists, agronomists, nutritionists, economists), especially of the University of Hawaii.

This team of researchers, working in all aspects of a crop, considered until now of second economic importance, due that is practised by multiple small aboriginal communities, is a real example of great vision to afford a problem. They have not only considered the plant itself, but also the thousands of peasants, distributed in islands, with very scarce technical elements and means of communications

The book cover:

A general background: botany, physiology and nutritive value.

Production technology: agronomy, pest and diseases.

Utilization: processed food, animal feed and industrial uses, and planning and development: production systems planning, socio-economic aspect of taro as food and production management considerations It calls the attention, in all chapters, to the details of the investigations carried on.

About Pest -- as an example -- it is presented the inventory of taro pest, cited, by separated, those that attack: leaves, petiols, corms and roots and adding the parasites and predators of the danger animals, and also cited those invertebrates and vertebrates, until now, known as associated with the crop.

The results and feasible recommendations presented, specially for the Pacific area, I am sure, will serve as well, for Asia, Africa and America, where this crop is also an important food, but technically neglected, as being practised by peasants.

Congratulations to Jaw-Kai Wang and all the equipment.

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