SCREENING OF CUARENTINO PEPPER (*CAPSICUM ANNUUM* L.) FOR RESISTANCE TO *MELOIDOGYNE INCOGNITA*

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ABSTRACT

Piedra Buena, A., J. A. López-Pérez, A. Bello, M. A. Díez-Rojo, L. Robertson, M. Escuer, and L. de León. 2006. Screening of Cuarentino pepper (*Capsicum annuum* L.) for resistance to *Meloidogyne incognita*. Nematropica 36:13-24.

The response of Cuarentino pepper (*Capsicum annuum*) against 66 isolates of *Meloidogyne incognita*, 52 from Spain and 14 from Uruguay, was studied with the objective of evaluating its potential to be included in breeding programs as a source of resistance genes against *M. incognita*. A bioassay was performed to determine races and biotypes of *M. incognita*, as well as to characterize the resistance of Cuarentino. Cuarentino was resistant to 13.5% of the Spanish isolates (7 of 52), but was not resistant to the Uruguayan isolates of *M. incognita*, with no statistical differences in resistant, moderately resistant and susceptible plant frequencies among the four biotypes and races of the nematode. Proportions of biotypes were similar in both countries while the prevalence of races varied. The races of *M. incognita* did not affect biotype proportions. Results suggest that Cuarentino carries resistance genes to *M. incognita* and that these genes are different from those carried by commercial pepper cultivars. The high susceptibility of Cuarentino to Uruguayan isolates suggests that its repeated cropping in the field has selected virulent nematode populations able to overcome the resistance. It shows the need for further seed selection and agronomic behavior studies of this local pepper, as well as the need to design management strategies that avoid the selection and spread of virulent nematode populations.

Key words: biotype, integrated crop management, race, root-knot nematode, Spain, Uruguay, virulence.

RESUMEN

Piedra Buena, A., J. A. López-Pérez, A. Bello, M. A. Díez-Rojo, L. Robertson, M. Escuer, y L. de León. 2006. Evaluación de la resistencia del pimiento Cuarentino (*Capsicum annuum* L.) frente a *Meloidogyne incognita*. Nematropica 36:13-24.

Se estudió la respuesta del pimiento Cuarentino (*Capsicum annuum*) frente a 66 aislamientos de *Meloidogyne incognita*, 52 de España y 14 de Uruguay, con el objetivo de evaluar su potencial para ser incluido en programas de mejoramiento genético como fuente de genes de resistencia a *M. incognita*. Se aplicó un bioensayo para determinar las razas y biotipos de *M. incognita*, así como para caracterizar la resistencia del pimiento Cuarentino. El pimiento Cuarentino fue resistente a 13,5% de los aislamientos españoles (7 de 52), pero a ninguno de los aislamientos uruguayos de *M. incognita*, sin diferencias en las frecuencias de plantas resistentes, moderadamente resistentes y susceptibles frente a cada uno de sus cuatro biotipos y razas. Las proporciones de los biotipos fueron similares en ambos países, mientras que la prevalencia de las razas fue variable. Las razas de *M. incognita* no afectaron las proporciones de los biotipos. Los resultados sugieren que el pimiento Cuarentino posee genes de resistencia a *M. incognita* y que éstos son diferentes a los presentes en los cultivares comerciales de pimiento. La elevada suceptibilidad del pimiento Cuarentino a los aislamientos uruguayos sugiere que la presión de selección ejercida por su cultivo reiterado en el campo ha dado lugar a poblaciones virulentas capaces de superar esta resistencia. Se plantea la necesidad de profundizar en la selección y estudio de las características agronómicas de este material local, así como en el diseño de estrategias de manejo que eviten la selección y propagación de poblaciones virulentas de nematodos.

Palabras claves: biotipo, España, nematodos formadores de nódulos, manejo integrado de cultivos, raza, Uruguay, virulencia.

INTRODUCTION

Root-knot nematodes (*Meloidogyne* spp.) are important pests of several crops worldwide. Among the non-chemical methods available to control them, the use of resistant cultivars is considered one of the most effective and environmentally safe alternatives. In pepper (*Capsicum annuum*), studies on susceptibility to *Meloidogyne* species have shown that, in general terms, it is parasitized by all *M. incognita* races but it is resistant to *M. javanica* (Hartman and Sasser, 1985; Peixoto *et al.*, 1997), although some authors have reported *M. javanica* parasitizing *C. annuum* and *C. frutescens* (Santos *et al.*, 1987; Stephan, 1988; Rammah and Hirschmann, 1990; Ahmad *et al.*, 1998; Carneiro *et al.*, 2003). The first resistance gene identified in pepper was named the N gene (Hare, 1956, 1957), and confers dominant resistance to *M. incognita*, *M. javanica* and *M. arenaria.* This resistance proved to be thermostable, being effective even at high temperatures (32°C) (Thies and Fery, 2002a). Dalmasso *et al.* (1985) and Hendy *et al.* (1985) found that at least five different genes were responsible for the resistance in *C. annuum* to *M. incognita*, *M. javanica* and *M. arenaria*, with the main genes involved being *Me1*, *Me2* and *Me3*. Pochard *et al.* (1986) stated that gene *Me5* is the main gene involved in the resistance to *M. incognita*, having two complementary genes *Me3* and *Me4*, but Castagnone-Sereno *et al.* (2001) observed that *Me1* was more effective than *Me3* in conferring resistance to *M. arenaria*, *M. incognita* and *M. javanica.* Fery and Dukes (1996) found that in some cases resistance in *C. annuum* to *M. incognita* is conferred by a dominant gene, while in others it depends on two genes, one of them dominant and the other recessive, conferring a higher level of resistance.

Although there are resistant cultivars commercially available, the loss of their effectiveness forces a continuous search for new resistance genes. The durability of the resistance will depend on its agronomic management and on the virulence of the nematode populations in the different crop areas (Kaloshian *et al.*, 1996; Blok *et al.*, 1997; Verdejo-Lucas *et al.*, 1997; Tzortzakakis *et al.*, 1999; Castagnone-Sereno, 2002a, b; Lacasa *et al.*, 2002; Thies and Fery, 2002b; Piedra Buena *et al.*, 2004; Ros *et al.*, 2004). Regarding nematode virulence, to date researchers have not found DNA polymorphisms linked to virulence that would allow the development of molecular markers to differentiate virulent and avirulent populations. Therefore, at present, nematode virulence cannot be characterized by molecular methods (Semblat and Castagnone-Sereno, 2001). However, recently Bello *et al.* (2004) modified the Differential Host Test of North Carolina (Hartman and Sasser, 1985) and developed a bioassay that allows the characterization of *Meloidogyne* populations virulent to resistant cultivars of pepper and tomato.

The Agronomy Department of Universidad de la República, Instituto Nacional de Investigación Agropecuaria (Agrarian Research Institute-INIA), and local nongovernmental organizations (NGOs) of Uruguay have collected and characterized local cultivars of different vegetables, derived from ancient varieties brought by European immigrants and kept, reproduced and selected by small farmers. Among these, Cuarentino pepper, mainly grown in the Northern area of the country (Salto province), has interesting agronomic characteristics such as precocity of production, high fruit set, and adaptation to local farming conditions. However, the small size and poor tolerance to transportation of the fruits do not fit the current market requirements (Galván *et al.*, 2000, 2005), except for local markets, where it is much appreciated. From a phytopathological aspect, it has been observed that populations of *M. javanica* do not parasitize this pepper, although it is parasitized by *M. hapla*, with *M. incognita* showing a variable behavior (De León *et al.*, 2001).

This work studies the resistance level of Cuarentino pepper to different isolates of *M. incognita* from Spain and Uruguay characterized by their virulence on resistant cultivars of tomato and pepper, in order to estimate its potential to be included in pepper breeding programs and to establish the relationship between frequent cropping of this pepper and selection of virulent *M. incognita* populations in Uruguay.

MATERIAL AND METHODS

Nematode Origin and Identification

Meloidogyne species in populations collected from vegetable fields of Spain and Uruguay were identified through morphometric (female perineal pattern) and molecular (SCAR-PCR) techniques (Zijlstra *et al.*, 2000). Once identified, 48 field populations of *M. incognita* coming from the laboratory collection, 37 from Spain and 11 from Uruguay, were selected (Table 1). These field populations were maintained in pots in a growth chamber on the susceptible tomato cv. Marmande.

Susceptible plants of tomato cv. Marmande with two true leaves, approximately 20 days post germination, were transplanted to pots containing 300 cm^3 of sterile sandy soil, in order to reproduce the selected populations. One week later, pots were inoculated with one egg mass from each original field population, achieving an inoculum level of about 120 J2/100 g sterile sandy soil. Field populations were replicated three times, using different egg masses to obtain each isolate. Tomato plants were kept in growth chambers for 45 days. Characterization of each isolate began when the galling index was higher than 5 on a 0-10 scale (Bridge and Page, 1980), to achieve sufficient infestation levels. Galling indices were determined by visual estimation of galling percentages on roots, the characteristic symptom of the genera, where an index of 5 equates to 50% of nematode affected roots, including main roots.

Characterization of M. incognita *Isolates to Race and Biotype*

Race and virulence biotype of each isolate of *M. incognita* were determined using two complementary bioassays. Race was determined using the Differential Host Test of North Carolina (Hartman and Sasser, 1985), and virulence to tomato and pepper (virulence biotype) was determined through the bioassay of Bello *et al.* (2004). The virulence bioassay is a modification of the Differential Host Test of North Carolina, including two susceptible pepper cvs., Capino and Sonar, three resistant pepper cvs., Charleston Belle, Carolina Wonder (Fery *et al.*, 1998) and Atlante (obtained by Ramiro Arnedo S.A., Spain), as well as susceptible tomato cv. Marmande and resistant tomato cv. Nikita. The bioas-

Table 1. Collection areas of the *M. incognita* field populations from Spain and Uruguay.

Reference No.	Collection area	Reference No.	Collection area
	Spanish populations		
1	El Perelló (Valencia)	22176	La Fuensanta (Albacete)
22	Villena (Alicante)	22243	Las Galletas (Tenerife)
23	Campo de Cartagena (Murcia)	22475	La Fuensanta (Albacete)
27	El Perelló (Valencia)	23758	San Javier (Murcia)
28	Campo de Cartagena (Murcia)	23760	San Javier (Murcia)
65	El Perelló (Valencia)	23762	San Javier (Murcia)
94	Villa del Prado (Madrid)	23766	Mazarrón (Murcia)
15841	El Perelló (Valencia)	23796	San Javier (Murcia)
16330	El Perelló (Valencia)	23798	San Javier (Murcia)
16388	Talavera de la Reina (Toledo)	23823	Almería (Almería)
17758	Los Moriscos (Tenerife)	23824	Alboraya (Valencia)
18366	Mareny de Barraquets (Valencia)	24269	Mazarrón (Murcia)
18467	Mareny de Barraquets (Valencia)	24440	Alcanadre (La Rioja)
18591	Mareny de Barraquets (Valencia)	24801	Santa Gertrudis (Ibiza)
21019	Llutxent (Valencia)	24841	Villa del Prado (Madrid)
21020	Paiporta (Valencia)	26834	Uleila del Campo (Almería)
21046	El Perelló (Valencia)	26838	Uleila del Campo (Almería)
21057	Mareny de Barraquets (Valencia)	26839	Uleila del Campo (Almería)
21696	San Pedro del Pinatar (Murcia)		
	Uruguayan populations		
22868	Salto (Salto)	24206	Bella Unión (Artigas)
22869	Salto (Salto)	24207	Tacuarembó (Tacuarembó)
24202	Bella Unión (Artigas)	24528	San Jacinto (Canelones)
24203	Tacuarembó (Tacuarembó)	24529	Libertad (San José)
24204	Tacuarembó (Tacuarembó)	25397	Montevideo (Montevideo)
24205	Tacuarembó (Tacuarembó)		

say also includes tobacco cv. North Carolina 95 and cotton cv. Deltapine 91, which allow the identification of *M. incognita* races, peanut cv. Florunner, which enables separation of the two races of *M. arenaria*, and watermelon cv. Charleston Gray, which allows *M. hapla* differentiation. Although these two species were not included in this work, all host plants were tested against the isolates in order to fully characterize them. Host plants were tested three times against each isolate.

All the experiments were performed in a growth chamber at 24°C (± 1°C) and 16 h light for at least 45 days, in order to allow nematodes to complete their life cycle.

After 45 days, root galling was estimated according to the Bridge and Page (1980) visual scale.

Root galling indices in susceptible pepper (cvs. Capino and Sonar), resistant pepper (cvs. Charleston Belle, Carolina Wonder and Atlante), susceptible tomato cv. Marmande and resistant tomato cv. Nikita were used to determine the biotypes. Host plants were considered resistant (R) when the mean root galling index (± standard deviation) was <3, and susceptible (S) when this value was ≥3. Biotypes were named after Bello *et al.* (2004): *Tomato* biotype corresponds to an isolate which does not parasitize resistant cultivars of tomato and pepper, *Tomato-Mi* biotype corresponds to an isolate which parasitize the resistant cultivar of tomato but not resistant pepper, *Pepper* biotype corresponds to an isolate which does not parasitize the resistant cultivar of tomato, but does parasitize resistant cultivars of pepper, and *Pepper-Mi* biotype corresponds to an isolate which parasitize the resistant cultivars of tomato and pepper.

Response of Cuarentino to the Isolates of M. incognita

In order to evaluate its resistance level to the different isolates of *M. incognita*, in this work Cuarentino was included as a host plant in the bioassays. It was tested against each isolate of *M. incognita* three times, using Cuarentino plants with 2 true leaves, and keeping plants in growth a chamber for 45 days. After 45 days, root galling was estimated using Bridge and Page (1980) visual scale, as done for the host plants of the bioassays performed for *M. incognita* characterization. Cuarentino was considered resistant (R) when the mean root galling index (± standard deviation) was 0, moderately resistant (MR) when the root galling index was from 1 to 3, and susceptible (S) when this value was >3.

Statistical Analysis

The results were statistically analyzed using a chi-square test ($p < 0.05$, exact signification, two-sided), with the SPSS statistic program for Windows (standard version 11.5.1, SPSS, Inc., 2002), to verify the similarity among *M. incognita* populations of Spain and Uruguay. This same test (chi-square test, $p < 0.05$, exact signification, two-sided) was used to compare the frequencies of resistant, moderately resistant and susceptible Cuarentino plants among the different races and biotypes of *M. incognita* from both countries.

RESULTS AND DISCUSSION

Characterization of M. incognita *Isolates to Race and Biotype*

The results of the characterization of *M. incognita* isolates using the bioassays of Hartman and Sasser (1985), and Bello *et al.* (2004) are shown in Figs. 1 and 2, and in Tables 2 to 4. As some isolates from the same field population showed a heterogeneous behavior, they were treated as different (some isolates coming from Spanish field populations 1, 22, 23, 94, 18366, 21020, 22176, 22475, 23762 and 23823, and Uruguayan field populations 22869 and 24207). Therefore, the total number of studied isolates was 66, 52 isolates coming from the 37 Spanish field populations, and 14 isolates coming from the 11 Uruguayan field populations (Table 4). This suggests the coexistence of different races and/or biotypes in the field, whose different behavior (phenotype) might be related to genetic variation (genotype), although at present there are no molecular markers able to differentiate virulent and avirulent populations. Therefore, further studies are needed on this subject. The variable predominance of different races and biotypes in "mixed" population might complicate their identifi-

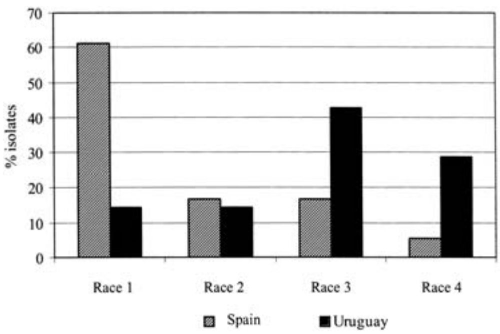

Fig. 1. Percentages of races 1, 2, 3 and 4 in isolates of *M. incognita* from Spain and Uruguay. Race 1: tobacco cv. North Carolina 95 and cotton cv. Deltapine 91 not parasitized; race 2: tobacco cv. NC95 parasitized but not cotton cv. DP91; race 3: tobacco cv. NC95 not parasitized, but cotton cv. DP91 parasitized; race 4: both tobacco cv. NC95 and cotton cv. DP91 parasitized.

cation in the laboratory, so it would be easier and more accurate to work with isolates obtained from single egg masses. On the other hand, nematode management in the field must also consider this variation to avoid the selection of virulent populations and to maintain the effectiveness of the resistant cultivars.

The four races of *M. incognita* were found in both countries (Fig. 1). Race 1 was prevalent in Spanish populations (60.4%), followed by races 2 and 3 (17.0% in both

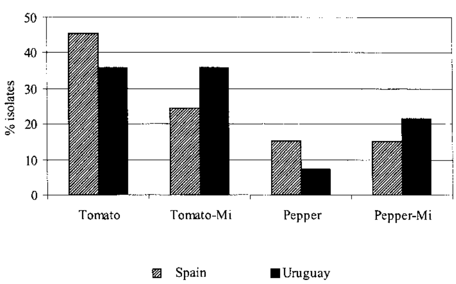

Fig. 2. Percentages of biotypes in isolates of *M. incognita* from Spain and Uruguay. *Tomato*: resistant cultivars of tomato and pepper not parasitized; *Tomato-Mi*: resistant cultivar of tomato parasitized but not resistant peppers; *Pepper*: resistant cultivar of tomato not parasitized, but resistant peppers parasitized; *Pepper-Mi*: both resistant cultivars of tomato and pepper parasitized.

cases), while in Uruguay race 3 was the most frequent (42.8%), followed by race 4 (28.6%). These differences in prevalence of races in Spain and Uruguay were confirmed by the chi-square test ($p < 0.05$, exact signification, two-sided), which found significant differences between both countries ($\chi^2 = 0.004$; $p < 0.05$). The statistical analysis also showed that these differences would remain in the present proportion even if more Uruguayan populations were studied.

The characterization of biotypes (Fig. 2) showed no differences between Spain and Uruguay ($\chi^2 = 0.658$; $p < 0.05$). In Spain, most of the biotypes found were avirulent to resistant tomato and pepper (45.3%, *Tomato* biotype), followed by *Tomato-Mi* (24.5%), and *Pepper* and *Pepper-Mi* (15.1% in both cases), while in Uruguay 70.0% of the isolates did not parasitize pepper (*Tomato* and *Tomato-Mi* biotypes, 35.7% each). Isolates virulent to pepper in Uruguay represented 21.4% (*Pepper-Mi* biotype) and 7.1% (*Pepper* biotype) of the isolates studied. The statistical analysis showed that, if a higher number of populations from Uruguay were studied, the frequency of each biotype would be similar to those of Spain. This suggests that races of *M. incognita*, with different prevalence in Spain and Uruguay, do not affect the proportion of virulence biotype, which is similar in both countries. From a practical point of view, it implies that for a more suitable management of vegetable resistance to nematodes in the field the biotype characterization would be more useful than the race identification.

Response of Cuarentino to the Isolates of M. incognita

Cuarentino behaved as resistant or moderately resistant to 18.2% of *M. incognita* isolates tested (11 of 66 isolates, 10 from Spain and 1 from Uruguay), which would indicate the presence of resistance

Table 2. Susceptible, moderately resistant and resistant frequencies within Cuarentino pepper tested against races of *M. incognita.*

		Susceptible[y]		Moderately resistant[y]		Resistant[y]	
Country	Races[x]	No. isolates[z]	%	No. isolates[z]	%	No. isolates[z]	%
Spain	1	26	83.9	2	6.5	3	9.7
	2	6	75.0	0	0.0	3	25.0
	3	6	75.0	2	16.7	1	8.3
	4	3	100.0	0	0.0	0	0.0
Uruguay	1	2	100.0	0	0.0	0	0.0
	2	2	100.0	0	0.0	0	0.0
	3	5	83.3	1	16.7	0	0.0
	4	4	100.0	0	0.0	0	0.0
Spain + Uruguay	1	28	84.8	2	6.1	3	9.1
	2	8	72.7	0	0.0	3	27.3
	3	11	73.3	3	20.0	1	6.7
	4	7	100.0	0	0.0	0	0.0

[x]Race 1: tobacco cv. North Carolina 95 and cotton cv. Deltapine 91 are not parasitized; race 2: tobacco cv. NC95 is parasitized but cotton cv. DP91 does not; race 3: tobacco cv. NC95 is not parasitized, but cotton cv. DP91 is parasitized; race 4: both tobacco cv. NC95 and cotton cv. DP91 are parasitized.
[y]S: susceptible, root galling index >3; MR: moderately resistant, root galling index = 1-3; R: resistant, root galling index = 0.
[z]Mean of three replicates (plants).

genes. A similar value (20.0%) was obtained even when Cuarentino was tested against *M. incognita* isolates virulent to pepper from both countries (*Pepper* and *Pepper-Mi* biotypes). The existence of moderately resistant plants indicates a quantitative resistant response that, along with the fact that some of the isolates able to parasitize resistant pepper cultivars carrying the N gene are not able to parasitize Cuarentino, suggest that this resistance to *M. incognita* could involve more than one gene. Evaluation of Cuarentino against *M. incognita* isolates unable to parasitize resistant pepper cultivars (*Tomato* and *Tomato-Mi* biotypes) from both countries showed that the percentage of moderately resistant and resistant plants (17.6%) was similar to that of *Pepper* and *Pepper-Mi* biotypes. It must be highlighted that Cuarentino was susceptible to most of the Uruguayan *M. incognita* isolates (13 of 14 isolates, 92.9%), with a lower percentage of susceptibility to Spanish isolates (41 of 52 isolates, 78.8%), suggesting that the repeated use of that crop in the field caused the selection of virulence in Uruguayan nematode populations. This is in agreement with previous research (Piedra Buena *et al.*, 2004; Piedra Buena, 2005), but further studies are required.

The statistical analysis to establish the similarity of the frequencies of susceptible, moderately resistant and resistant plants among the different biotypes and races

Table 3. Susceptible, moderately resistant and resistant frequencies within Cuarentino pepper tested against biotypes of *M. incognita*.

Country	Biotype[x]	Susceptible[y]		Moderately resistant[y]		Resistant[y]	
		No. isolates[z]	%	No. isolates[z]	%	No. isolates[z]	%
Spain	Tomato	18	78.3	2	8.7	3	13.0
	Tomato-Mi	11	73.3	0	0.0	2	26.7
	Pepper	6	75.0	2	25.0	0	0.0
	Pepper-Mi	6	66.7	0	0.0	2	33.3
Uruguay	Tomato	5	100.0	0	0.0	0	0.0
	Tomato-Mi	4	80.0	1	20.0	0	0.0
	Pepper	1	100.0	0	0.0	0	0.0
	Pepper-Mi	3	100.0	0	0.0	0	0.0
Spain + Uruguay	Tomato	23	82.1	2	7.2	3	10.7
	Tomato-Mi	15	83.3	1	5.6	2	11.1
	Pepper	7	77.8	2	22.2	0	0.0
	Pepper-Mi	9	81.8	0	0.0	2	18.2

[x]Tomato: resistant cultivars of tomato and pepper are not parasitized; Tomato-Mi: resistant cultivar of tomato is parasitized but resistant peppers do not; Pepper: resistant cultivar of tomato is not parasitized, but resistant cultivars of pepper are parasitized; Pepper-Mi: both resistant cultivars of tomato and pepper are parasitized.
[y]S: susceptible, root galling index >3; MR: moderately resistant, root galling index = 1-3; R: resistant, root galling index = 0.
[z]Mean of three replicates (plants).

characterized was performed using a chi-square test ($p < 0.05$, exact signification, two-sided) (Tables 2 and 3). In the case of biotypes, their similar frequencies in Spain and Uruguay allowed their comparison, as well as studying each country alone, as done for the races. The results did not show significant differences for frequencies of susceptible, moderately resistant and resistant plants among the different biotypes ($\chi^2 = 0.817$ Spain, $\chi^2 = 1.000$ Uruguay, $\chi^2 = 0.967$ Spain + Uruguay, $p < 0.05$) or races of *M. incognita* ($\chi^2 = 0.224$ Spain, $\chi^2 = 1.000$ Uruguay, $p < 0.05$). This means that these frequencies are the same, regardless of the biotype or race of the nematode, which is the typical behavior observed when including a new plant species or resistance gene in a bioassay. These results suggest that resistance genes carried by tomato and pepper cultivars used in the bioassays are clearly different from those present in Cuarentino.

Although Cuarentino pepper has been selected by small farmers based on agronomical characteristics such as crop yield or fruit quality, the low proportion of resistant plants in the bioassays suggest that these criteria did not favor selection for root-knot nematode resistance. Taking into account the obtained results and the high local interest of Cuarentino, further studies should be focused on 1) plant selection based on resistance to root-knot

Table 4. Response of Cuarentino pepper to isolates of *M. incognita* from Spain and Uruguay (mean index of three replicates).

Cuarentino pepper									
No. isolate[v]	Biotype[w]	Race[x]	Index ± SD[y]	Resp[z]	No. isolate[v]	Biotype[w]	Race[x]	Index ± SD[y]	Resp[z]
Spanish isolates									
28	Tomato	1	8.5 ± 2.1	S	18366-I	Tomato-Mi	1	6.8 ± 1.4	S
15841	Tomato	1	8.5 ± 2.1	S	23-II	Tomato-Mi	1	6.0 ± 1.7	S
23762-I	Tomato	1	8.0 ± 0.0	S	94-I	Tomato-Mi	1	5.6 ± 2.2	S
26834	Tomato	1	8.0 ± 0.0	S	18591	Tomato-Mi	1	4.8 ± 2.1	S
21019	Tomato	1	7.5 ± 3.5	S	17758	Tomato-Mi	1	4.7 ± 1.6	S
1-I	Tomato	1	7.5 ± 1.9	S	94-II	Tomato-Mi	1	2.5 ± 3.5	S
23798	Tomato	1	7.0 ± 0.0	S	23823-II	Tomato-Mi	2	8.0 ± 0.0	S
27	Tomato	1	6.3 ± 2.0	S	23824	Tomato-Mi	2	6.9 ± 2.6	S
23758	Tomato	1	6.0 ± 5.7	S	23766-II	Tomato-Mi	2	0.0 ± 0.0	R
23-I	Tomato	1	6.0 ± 0.0	S	24801	Tomato-Mi	3	0.0 ± 0.0	R
23796	Tomato	1	6.0 ± 0.0	S	22475-I	Pepper	1	8.0 ± 1.7	S
24841	Tomato	1	6.0 ± 0.0	S	1-II	Pepper	1	7.0 ± 0.0	S
23760	Tomato	1	4.0 ± 0.0	S	22475-II	Pepper	1	0.5 ± 1.0	MR
21696	Tomato	1	3.5 ± 1.8	S	21046	Pepper	3	9.0 ± 1.4	S
16330	Tomato	1	2.0 ± 0.0	MR	21057	Pepper	3	6.5 ± 3.3	S
65	Tomato	1	0.0 ± 0.0	R	22-I	Pepper	3	2.5 ± 1.3	S
23823-II	Tomato	2	8.0 ± 0.0	S	22-II	Pepper	3	1.0 ± 1.4	MR
26839	Tomato	2	8.0 ± 0.0	S	22-III	Pepper	4	3.5 ± 2.1	S
26838	Tomato	2	4.0 ± 0.0	S	23-III	Pepper-Mi	1	4.0 ± 0.0	S
23766-I	Tomato	2	0.0 ± 0.0	R	18366-II	Pepper-Mi	1	0.0 ± 0.0	R
16388	Tomato	2	0.0 ± 0.0	R	18467	Pepper-Mi	1	0.0 ± 0.0	R
21020-I	Tomato	3	4.0 ± 2.0	S	23762-III	Pepper-Mi	2	3.0 ± 0.0	S
21020-II	Tomato	3	0.7 ± 1.2	MR	22176-I	Pepper-Mi	3	6.8 ± 2.9	S
24269	Tomato-Mi	1	9.0 ± 0.0	S	24440	Pepper-Mi	3	4.5 ± 0.7	S

[v]Arabic numbers: field population; roman numbers: isolate, in those cases when isolates coming from the same field population had different behavior.

[w]Tomato: resistant cultivars of tomato and pepper not parasitized; Tomato-Mi: resistant cultivar of tomato parasitized but not resistant peppers; Pepper: resistant cultivar of tomato not parasitized, but resistant peppers parasitized; Pepper-Mi: both resistant cultivars of tomato and pepper parasitized.

[x]Race 1: tobacco cv. North Carolina 95 and cotton cv. Deltapine 91 not parasitized; race 2: tobacco cv. NC95 parasitized but not cotton cv. DP91; race 3: tobacco cv. NC95 not parasitized, but cotton cv. DP91 parasitized; race 4: both tobacco cv. NC95 and cotton cv. DP91 parasitized.

[y]SD: standard deviation.

[z]Response: S: susceptible, root galling index >3; MR: moderately resistant, root galling index = 1-3; R: resistant, root galling index = 0.

Table 4. (Continued) Response of Cuarentino pepper to isolates of *M. incognita* from Spain and Uruguay (mean index of three replicates).

Cuarentino pepper									
No. isolate[v]	Biotype[w]	Race[x]	Index ± SD[y]	Resp[z]	No. isolate[v]	Biotype[w]	Race[x]	Index ± SD[y]	Resp[z]
23762-II	Tomato-Mi	1	8.0 ± 1.5	S	22176-II	Pepper-Mi	4	5.8 ± 3.1	S
23823-I	Tomato-Mi	1	8.0 ± 0.0	S	22243	Pepper-Mi	4	4.0 ± 0.0	S
Uruguayan isolates									
25397	Tomato	1	6.4 ± 2.5	S	22869-II	Tomato-Mi	3	0.9 ± 1.4	MR
24205	Tomato	1	5.8 ± 2.5	S	24207-I	Tomato-Mi	4	8.7 ± 1.2	S
24203	Tomato	2	8.3 ± 1.5	S	24528	Tomato-Mi	4	6.5 ± 2.1	S
24529	Tomato	2	6.0 ± 0.0	S	24204	Pepper	4	5.3 ± 1.7	S
24206	Tomato	4	3.0 ± 2.0	S	24207-II	Pepper-Mi	3	3.7 ± 3.2	S
22868	Tomato-Mi	3	5.2 ± 2.2	S	24202	Pepper-Mi	3	3.5 ± 2.3	S
22869-I	Tomato-Mi	3	2.9 ± 2.6	S	22869-III	Pepper-Mi	3	3.4 ± 2.5	S

[v]Arabic numbers: field population; roman numbers: isolate, in those cases when isolates coming from the same field population had different behavior.

[w]Tomato: resistant cultivars of tomato and pepper not parasitized; Tomato-Mi: resistant cultivar of tomato parasitized but not resistant peppers; Pepper: resistant cultivar of tomato not parasitized, but resistant peppers parasitized; Pepper-Mi: both resistant cultivars of tomato and pepper parasitized.

[x]Race 1: tobacco cv. North Carolina 95 and cotton cv. Deltapine 91 not parasitized; race 2: tobacco cv. NC95 parasitized but not cotton cv. DP91; race 3: tobacco cv. NC95 not parasitized, but cotton cv. DP91 parasitized; race 4: both tobacco cv. NC95 and cotton cv. DP91 parasitized.

[y]SD: standard deviation.

[z]Response: S: susceptible, root galling index >3; MR: moderately resistant, root galling index = 1-3; R: resistant, root galling index = 0.

nematodes in order to use Cuarentino as a complementary source of resistance genes in pepper breeding programs, and 2) confirmation that its repeated cropping in Uruguay has selected nematode populations virulent to pepper.

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