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Reaction of different pepper varieties to *Meloidogyne* spp.

Reacción de diferentes variedades de pimiento a Meloidogyne *spp.*

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ABSTRACT

Pepper (Capsicum annuum) is an important crop in Peru and is negatively affected by the knot nematode. This studio's objective is to evaluate the reaction of three pepper varieties (Papri King, Papri Queen, and Bell pepper cv. 'Yolo Wonder') to *Meloidogyne arenaria, M. incognita*, and *M. hapla*. The experimental design was completely randomized into three pepper varieties and three *Meloidogyne* spp. with six replicates. The peppers were maintained in a plastic shade house, cultivated in polyethylene bags with 4 kg of sterilized sand, which were inoculated with 5000 eggs and juveniles (J2). At 90 days after inoculation, leaf height (LH), root length (RL), dry leaf weight (DLW), fresh root weight (FRW), chlorophyll index (SPAD), root gall index (RGI), and reproduction factor (RF) were evaluated. The results showed that all pepper varieties were susceptible to *M. incognita*, *M. arenaria,* and *M. hapla*. LH, RL, DLW, FRW, and SPAD all indicated a decrease in pepper growth and development, with the highest reduction, observed in the presence of *M. incognita*, followed by *M. arenaria* and *M. hapla*.
Keywords: *Capsicum annuum;* resistance; root-knot nematode; susceptibility.

RESUMEN

El pimiento (Capsicum annuum) es un cultivo importante en Perú y se ve afectado por el nematodo agallador. El objetivo de este estudio es evaluar la reacción de tres variedades de pimiento (Papri King, Papri Queen y Bell pepper cv. "Yolo Wonder") a Meloidogyne arenaria, M. incognita *y* M. hapla*. El diseño experimental fue completamente al azar en tres variedades de pimiento y tres especies* Meloidogyne *spp. con seis réplicas. Los pimientos se mantuvieron en un espacio con sombra de plástico, cultivados en bolsas de polietileno con 4 kg de arena esterilizada, que se inocularon con 5000 huevos y juveniles (J2). 90 días después de la inoculación se evaluó la altura de hoja (AH), longitud de raíz (LR), peso de hoja seca (PHS), peso de raíz fresca (PRF), índice de clorofila (SPAD), índice de agallas de raíz (IG) y factor de reproducción (FR). Los resultados mostraron que todas las variedades de pimiento eran susceptibles a* M. incognita, M. arenaria *y* M. hapla*. AH, LR, PHS, PRF y SPAD indicaron una disminución en el crecimiento y desarrollo del pimiento, con la mayor reducción observada en presencia de* M. incognita*, seguido de* M. arenaria *y* M. hapla.
Palabras clave*:* Capsicum annuum*; resistencia; nematode agallador; susceptibilidad.*

Introduction

The pepper (*Capsicum annuum* L.) is a key commercial crop, a vegetable species and oleoresin from which capsaicin is extracted (Aguilar-Melendez *et al*., 2009). Phytoparasitic nematodes are an important factor that limits pepper production in the country, and root-knot nematodes have been reported to cause losses of up to 23% in pepper production (Robertson *et al*., 2006; Santiago-Luna *et al*., 2018). Similarly, more than 100 root gall nematode species have been described (Skantar *et al*., 2008), but worldwide, only four species, *Meloidogyne incognita, M. javanica, M. hapla,* and *M. arenaria* are pimiento pepper pests (Theis and Fery, 2002; Miranda *et al*., 2011).

The genus *Meloidogyne* has a wide geographical distribution and is most frequently associated with pepper crops among the plant nematodes. It is responsible for increasing losses, mainly caused by the expansion of pepper cultivation to new agricultural areas, monoculture intensification, and

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the adoption of management practices appropriate for these pathogens (Juhasz *et al*., 2013).

In integrated management, combined strategies such as cultural (crop rotation), genetic (resistant cultivars), chemical (nematicides), and biological (fungi and bacteria) control should be used (Almeida *et al*., 2005). Therefore, plant breeding has been used to develop high-yield crop cultivars with broad adaptation and good resistance/ tolerance to pathogens. Genetic resistance is one of the best ways to control nematodes without increasing the production and environmental costs of using pesticides. This strategy is, therefore, easily accepted by farmers (Oliveira *et al*., 2009).

Currently, there is no data available on the reaction of pepper varieties to *Meloidogyne* spp., which is crucial considering the use of an integrated management alternative. Therefore, this study aimed to determine the reaction of pepper varieties to *M. incognita*, *M. arenaria,* and *M. hapla*.

Materials and methods

This experimental study was conducted in a plastic shade house at the Plant Pathology Laboratory of the National University of San Agustín (*Universidad Nacional de San Agustín* – UNSA), Arequipa, Peru (16º 24' 32" S, 71º 31' 18" W), from March 2019 to February 2020. During this period, the reaction of three pepper varieties, Papri King, Papri Queen, and Bell pepper cv 'Yolo Wonder' to *M. arenaria, M. incognita,* and *M. hapla* was evaluated.

The seeds were sown in trays of 200 units containing sterile substrate (promix). At 42 days after emergence, one seedling was transferred to 4-kg bags with fine sterilized sand and, at 7 days after transfer, inoculated with pure *Meloidogyne* species replicated in tomato (*Solanum lycopersicum* cv. 'Rio Grande').

The method described by Hussey and Barker (1973) was used to inoculate the pepper varieties at a dose of 5000 eggs and juveniles (J2) distributed into three holes around the plant. Tomato plants were used to test the viability of the inocula. These plants were inoculated with the same dose as the pepper varieties. The pepper and tomato varieties were both kept at (27 ºC ± 5 ºC) temperature and (50 ± 5%) humidity.

At 90 days after inoculation, leaf height (LH), root length (RL), dry leaf weight (DLW), fresh root weight (FRW), chlorophyll index (SPAD), root gall index (RGI), and reproduction factor (RF) of the pepper varieties were evaluated. A Minolta SPAD 502 chlorophyll meter was used to determine the SPAD, and the RGI was assessed by directly counting the number of root galls; eggs and J2 were extracted using the technique described by Hussey and Barker (1973), and the RF was determined according to the method described by Oostenbrink (1996).

The experimental design was completely randomized into three pepper varieties and three *Meloidogyne* spp. with six replicates. The data were subjected to analysis of variance (ANOVA, $p < 0.05$), comparing results using the Duncan test ($p < 0.05$) and the software SAS, version 9.0.

Results and discussion

The ANOVA found significance among the nematode species for RF, LH, RL, DLW, FRW, and SPAD, with a significant difference for the Duncan test ($p < 0.05$).

The three pepper varieties, Papri King, Papri Queen, and Bell pepper cv 'Yolo Wonder,' showed a higher RF of *M. hapla, M. incognita,* and *M. arenaria*, presenting a susceptibility reaction (Oostenbrink, 1966).

The Papri King and Papri Queen pepper varieties were more susceptible to *M. hapla*, with RFs of 49.62 and 37.83, showing the highest RGI of 163 and 140, respectively. Conversely, the Bell Pepper cv. 'Yolo Wonder' was the least susceptible pepper variety with an RF of 4.05 and an RGI of 18 (Table 2). Thus, the RF is related to the RGI for all studied pepper variables.

The variety most susceptible to *M. incognita* was Papri Queen, with an RF of 16.33, while the least susceptible was Bell Pepper cv. 'Yolo Wonder' with an RF of 7.58. Similarly, the variety of Bell pepper cv. 'Yolo Wonder' had an RGI of 209 and the Papri Queen an RGI of 111 (Table 2), demonstrating no relationship between the RF and RGI. This is consistent with another study, which observed that root galls and nematode reproduction are not always related (Williamson and Roberts, 2009). Similarly, it highlighted the contradictory data on the susceptibility of peppers to *M. javanica* and *M. incognita*. Different nematode populations exhibited different parasitic effects on pepper, which was susceptible to the *M. incognita* population's four races, albeit resistant to *M. javanica*.

Studies have reported *M. incognita* susceptibility to *C. annuum* L. 'Sweet Mini Pepper' (Aguilar *et al*., 2014) "Baron" and "Atlante" (Ros-Ibáñez *et al*., 2014), with estimated damages higher than 50%, with destroyed roots, chlorotic plants, and reduced growth.

The variety most susceptible to *M. arenaria* was the Papri King with a RF of 30.37, and the least susceptible variety was Papri Queen with a RF of 8.68, (Table 2). Likewise, the RGI of the Bell pepper cv. 'Yolo Wonder' variety was 102, and the RGI of Papri Queen was 74, thus corroborating previous reports' results (Williamson and Roberts, 2009).

Table 1. Effect of the three nematodes species on plant height, root length, fresh root weight, dry leaf weight, and chlorophyll index by variety.

Varieties	Plant height (cm)			
	M. hapla	*M. incognita*	*M. arenaria*	*Control*
Papri queen	26.83[b]	24.83 [b]	29.17[b]	30.67[a]
Papri King	34.67[a]	35.33 [a]	40.33[a]	35.67[a]
Bell pepper	24.83[b]	27.67 [b]	26.17[b]	34.67[a]
Cv %	18.43			
Root length (cm)				
Papri queen	20.83[b]	23.33[a]	30.10[a]	26.42[a]
Papri King	33.25[a]	25.33[a]	37.05[a]	34.62[a]
Bell pepper	30.08[a]	29.32[a]	27.63[a]	35.27[a]
Cv %	25.92			
Fresh root weight (g)				
Papri queen	2.45[b]	2.20[b]	3.17[a]	3.63[b]
Papri King	3.98[a]	3.00[b]	4.53[a]	4.07[b]
Bell pepper	4.47[a]	5.00[a]	3.97[a]	7.90[a]
Cv %	26.16			
Dry root weight (g)				
Papri queen	1.25[a]	0.83[a]	0.95[b]	0.93[b]
Papri King	1.28[a]	1.18[a]	1.68[a]	1.27[b]
Bell pepper	1.52[a]	1.58[a]	1.52 [a]	2.48 [a]
Cv %	26.60			
Chlorophyll index				
Papri queen	39.15[b]	41.65[a]	44.67[a]	50.90[a]
Papri King	31.62[c]	30.18[c]	29.73[b]	48.67[b]
Bell pepper	41.62[a]	36.68[b]	44.50[a]	40.15[c]
[z]Cv %	17.42			

The lower-case letters indicate significant differences between treatments (Duncan test P ≤ 0.05).
Cv: Coeffcient of variation.

The LH, RL, FRW, DLW, and SPAD (Table 1) indicate that all biometric variables showed differences in the pepper varieties' response to the studied nematode species. *M. hapla* decreased the RL, FRW, DLW, and SPAD of Papri Queen, and the LH of Bell pepper cv. 'Yellow Wonder'; the species *M. incognita* decreased all biometric characteristics of Papri Queen; lastly, *M. arenaria* decreased the LH, FRW, and DLW of Papri Queen, the RL and DLW of Bell pepper cv. 'Yellow Wonder', and the photosynthetic rate, based on the SPAD, of Papri King. These results are corroborated by another study that reported that *M. incognita* decreased the plant height, root length, root weight, and shoot weight compared with the control. This was attributed to *M. incognita* being the predominant species, which causes approximately 30% crop production losses (Robertson *et al*., 2006; Talavera *et al*., 2012). Importantly, this research is one of the first studies to determine the pepper varieties' reaction to *M. arenaria* and *M. hapla* parasites.

Table 2. Root gall index (RGI), Reproduction factor (RF), and reaction of different pepper varieties to *Meloidogyne hapla, M. incognita,* and *M. arenaria*.

Varieties	Root gall number		
	M. hapla	*M. incognita*	*M. arenaria*
Papri queen	163[a]	111[b]	74[a]
Papri King	140[a]	139[b]	79[a]
Bell pepper	180[b]	209[a]	102[a]
Tomato[y]	636	414	540
[z]Cv %	32.51		
Reproduction factor			
Papri queen	37.83[a]	16.33[a]	8.68[c]
Papri King	49.62[a]	13.58[a]	30.37[a]
Bell pepper	4.05[b]	7.58[a]	9.05[b]
Tomato [y]	2.86	21.13	2.72
[z]Cv %	26.82		
Reaction			
Papri queen	S	S	S
Papri King	S	S	S
Bell pepper	S	S	S
Tomato [y]	S	S	S

Means followed by the same lowercase letter in the column do not differ according to the Duncan test with 5% probability.
RF = final population (FP)/initial population (Pi = 5000).
[y] Susceptible control, *Solanum licopersicum* var. Rio Grande.
RF: Reproduction factor; S: susceptible.

Conclusions

All tested pepper varieties are susceptible to all root gall nematode species. Therefore, the studied varieties should not be used in crop rotation because they would facilitate the maintenance and further expansion of *Meloidogyne* spp. Finally, future research should be carried out to verify and identify the resistance genes in other pepper varieties when inoculated with populations of different species of Meloidogyne.

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