UNIVERSIDAD NACIONAL DE SAN AGUSTIN DE AREQUIPA

FACULTAD DE AGRONOMÍA

TESIS FORMATO ARTICULO:

REACTION OF GRAPEVINE ROOTSTOCKS AND CULTIVARS TO MELOIDOGYNE INCOGNITA, M. ARENARIA AND M. HAPLA.

Presentado por el bachiller
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Para optar Título Profesional de
Ingeniero Agrónomo

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Arequipa – Perú

2021

Agradecimientos

A la Universidad Nacional de San Agustín de Arequipa, Perú, por el financiamiento del proyecto, Contrato de Subvención N° TP- 10 – 2019 - UNSA, Trabajo de Investigación para Optar Título Profesional.

Al vicerrectorado de investigación de la Universidad Nacional de San Agustín en representación al Dr. Horacio Barreda Tamayo, a UNSA INVESTIGA en representación a la Dr. Julieta Cabrera Sotelo y a mis monitores por el acompañamiento y seguimiento en la elaboración de este Trabajo de Investigación.

A mis asesores, Ph. D. Cristiano Belle, por toda su disposición y conocimiento; Mg. Sc. Juan José Tamo Zegarra y Mg Sc. Gloria Casa Ruiz por la paciencia, acompañamiento, enseñanza y formación para ser un buen profesional.

Agradecer infinitamente a mis padres Alicia y Percy por todo el amor y apoyo incondicional que me dieron; a mis hermanos Gabriel y Adriana por siempre estar conmigo.

A mis amigos, María, Leslie, Nataly y Jorge que me ayudaron muchísimo en la elaboración de este trabajo y por todas las aventuras en el camino.

A mis amigos Jessenia, Dayana, Bilijin, Flor, Ingrid, Julio y Víctor por las palabras de aliento y apoyo en muchos momentos y a Cielo por darme ese impulso y fuerza para realizar este trabajo.

¡A todos muchas gracias!

Resumen

El presente estudio se realizó para evaluar la reacción de seis portainjertos (MGT 101-14, Ritcher 110, Paulsen 1103, K 5BB, SO4, Salt creek) y dos cultivares de vid (Quebranta y Torontel) a tres especies del nematodo de la agalla (*Meloidogyne incognita*, *M. arenaria* and *M. hapla*). El experimento se realizó con un diseño completamente al azar con un esquema factorial de 8 × 3 y seis repeticiones por tratamiento. La unidad experimental en cada repetición estuvo constituida por una estaca de vid plantada en bolsas de 3 kg con sustrato esterilizado. Se inocularon las estacas con 5000 huevos + juveniles J2) de *M. incognita*, *M. arenaria* y *M. hapla*. Seis meses después de la inoculación, las plantas se extrajeron de las bolsas y la reacción se determinó evaluando el número de agallas (NA), el número de nematodos por gramo de raíz (NNGR) y el factor de reproducción (FR). Los portainjertos evaluados, MGT 101-14, Ritcher 110, Paulsen 1103, K 5BB, SO4 y Salt Creek, fueron resistentes a *M. incognita*, *M. arenaria* y *M. hapla*, excepto Salt creek, que fue susceptible a este último. Los cultivares Quebranta y Torontel fueron susceptibles a las especies de *Meloidogyne* en estudio.

Palabras claves: nematodo de la agalla; resistencia; susceptibilidad; *Vitis* spp.

Abstract

This study aimed to evaluate the reaction of six grapevine rootstocks (MGT 101-14, Ritcher 110, Paulsen 1103, K 5BB, SO4, Salt creek) and two cultivars (Quebranta and Torontel) to three species of the root-knot nematode (*Meloidogyne incognita*, *M. arenaria* and *M.hapla*). The experiment was performed as a completely randomized design with an 8 × 3 factorial scheme and six replicates per treatment. The experimental unit in each replicate comprised a grapevine cutting planted in 3 kg bags with sterilized soil. Cuttings were inoculated with 5000 eggs + juveniles (J2) of *M. incognita*, *M. arenaria* and *M. hapla*. Six months after inoculation, plants were removed from the bags, and the reaction was determined by evaluating the number of galls (NG), number of nematodes per gram of root (NNGR), and reproduction factor (RF). The evaluated rootstocks, MGT 101-14, Ritcher 110, Paulsen 1103, K 5BB, SO4 and Salt Creek, were resistant to *M. incognita, M. arenaria* and *M. hapla*, except for Salt creek, which was susceptible to the latter. The Quebranta and Torontel cultivars were susceptible to the *Meloidogyne* species under study.

Keywords: root-knot nematode; resistance; susceptibility; *Vitis* spp

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´´ Reaction of grapevine rootstocks and cultivars to *Meloidogyne incognita*, *M. arenaria* y *M. hapla*´´

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3. Planteamiento del Problema:

La vid (*Vitis* sp.) es un cultivo predominante y extenso a nivel mundial, con una fuerte tendencia productiva en la última década (Seccia, Santeramo y Nardone, 2015), con más de 21 millones de toneladas en el mundo. En el Perú, las condiciones agroclimáticas son favorables para el cultivo, y es el quinto producto primario de la agricultura nacional, representando el 4,6% del valor bruto de la producción agrícola. (MINAGRI, 2019)

La especie *Meloidogyne* (nematodo agallador) es una de las principales causas de daño a la vid (Somavilla, Bauer Gomes y Vera, 2012). Induce la formación de agallas radiculares, que restringen la absorción de agua y nutrientes así como el crecimiento de las plantas, predisponiéndolas al ataque de otros patógenos (Perry y Moens, 2014).

El uso de portainjertos resistentes demuestra características muy útiles para la resistencia o tolerancia a nematodos, además, a nivel mundial más del 80% de todos los viñedos cultivan cepas injertadas sobre portainjertos (Ollat, Bordenave, Tandonnet, Boursiquot y Marguerit, 2016).
En Perú se han utilizado diferentes portainjertos, pero no hay reportes de reacción con especies de *Meloidogyne* en los portainjertos y cultivares utilizados en las condiciones de la región de Arequipa.

4. Objetivo General:

- Evaluar la reacción de portainjertos y cultivares de Vid (MGT 101-14, Paulsen 1103, K 5BB, SO4, Ritcher 110, Salt Creek, Quebranta y Torontel) a *Meloidogyne incógnita, M. arenaria* y *M. hapla.*

5. Justificación

En el Perú, las condiciones agroclimáticas son favorables para el cultivo, y es el quinto producto primario de la agricultura nacional, representando el 4,6% del valor bruto de la producción agrícola; Las áreas de cultivo más intensivo incluyen las regiones de Ica, Piura y Lima, que representan el 93% del total de la producción nacional. Hasta 2017, la región de Arequipa tenía un área cosechada de 1336 ha, con rendimientos de 22139 kg ha-1 (MINAGRI, 2019).

6. Antecedentes

La uva de mesa (*Vitis vinifera* L.) se cultiva en Ica, Arequipa y otras regiones del norte del Perú, se exporta a más de 60 mercados, siendo Estados Unidos el principal mercado de exportación (38 % de participación), seguido de los Países Bajos, Hong Kong y China. En el Perú, las condiciones agroclimáticas son favorables para el cultivo, y es el quinto producto primario de la agricultura nacional, representando el 4,6% del valor bruto de la producción agrícola. (MINAGRI, 2019)

Meloidogyne spp. (Nemátodo de la agalla), considerado uno de las causas más importantes de daño en la vid (Somavilla et al., 2012; Goldammer, 2013), e induce a la formación de agallas en las raíces, restringiendo la absorción de agua, nutrientes, crecimiento de la planta predisponiendo al ataque de otros patógenos (Perry y Moens, 2014).

Meloidogyne incognita, M. javanica, M. ethiopica, M. arenaria y *M. hapla* son las especies de mayor importancia que afectan el cultivo de vid a nivel mundial (Ferris et al., 2012, 2013; Goldammer, 2013; Aballay y Vilches, 2015).

En el Perú se han identificado mediante isoenzima esterasa a *M. arenaria* (Est. A2) en las regiones de Arequipa, Ica y Piura, *M. incognita* (Est. I2) en Ica y *M. javanica* (Est. J3) en Ica y Piura (Varas, 2018). De igual manera, se hicieron los primeros reportes de nemátodos de importancia fitopatológica realizados por Krusberg y Hirschmann (1958), Martín (1959) y Gómez y Martin (1967), este último a nivel de especies, indican al género Meloidogyne como el nematodo mayormente diseminado a lo largo de la costa del país. Gómez y Martin (1967), reportan también a *M. javanica* y *M. arenaria*, en cultivos de papayo y melocotonero en la costa central y Chanchamayo. Posteriormente, Mullin et al. (1991), reportan a *M. javanica* en frijol en los departamentos de Ica y La Libertad. García (1992), determina también la presencia de *M. javanica* en cultivos de café en Villa Rica, Pasco, junto con *M. incognita* y *M. exigua*. Murga-Gutiérrez, et al. (2012), colectaron suelo de espárrago infestado con Meloidogyne en Virú y Chao, La Libertad, enviando las muestras al Istituto per la Protezione delle Piante y al Istituto di Bioscienze e BioRisorse (ex Istituto di Genetica Vegetale) en Italia, donde realizaron su identificación molecular, reportando a *M. incognita* y *M. ethiopica* (Vera 2014)

Según Vilches (2010) Distingue a *M. ethiopica* como una especie de comportamiento más agresivo para las condiciones de Chile. Estadísticamente *M. hapla* fue menos agresiva que *M. ethiopica*, pero más agresiva que *M. javanica*. Sin embargo, los portainjertos fueron resistentes a la presencia de las 3 especies de Meloidogyne.

(Trudgill, 1992) señala que una planta resistente limita o previene la reproducción del nematodo por la activación de mecanismos de resistencia en respuesta a la infección de este.

(Edwars, 1989) señala que SO4 y K5BB son resistentes a *M. javanica*, sin embargo, (Dalmasso y Cuani, 1976) indican que SO4 es susceptible a *M. hapla*. (Boubals, 1979) menciona a 101-14 como resistente a *M. javanica*. (Muñoz y Gonzalez, 2000) por su parte, mencionan a 3309 como un portainjerto susceptible al género Meloidogyne.

El uso de portainjertos resistentes demuestran características que son de gran utilidad para la resistencia o tolerancia a los nematodos, además presentan resistencia a filoxera, hongos del suelo y adaptación a las propiedades físicas, químicas del suelo (Somavilla et al., 2012) y compatibilidad con el injerto (Zhang et al., 2016).

7. Descripción del proyecto

El experimento se realizó en una caseta de malla con cubierta plástica (temperatura de 25 ± 5 ° C y humedad de 50 ± 5%, condiciones aptas para el cultivo de la vid) del Laboratorio de Fitopatología de la Facultad de Agronomía, Universidad Nacional de San Agustín (16 ° 24 '32.79" S, 71 ° 31 '18.87" W; 2365 m s.n.m.), Arequipa, Perú. El experimento siguió un diseño completamente al azar, con un esquema factorial de 8 × 3, donde los factores fueron los portainjertos, cultivares y especies de nematodos. Hubo seis réplicas por tratamiento y cada réplica consistió en una bolsa con una planta de vid.
Se utilizaron un total de seis portainjertos: MGT 101-14 (*V. riparia* x *V. rupestris*), Ritcher 110 (*Vitis berlandieri* x *Vitis rupestris*), Paulsen 1103 (*V. berlandieri* x *V. rupestris*), S04 (*V. berlandieri* x *V. riparia*), Salt Creek (*V. candicans* x *V. rupestris*) y K 5BB (*V. berlandieri* x *V. riparia*). Se utilizaron dos cultivares de vid (*V. vinifera*): Quebranta y Torontel. Los esquejes se desinfectaron con Vitavax-300 y enraizados en lechos con sustrato de arena y piedra pómez (2: 1). Una vez enraizados, se trasplantaron en sacos de 3 kg con un sustrato previamente esterilizado de arena fina y promix (3: 1).

M. incognita (Est I2), *M. arenaria* (Est A2) y *M. hapla* (Est H1) se utilizaron para infectar vides de la región de Arequipa. La identificación de las especies de *Meloidogyne* se realizó mediante la caracterización morfológica del patrón perineal femenino (Hartmann y Sasser, 1985) y la caracterización bioquímica de la isoenzima esterasa mediante electroforesis (Carneiro y Almeida, 2001).

Las especies de *Meloidogyne* se mantuvieron en plantas de tomate donde se multiplicaron (*Solanum lycopersicum* cv. "Rio Grande") durante un período de tres meses. Un mes después del trasplante, se inocularon esquejes con la especie de nematodo. Los huevos se extrajeron de las raíces según el método descrito por Hussey y Barker (1973). Luego se suspendieron en agua y se inocularon, con una pipeta, a una dosis de 5000 huevos + J2 juveniles por bolsa, en cuatro agujeros hechos en el suelo alrededor de la planta. Para controlar la viabilidad de los inóculos, se inocularon plantas de tomate susceptibles (*Solanum lycopersicum* cv. 'Rio Grande') con una suspensión de 5000 huevos + J2 juveniles de cada especie de *Meloidogyne* y se instalaron y condujeron en las mismas condiciones que los portainjertos de vid. y cultivares.

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9. Link del artículo

DOI: https://doi.org/10.31047/1668.298x.v38.n1.29368

Reaction of grapevine rootstocks and cultivars to *Meloidogyne incognita*, *M. arenaria* and *M. hapla*

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DOI: 10.31047/1668.298x.v38.n1.29368

SUMMARY
This study aimed to evaluate the reaction of six grapevine rootstocks (MGT 101-14, Ritcher 110, Paulsen 1103, K 5BB, SO4, Salt creek) and two cultivars (Quebranta and Torontel) to three species of the root-knot nematode (*Meloidogyne incognita*, *M. arenaria* and *M.hapla*). The experiment was performed as a completely randomized design with an 8 × 3 factorial scheme and six replicates per treatment. The experimental unit in each replicate comprised a grapevine cutting planted in 3 kg bags with sterilized soil. Cuttings were inoculated with 5000 eggs + juveniles (J2) of *M. incognita, M. arenaria* and *M. hapla.* Six months after inoculation, plants were removed from the bags, and the reaction was determined by evaluating the number of galls (NG), number of nematodes per gram of root (NNGR), and reproduction factor (RF). The evaluated rootstocks, MGT 101-14, Ritcher 110, Paulsen 1103, K 5BB, SO4 and Salt Creek, were resistant to *M. incognita, M. arenaria* and *M. hapla*, except for Salt creek, which was susceptible to the latter. The Quebranta and Torontel cultivars were susceptible to the *Meloidogyne* species under study.

Keywords: root-knot nematode; resistance; susceptibility; *Vitis* spp.

Vega-Callo, R. A., Tamo-Zegarra, J. J. y Bellé, C, 2021. Reacción de portainjertos y cultivares de vid a *Meloidogyne incognita, M. arenaria* y *M. hapla*. Agriscientia 38:

RESUMEN
El presente estudio se realizó para evaluar la reacción de seis portainjertos (MGT 101-14, Ritcher 110, Paulsen 1103, K 5BB, SO4, Salt creek) y dos cultivares de vid (Quebranta y Torontel) a tres especies del nematodo de la agalla (*Meloidogyne incognita*, *M. arenaria* and *M. hapla*). El experimento se realizó con un diseño completamente al azar con un esquema factorial de 8 × 3 y seis repeticiones por tratamiento. La unidad experimental en cada repetición estuvo constituida por una estaca de vid plantada en bolsas de 3 kg con sustrato esterilizado. Se inocularon las estacas con 5000 huevos + juveniles

Fecha de recepción: 03/08/2020; fecha de aceptación: 07/05/2021.

(J2) de *M. incognita, M. arenaria* y *M. hapla*. Seis meses después de la inoculación, las plantas se extrajeron de las bolsas y la reacción se determinó evaluando el número de agallas (NA), el número de nematodos por gramo de raíz (NNGR) y el factor de reproducción (FR). Los portainjertos evaluados, MGT 101-14, Ritcher 110, Paulsen 1103, K 5BB, SO4 y Salt Creek, fueron resistentes a *M. incognita, M. arenaria* y *M. hapla*, excepto Salt creek, que fue susceptible a este último. Los cultivares Quebranta y Torontel fueron susceptibles a las especies de *Meloidogyne* en estudio.

Palabras clave: nematodo de la agalla; resistencia; susceptibilidad; *Vitis* spp.

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INTRODUCTION

Grapevine (*Vitis* sp.) is a predominant crop, extensively grown worldwide, with a strong productive trend in the last decade (Seccia, Santeramo and Nardone, 2015), with more than 21 million tons in the world. In Peru, agroclimatic conditions are favorable for the crop, and it is the fifth primary product in national agriculture, representing 4.6 % of the gross value of agricultural production; areas of more intensive culture include the Ica, Piura and Lima regions, which represent 93 % of the total national production. Until 2017, the Arequipa region had a harvested area of 1336 ha, with yields of 22 139 kg ha^{-1} (MINAGRI, 2019).

Meloidogyne species (root-knot nematode) is one of the major causes of grapevine damage (Somavilla, Bauer Gomes and Vera, 2012). It induces the formation of root galls, which restrict the absorption of water and nutrients as well as plant growth, predisposing it to the attack of other pathogens (Perry and Moens, 2014).

Meloidogyne incognita, *M. javanica*, *M. ethiopica, M. arenaria*, and *M. hapla* are the most important species that affect grapevine crops worldwide (Ferris, Zheng and Walker, 2012; 2013; Aballay and Vilches, 2015). In Peru, *M. arenaria* (Esterase phenotype - Est A2) was identified through its esterase isoenzyme in the Arequipa, Ica, and Piura regions, *M. incognita* (Est. I2) in Ica and *M. javanica* (Est. J3) in Ica and Piura (Varas, 2018).

The use of resistant rootstocks demonstrates characteristics that are very useful for resistance or tolerance to nematodes, additionally, worldwide more than 80 % of all vineyards grow vines grafted onto rootstocks (Ollat, Bordenave, Tandonnet, Boursiquot and Marguerit, 2016). The rootstocks are resistant to phylloxera and soil fungi, they adapt to the physical and chemical properties of the soil (Somavilla *et al.*, 2012), including tolerance to abiotic stress such as drought (Fort, Fraga, Grossi and Walker, 2017; Peccoux *et al.*, 2018), salinity (Sohrabi, Ebadi, Jalali and Salami, 2017) and calcareous soils (Bavaresco and Lovisolo, 2015) and they provide greater vigor to the graft (Zhang, Marguerit, Rossdeutsch, Ollat and Gambetta, 2016).

In Peru, different rootstocks have been used, but there are no reports of a reaction with *Meloidogyne* species in the rootstocks and cultivars used under the conditions of the Arequipa region. This study aimed to evaluate the reaction of grapevine rootstocks and cultivars to *M. incognita*, *M. arenaria* and *M. hapla.*

MATERIALS AND METHODS

The experiment was conducted in a mesh house with a plastic cover (temperature of 25 ± 5 °C and humidity of 50 ± 5 %, conditions that are suitable for grapevine cultivation) in the Phytopathology Laboratory of the Agronomy Faculty, National University of San Agustín (16° 24' 32.79" S, 71° 31' 18.87" W; 2365 m a.s.l.), Arequipa, Peru.

The experiment followed a completely randomized design, with an 8 × 3 factorial scheme, where the factors were the rootstocks, cultivars,

and nematode species. There were six replicates per treatment and each replicate consisted of a bag with a grapevine plant.

A total of six rootstocks were used: MGT 101-14 (*V. riparia x V. rupestris)*, Ritcher 110 (*Vitis berlandieri x Vitis rupestris*), Paulsen 1103 (*V. berlandieri x V. rupestris*), S04 (*V. berlandieri x V. riparia),* Salt Creek (*V. candicans x V. rupestris),* and K 5BB (*V. berlandieri x V. riparia)*. Two grapevine cultivars (*V. vinifera*) were used: Quebranta and Torontel. The cuttings were disinfected with Vitavax-300 and rooted in beds with a sand and pumice substrate (2:1). Once rooted, they were transplanted into 3 kg bags with a previously sterilized substrate of fine sand and promix (3:1).

M. incognita (Est I2), *M. arenaria* (Est A2), and *M. hapla* (Est H1) were used to infect grapevines of the Arequipa region. The identification of *Meloidogyne* species was made through the morphological characterization of the female perineal pattern (Hartmann and Sasser, 1985) and the biochemical characterization of the esterase isoenzyme through electrophoresis (Carneiro and Almeida, 2001). *Meloidogyne* species were kept in tomato plants where they multiplied (*Solanum lycopersicum* cv. 'Rio Grande') for a period of three months.

One month after transplantation, cuttings were inoculated with the nematode species. The eggs were extracted from the roots according to the method described by Hussey and Barker (1973). They were then suspended in water and inoculated, using a pipette, at a dose of 5000 eggs + J2 juveniles per bag, in four holes made in the soil around the plant. To control the viability of the inocula, susceptible tomato plants (*Solanum lycopersicum* cv. 'Rio Grande') were inoculated with a suspension of 5000 eggs + J2 juveniles of each *Meloidogyne* species and they were installed and conducted under the same conditions as the grapevine rootstocks and cultivars.

After six months, plants were collected to evaluate their reaction to *Meloidogyne* species. The aerial part was separated from the roots, carefully washed to determine the number of galls (NG). Subsequently, root systems were processed according to the method of Hussey and Barker (1973) to quantify the final population of nematodes (FP). From the final nematode population in the root system, calculations of number of nematodes per gram of root (NNGR) and the reproduction factor (RF = final population / initial population) of *Meloidogyne* species were performed for each repetition. The grapevine rootstocks and cultivars were considered immune (RF = 0), resistant (RF <1) and susceptible (RF> 1) to the *Meloidogyne* species (Oostenbrink, 1966). The number of nematodes per gram of root was estimated by the ratio between the total number of nematodes and the total root mass (in grams) for each repetition.

The data for each nematode species were analyzed in the different rootstocks and cultivars (NG, NNGR, and RF variables were transformed into). The respective analysis of variance (ANOVA) was performed, and means were compared with Duncan's multiple test ($p< 0.05$), the SAS® University Edition software was used for data analysis.

RESULTS AND DISCUSSION

Results of ANOVA revealed an interaction in terms of NG, NNGR and RF between *M. incognita*, *M. arenaria*, *M. hapla* and the different rootstocks and cultivars evaluated. This interaction was corroborated with Duncan's Test ($p< 0.05$). *Meloidogyne* species induce gall formation and can reproduce in all the rootstocks and cultivars studied (Tables 1, 2 and 3).

None of the evaluated rootstocks were immune, since the three nematode species could reproduce in a limited way. Rootstocks infected with *Meloidogyne* species had an RF = 0.01 to 0.73 (Tables 1, 2 and 3). Most were resistant; however, the 'Salt creek' rootstock, although resistant to *M. incognita* and *M. arenaria*, was susceptible to the attack by *M. hapla*, with an RF = 1.39 (Table 3).

The Quebranta and Torontel cultivars were susceptible to the three species of *Meloidogyne*, with the highest RF of 1.6 to 3.49. Somavilla *et al*., (2012), Aballay and Vilchez (2015) reported a similar susceptibility of cultivars to *M. incognita, M. ethiopica, M. hapla and M. javanica*.

The SO4, Salt Creek, MGT-101-14, K5BB, Ritcher 110, and Paulsen 1103 rootstocks were resistant to *M. incognita*. According to Boubals (1992), the Paulsen 1103 rootstock is moderately resistant to *M. incognita.* Similarly, SO4 is resistant to *M. incognita* and *M. arenaria* (McKenry and Anwar, 2006). Somavilla *et al.* (2012) also reported that SO4, Salt Creek, and K 5BB are resistant to *M. incognita*. Moura *et al*. (2014) reported that MGT 101-14 and K 5BB are resistant to *M. incognita.* As described by Gutierrez- Gutierrez, Palomares-Rius, Jiménez-Díaz and Castillo (2011), the Ritcher 110 rootstock has a nematode-resistant reaction, which agrees with the results obtained in this experiment. The K5BB and Ritcher 110 rootstocks showed the lowest reproduction rates of *M. incognita*, with a RF= 0.29 and 0.28, respectively. Quebranta

Table 1. Number of galls (NG), number of nematodes per gram of root (NNGR), reproduction factor (RF), and reaction of rootstocks and cultivars to *Meloidogyne incognita*

Rootstocks and cultivars	*M. incognita*			
	NG[t]	NNGR[u]	RF[v]	Reaction[w]
SO4	3.50 d[x]	188 bc	0.63 c	R
Salt Creek	8.33 c	116 c	0.67 c	R
MGT 101-14	2.67 d	171 bc	0.44 cd	R
K 5BB	2.50 d	143 bc	0.29 d	R
Ritcher-110	2.83 d	46 c	0.28 d	R
Quebranta	65.33 a	560 a	2.97 a	S
Torontel	33.50 b	325 ab	2.28 b	S
Paulsen 1103	10.17 c	209 b	0.49 cd	R
Tomato cv. 'Rio Grande'[y]	414.30	6932	8.4	S
CV (%)[z]	18.01	28.61	6.92	

[t]NG = Number of galls. [u]NNGR = Number of nematodes per gram of root. [v]RF = Reproduction factor (RF = final population/ initial population).[w]Reaction = (S) susceptible; (R) resistant; (I) immune. [x]Means followed by the same letter in the columns are not significantly different by Duncan's test (P<0.05). [y]Susceptible control for *Meloidogyne incognita, Solanum lycopersicum*' Rio Grande'. [z]CV = coefficient of variation.

Table 2. Number of galls (NG), number of nematodes per gram of root (NNGR), reproduction factor (RF), and reaction of rootstocks and cultivars to *Meloidogyne arenaria*

Rootstocks and cultivars	*M. arenaria*			
	NG[t]	NNGR[u]	RF[v]	Reaction[w]
SO4	0.83 d	15.55 cd[x]	0.06 e	R
Salt Creek	12.00 b	174.91 b	0.73 c	R
MGT 101-14	0.33 d	14.62 d	0.02 e	R
K 5BB	0.67 d	32.71 cd	0.04 e	R
Ritcher-110	3.83 c	73.33 bcd	0.32 d	R
Quebranta	37.66 a	527.93 a	2.43 a	S
Torontel	19.50 b	189.63 b	1.6 b	S
Paulsen 1103	2.00 d	105.61 bc	0.14 of	R
Tomato cv. 'Rio Grande'[y]	535.7	1617.4	2.47	S
CV (%)[z]	18.91	25.78	6.00	

[t]NG = Number of galls. [u]NNGR = Number of nematodes per gram of root. [v]RF = Reproduction factor (RF = final population/ initial population).[w]Reaction = (S) susceptible; (R) resistant; (I) immune. [x]Means followed by the same letter in the columns are not significantly different by Duncan's test (p<0.05). [y]Susceptible control for *Meloidogyne arenaria, Solanum lycopersicum*' Rio Grande'. [z]CV = coefficient of variation.

Table 3. Number of galls (NG), Number of nematodes per gram of root (NNGR), reproduction factor (RF), and reaction of rootstocks and cultivars to *Meloidogyne hapla*

Rootstocks and cultivars	*M. hapla*			
	NG[t]	NNGR[u]	RF[v]	Reaction[w]
SO4	14.50 c	143.19 b	0.44 c	R
Salt Creek	40.50 b	425.67 ab[x]	1.39 b	S
MGT 101-14	0.50 d	28.85 c	0.09 e	R
5BB	0.00 d	0.12 c	0.01 e	R
Ritcher-110	1.67 d	25.24 c	0.12 e	R
Quebranta	92.16 a	534.92 a	3.49 a	S
Torontel	80.50 a	434.52 ab	3.37 a	S
Paulsen 1103	13.33 c	368.67 ab	0.59 c	R
Tomato cv. 'Rio Grande'[y]	530.73	1928.93	2.53	S
CV (%)[z]	15.03	20.60	5.03	

[t]NG = Number of galls. [u]NNGR = Number of nematodes per gram of root. [v]RF = Reproduction factor (RF= final population/ initial population).[w]Reaction = (S) susceptible; (R) resistant; (I) immune. [x]Means followed by the same letter in the columns are not significantly different by Duncan's test (p<0.05). [y]Susceptible control for *Meloidogyne hapla, Solanum lycopersicum*' Rio Grande'. [z]CV = coefficient of variation.

and Torontel cultivars show a high susceptibility, with an RF = 2.97 and 2.28, respectively (Table 1). However, no other studies have indicated the susceptibility reaction of these cultivars, although similar behavior was evident to the cultivars evaluated by Somavilla *et al.* (2012), Aballay and Vilches (2015).

M. arenaria exhibited the lowest population levels in the experiment, with an RF= 0.02 to 0.73. All rootstocks were considered resistant, as the RF was low compared to the previous *Meloidogyne* species evaluated. According to Somavilla *et al*. (2012), SO4, Salt Creek, and K 5BB were equally resistant to *M. arenaria*. Nevertheless, Paulsen 1103 was susceptible to the nematode, although this result may have been affected by crop conditions, such as soil characteristics, irrigation, and carrier clonal differences. Gutierrez-Gutierrez *et al*. (2011) indicated that Ritcher 110 and SO4 rootstocks are resistant to *M. arenaria.* Furthermore, Ferris *et al.* (2012) found that the MGT 101-14 rootstock was resistant and Ritcher 110 moderately resistant to *M. arenaria*. The authors also found Paulsen 1103 was susceptible, which is corroborated in this research. Moreover, Quebranta and Torontel cultivars, with an RF = 2.43 and 1.6, respectively, are considered susceptible to *M. arenaria* (Table 2).

Regarding the reaction of the rootstocks to *M. hapla*, SO4, MGT 101-14, K 5BB, Ritcher 110, and Paulsen 1103 were resistant, except Salt Creek, which was susceptible, with an RF = 1.39. According to Télis and Landa (2007), Salt Creek, SO4, and K5BB are resistant to *M. hapla*. Moreover, according to Aballay and Vilches (2015), SO4, K5BB, Paulsen 1103, and MGT 101-14 are not immune to *M. hapla,* but rather are more resistant than a grapevine cultivar. Ritcher 110 and SO4 rootstocks are resistant to *M. hapla* (Gutierrez-Gutierrez *et al.*, 2011). These reports differed from the results obtained in the experiment. On the contrary, Dalmasso and Cuani (1976) reported that SO4 is susceptible to *M. hapla*. Finally, Quebranta and Torontel cultivars presented the highest population levels, with a RF = 3.49 and 3.37, indicating susceptibility (Table 3).

CONCLUSIONS

Results indicate that SO4, K5BB, Ritcher 110, MGT 101-14, Paulsen 1103, and Salt Creek rootstocks are resistant to *M. incognita* and *M. arenaria*. Only the Salt Creek rootstock is susceptible to *M. hapla*. The cultivars Quebranta and Torontel are susceptible to *M. incognita*, *M. arenaria* and *M. hapla.* As a conclusion, it is suggested to continue the studies of reaction to *Meloidogyne* with other rootstocks and root-knot nematodes, which is essential for a right choice of the rootstock to use.

ACKNOWLEDGMENTS

This research was financed by the Universidad Nacional de San Agustín de Arequipa, Peru, Grant Contract No. TP- 10 - 2019 - UNSA, Research Work to Opt for a Professional Degree.

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