

# Reaction of *Chenopodium quinoa* to different species of *Meloidogyne*

## Reacción de *Chenopodium quinoa* a diferentes especies de *Meloidogyne*

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### Abstract

Currently, there are no studies on the cultivation of quinoa (*Chenopodium quinoa*) in Peru related to the reaction of *Meloidogyne* spp. This study aimed to evaluate the reaction of five quinoa cultivars ('Salcedo INIA', 'Choclitó', 'Huariponcho', 'Negra Collana', and 'Kcancolla') to *Meloidogyne arenaria*, *Meloidogyne incognita*, and *Meloidogyne hapla*. The experiment was carried out using a completely randomized design, with five quinoa cultivars and three species of *Meloidogyne* spp. with six repetitions. Quinoa plants were kept in a mesh house and placed in polyethylene bags with 3,000 dm<sup>3</sup> of sterile soil inoculated with 5,000 eggs + juveniles (J2). After 90 days of inoculation, the number of nematodes per gram of root, number of galls, and the reproduction factor (final population/initial population) were determined. All quinoa cultivars were susceptible to *M. incognita* and resistant to *M. arenaria* and *M. hapla*, except for 'Negra Collana', which was susceptible to *M. arenaria*, and 'Salcedo INIA' and 'Huariponcho', susceptible to *M. hapla*.

**Keywords:** Quinoa, genotypes, root-knot nematode, resistance, susceptibility.

### Resumen

Actualmente el cultivo de quinua (*Chenopodium quinoa*) en el Perú no cuenta con estudios relacionados a la reacción de *Meloidogyne* spp. La investigación tuvo como objetivo evaluar la reacción de cultivares de quinua ('Salcedo INIA', 'Choclitó', 'Huariponcho', 'Negra Collana' y 'Kcancolla') a *Meloidogyne incognita*, *Meloidogyne arenaria* y *Meloidogyne hapla*. Las plantas de quinua se manejaron en casa malla y fueron colocadas en bolsas de polietileno con 3.000 dm<sup>3</sup> de suelo estéril, los cuales fueron inoculados con 5.000 huevos + juveniles (J2). Después de los 90 días de la inoculación, se determinó el número de nematodos por gramo de raíz, número de agallas y factor de reproducción (población final/población inicial). Todos los cultivares de quinua son clasificados como susceptibles a *M. incognita*, resistentes a *M. arenaria* y *M. hapla* a excepción de Negra Collana siendo considerado susceptible a *M. arenaria*, asimismo, 'Salcedo INIA' y 'Huariponcho' son considerados susceptibles a *M. hapla*.

**Palabras clave:** Quinoa, genotipos, nematodo agallador, resistencia, susceptibilidad.

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### Introduction

Quinoa (*Chenopodium quinoa* Willd.) is an important crop in South America because of its high nutritional value and tolerance to external abiotic stress (Jarvis *et al.*, 2008; Novak *et al.*, 2016). Its composition has attracted the attention of many scientists owing to its high nutritional value and presence of proteins, lipids, fibers, vitamins, minerals, and essential amino acids; gluten-free nature (Navruz-Varli and Sanlier, 2016; Filho *et al.*, 2017); tocopherols; and organic acids (Pereira *et al.*, 2019). All these components contribute to food security (Nowak *et al.*, 2016). Peru is one of the main exporters of quinoa worldwide. The Arequipa region achieved a yield of 4.086 kg ha<sup>-1</sup> (Bedoya *et al.*, 2018), increasing its production in the last two decades (Vargas *et al.*, 2015).

The phytosanitary problems that affect quinoa are the kona-kona (*Eurysacca quinoa* Povolny), cutworms (*Copitarsia turbata* Herrich & Schäffer), chinch bugs (*Epitrix subcrinita* Lec.), the green aphid (*Macrosiphum euphorbiae* Thomas), mildew (*Peronospora farinosa*

Fries), and worldwide economically important nematodes (León *et al.*, 2018). The identified genera of nematodes associated with quinoa crops are *Meloidogyne*, *Nacobbus*, *Pratylenchus*, *Helicotylenchus*, *Mesocriconema*, *Xiphinema*, *Dorylaimus*, *Hemiciclyophora*, and *Globodera* (Franco, 2003; Lima-Medina *et al.*, 2019).

*Meloidogyne* Göldi, 1887 is a genus that causes problems in the quinoa crop; it also affects other crops such as artichoke, paprika, grapevines, and asparagus. In addition, the agricultural frontier is basically expanded in irrigated soils, where sandy soils and low biological diversity allow a growing population of *Meloidogyne* spp. (Palomo, 2018). Currently, there are no reports of

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**Table 1.** Number of nematodes per gram of root (Nematodes g<sup>-1</sup> root), number of galls (NG), reproduction factor (RF), and reaction of different quinoa (*Chenopodium quinoa*) cultivars to *Meloidogyne arenaria*, *Meloidogyne hapla*, and *Meloidogyne incognita*.

<i>Meloidogyne arenaria</i>				
Cultivar	Nematodes g <sup>-1</sup> root <sup>a</sup>	NG <sup>b</sup>	RF <sup>c</sup>	Reaction <sup>d</sup>
Salcedo INIA	436 a <sup>e</sup>	9 a	0.3 a	R
Choclitito	609 a	36 a	0.4 a	R
Huariponcho	1,609 a	27 a	0.7 a	R
Negra Collana	2,301 a	29 a	1.1 a	S
Kcancolla	629 a	34 a	0.5 a	R
Tomato <sup>f</sup>	1,575	540	2.7	S
CV (%) <sup>g</sup>	31.13	19.75	21.13	-
<i>Meloidogyne hapla</i>				
Salcedo INIA	1,997 a	101 a	1.3 a	S
Choclitito	536 a	96 a	0.4 a	R
Huariponcho	1,132 a	63 a	1.1 a	S
Negra Collana	1,018 a	132 a	0.5 a	R
Kcancolla	742 a	66 a	0.5 a	R
Tomato	1,909	636	2.9	S
CV (%)	30.03	21.5	20.16	
<i>Meloidogyne incognita</i>				
Salcedo INIA	11,595 ab	117 a	10.2 b	S
Choclitito	6,330 bc	195 a	6.5 c	S
Huariponcho	1,6508 a	212 a	14.3 a	S
Negra Collana	5,257 c	120 a	2.5 d	S
Kcancolla	4,081 c	252 a	4.8 c	S
Tomato	6,932	414	8.3	S
CV (%)	29.45	21.90	20.10	

<sup>a</sup> Nematodes g<sup>-1</sup> root = Number of nematodes per gram of root (final population/weight of roots).

<sup>b</sup> NG = Number of galls.

<sup>c</sup> RF = Reproduction factor (RF = final population/initial population).

<sup>d</sup> Reaction: S = Susceptible (RF ≥ 1) and R = Resistant (RF ≤ 1) (Oostenbrink, 1966).

<sup>e</sup> Means followed by the same letter in each column do not differ significantly by the Duncan's test at 5 % probability;

<sup>f</sup> Susceptible control: *Solanum lycopersicum* 'Rio Grande'.

<sup>g</sup> Coefficient of variation.

*Meloidogyne* in quinoa cultivars for the Arequipa region; therefore, this study aimed to evaluate the response of quinoa cultivars to *Meloidogyne arenaria* (Neal, 1889) Chitwood, 1949, *Meloidogyne incognita* (Kofoid and White, 1919) Chitwood, 1949, and *Meloidogyne hapla* Chitwood, 1949.

## Material and methods

The experiment was conducted in a mesh house with a temperature of 25 °C ± 5 °C at the Phytopathology Laboratory of the Universidad Nacional de San Agustín, Arequipa, Peru (16° 24' 32" S, 71° 31' 18" W), from November 2019 to February 2020. The response of five quinoa cultivars ('Salcedo INIA', 'Choclitito', 'Huariponcho', 'Negra Collana', and 'Kcancolla') to *M. incognita*, *M. arenaria*, and *M. hapla* was evaluated.

Quinoa seeds were sown in trays of 200 units with a sterile substrate (Promix®). Twenty days after emergence, each seedling was transplanted to a bag with 3,000 dm<sup>3</sup> of sterilized fine sand. Seven days

after transplantation, seedlings were inoculated with pure species of *Meloidogyne* propagated in tomato (*Solanum lycopersicum* 'Rio Grande').

The quinoa cultivars were inoculated following the method described by Hussey and Barker (1973) using a dose of 5,000 eggs + juveniles that were distributed in three holes around the plant. The viability of the inoculum was evaluated in tomato plants ('Rio Grande') inoculated at the same dose as the quinoa cultivars. Quinoa and tomato cultivars were kept at a temperature of 25 °C ± 5 °C and a humidity of 40 ± 5.

The number of galls (NG), number of nematodes per gram of root (nematodes g<sup>-1</sup> root), and the reproduction factor (RF) were evaluated 90 days after inoculation. The number of galls was determined by direct root counting; the extraction of eggs + juveniles was performed using the technique proposed by Hussey and Barker (1973) and the RF was determined according to the methodology described by Oostenbrink (1996), they were considered immune (RF = 0), resistant (RF <1) and susceptible (RF > 1) species. 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 experimental design was completely randomized with five quinoa cultivars and three species of *Meloidogyne* spp., and six replicates were used. Data were subjected to an analysis of variance (ANOVA,  $p < 0.05$ ) and comparisons were made using the Duncan's test ( $p < 0.05$ ) using SAS, version 9.0.

## Results and discussion

The ANOVA detected a significant effect between nematodes per gram of root (nematodes  $g^{-1}$  root), number of galls (NG) and reproduction factor (RF) for cultivars of quinoa and the nematode species *M. arenaria*, *M. hapla* and *M. incognita*, with a significant difference for the Duncan test ( $p < 0.05$ ).

The RF of *M. arenaria* and *M. hapla* was low in most quinoa cultivars; therefore, these were classified as resistant, except for 'Negra Collana', which was considered susceptible to *M. arenaria* with an RF = 1.1 (Table 1). However, for *M. hapla*, 'Salcedo INIA' and 'Huariponcho' with an RF = 1.3 and 1.1, respectively, were considered susceptible (Table 1). Furthermore, the reproduction factor of *M. incognita* was high in all quinoa cultivars; therefore, all cultivars were classified as susceptible (Table 1) according to Oostenbrink (1966).

'Salcedo INIA', 'Choclito', 'Kcancolla', and 'Huariponcho' were classified as resistant to *M. arenaria* with an RF = 0.3, 0.4, 0.5, and 0.7, respectively. 'Salcedo INIA' showed a lower reproduction rate, which indicates a higher level of resistance, a lower nematodes  $g^{-1}$  root with 436, and the lowest number of galls with 9. Furthermore, 'Negra Collana' had the highest reproduction rate, which indicates it is susceptible, with a nematodes  $g^{-1}$  root of 2,301 and a number of galls of 29.5, which although high, was not the highest. 'Choclito' had the highest number of galls with 35.8; however, with an RF of 0.4 and a nematodes  $g^{-1}$  root of 609, it was considered resistant (Table 1).

In the case of *M. hapla*, 'Salcedo INIA' showed the highest reproduction rate, RF = 1.26, and thus, it was classified as susceptible to this nematode. It also had the highest nematodes  $g^{-1}$  root of 1,997 and a number of galls of 102. 'Choclito', with an RF = 0.4, had the lowest reproduction rate and was therefore considered the most resistant; with a nematodes  $g^{-1}$  root of 536 and a higher number of galls (96.17) than that of the 'Huariponcho' cultivar (63); considered susceptible, with an RF = 1.1 and a nematodes  $g^{-1}$  root of 1132 (Table 1).

All quinoa cultivars were susceptible to *M. incognita*. These data coincide and exceed those reported by Asmus *et al.* (2005), who indicate that *C. quinoa* is susceptible to *M. incognita* race 3 with an RF = 2.6, 'Huariponcho' had the highest reproduction rate with an RF = 14.2, being considered as the most susceptible and with the highest nematodes  $g^{-1}$  root of 16,508. These data are similar to those reported by Asmus *et al.* (2001), where they indicate that the quinoa crop had the highest multiplication of nematodes and its use in infested areas can increase, or at least maintain, the population of *Meloidogyne javanica* (Treub, 1885) Chitwood 1949. However, 'Negra Collana' presented the lowest RF = 2.5

and a nematodes  $g^{-1}$  root of 5,257; therefore, it was considered the least susceptible (Table 1).

In Peru, quinoa species are commonly used in crop rotations for pest management; therefore, knowing the response of different quinoa cultivars to *M. incognita*, *M. arenaria*, and *M. hapla* is essential for researchers and farmers during crop rotation. This study is one of the first to evaluate the response of quinoa cultivars to *Meloidogyne* spp. Further research regarding the susceptibility and resistance to *Meloidogyne* spp. is required, as quinoa is of great importance to food security.

## Conclusions

All quinoa cultivars were susceptible to *M. incognita*, 'Salcedo INIA' and 'Huariponcho' are also susceptible to *M. hapla*, and 'Negra Collana' to *M. arenaria*. However, 'Salcedo INIA', 'Choclito', 'Huariponcho', and 'Kcancolla' are resistant to *M. arenaria* and 'Choclito', 'Negra Collana', and 'Kcancolla' are resistant to *M. hapla*.

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