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Original Article

Susceptibility of Pitaya genotypes to *Meloidogyne incognita* and *M. javanica*: implications for nematode management in Brazil

Suscetibilidade de genótipos de Pitaya a *Meloidogyne incognita* e *M. javanica*: implicações para o manejo de nematoides no Brasil

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Abstract

Pitaya (*Selenicereus* spp., Cactaceae) has gained popularity among fruit consumers due to its distinctive flavor, shape, color, as well as vitamin C and B contents. However, recent studies have reported pitaya as a host for economically important nematodes of the genus *Meloidogyne*. These nematodes exhibit a wide host range and are distributed across Brazil. This study assessed the susceptibility of six pitaya genotypes (*S. undatus*, *S. polyrhizus*, *S. undatus* subsp. *lithocarpus*, *S. megalanthus*, *S. setaceus*, and *S. megalanthus* × *S. costaricensis* 'Orange') to *Meloidogyne incognita* and *M. javanica*. The experiment was conducted in a completely randomized design with 20 replicates. The total numbers of eggs and second-stage juveniles (J2), as well as eggs and J2 per gram of root, were used to calculate the reproduction factor and reproduction index. Plant assessments included measurements of shoot and root fresh weights. The pitaya genotypes *S. undatus*, *S. polyrhizus*, *S. undatus* subsp. *lithocarpus*, *S. megalanthus*, *S. setaceus*, and *S. megalanthus* × *S. costaricensis* 'Orange' were classified as susceptible to *M. incognita* and *M. javanica*, as their reproduction factors exceeded 1. Further studies are necessary to identify pitaya genotypes resistant to plant-parasitic nematodes, as genetic resistance remains one of the most effective and cost-efficient strategies for nematode control in agricultural systems.

Keywords: Cactaceae, dragon fruit, *Selenicereus* spp., root-knot nematodes, susceptibility.

Resumo

A pitaya, que pertence à família Cactaceae, tornou-se muito popular entre os consumidores devido ao seu formato e coloração. É também fonte de vitaminas C e B. Algumas espécies de *Meloidogyne* apresentam ampla gama de hospedeiros e estão distribuídas por todo o Brasil. Pesquisas recentes demonstraram a pitaya como um novo hospedeiro para as principais espécies de *Meloidogyne*. Esta pesquisa teve como objetivo avaliar a suscetibilidade de seis espécies de pitaya (*Selenicereus undatus, S. polyrhizus, S. undatus subsplithocarpus, S. megalanthus, S. setaceus e S. megalanthus x S. costaricensis orange*), inoculadas com *Meloidogyne incognita* e *M. javanica*. O experimento foi conduzido em delineamento inteiramente casualizado com 20 repetições. As variáveis, número total de ovos e juvenis (NTODED) e número total de ovos e juvenis por grama de raízes (NTOJGR), foram avaliadas quanto ao fator de reprodução (FR) e índice de reprodução (IR%). Além disso, foram realizadas análises vegetativas da matéria fresca da parte aérea (MFPA) e raízes (MFR). As espécies de pitaya (*Selenicereus undatus, S. polyrhizus, S. undatus subsp lithocarpus, S. megalanthus, S. setaceus e S. megalanthus x S. costaricensis orange*), foram classificadas como suscetíveis e hospedeiras de *M. incognita* e *M. javanica* por apresentarem FR≥ 1. Portanto, há necessidade de realização de mais pesquisas para identificar espécies de pitaya resistentes a fitonematoides, considerando a resistência genética um dos métodos mais eficientes e econômicos para o controle de nematoides.

Palavras-chave: Cactaceae, fruta do dragão, *Selenicereus* spp., nematoides de galhas, suscetibilidade.

1. Introduction

World pitaya production is largely dominated by Asian countries. Vietnam is the leading producer, followed by China, with annual productions of 602,608 Mg and 200,000 Mg, respectively. Colombia and Mexico also have substantial pitaya production (Araújo et al., 2021). In Brazil and other Latin American countries, pitaya production is expanding in both domestic and export markets, although some production data remain unavailable. The Southeast is the

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primary pitaya-producing region in Brazil, with a yield of 812.64 Mg in 2019, followed by the South (502.08 Mg) and North (157.01 Mg), which together account for over 98% of the country's total production, whereas the Central West (12.35 Mg) and Northeast (9.12 Mg) regions recorded the lowest production (IBGE, 2017).

Pitaya is a relatively recent crop in Brazil; thus, reports on phytopathogens in scientific literature are limited. This scarcity complicates the identification and effective management of diseases, contributing to yield losses and reduced orchard longevity. Phytopathogens associated with pitaya include root-knot nematodes, specifically *Meloidogyne javanica* and *M. incognita* (Nascimento et al., 2020; Souza et al., 2022). These nematodes parasitize the root system, adversely affecting vegetative and reproductive development, reducing fruit yield and quality, and consequently decreasing overall crop production and profitability (Guzmán-Piedrahita et al., 2012). In addition to root damage, nematodes facilitate the entry of secondary pathogens, rendering production in the affected area unfeasible (Lopes and Ferraz, 2016).

Some *Meloidogyne* species are major pathogens of cultivated plants, as they are polyphagous, globally distributed, and capable of causing substantial damage to agricultural crops (Phani et al., 2021; Subbotin et al., 2021). *M. javanica* and *M. incognita* are the dominant root-knot nematode species in tropical climates, where they are widely distributed (Soares and Nascimento, 2021).

M. incognita was first documented in pitaya plants in Brazil, associated with white pitaya in Laranjal Paulista, state of São Paulo (Souza et al., 2022), but had previously been reported causing damage to pitaya plants in Colombia (Castaño et al., 1991; Guzmán-Piedrahita et al., 2012). In Brazil, *M. javanica* has been reported to cause damage in pitaya crops, including stunted growth, chlorosis, absence of fruit, and gall formation on roots (Nascimento et al., 2020). Reports of damage in pitaya crops caused by *M. incognita* also include stunted growth, chlorosis, and substantial gall formation on roots, particularly secondary roots (Souza et al., 2022).

The recent expansion of pitaya cultivation, combined with severe damage caused by root-knot nematodes and limited information on specific management, has necessitated new nematode management solutions for this crop. In this context, the search for resistant genotypes may offer a viable alternative. The reproduction factor is the most used criterion in studies determining resistance of genotypes to nematode parasitism (Ferraz and Brown, 2016). Therefore, this study assessed the susceptibility of six pitaya genotypes (*Selenicereus undatus, S. polyrhizus, S. undatus* subsp. *lithocarpus, S. megalanthus, S. setaceus*, and *S. megalanthus × S. costaricensis* 'Orange'), to *M. incognita* and *M. javanica*.

2. Materials and Methods

2.1. Characterization of the experimental area

The experiment was conducted from January 2019 to January 2020 in a greenhouse at the Nematology Laboratory (LabNema), School of Agricultural and Veterinary Sciences (FCAV), São Paulo State University (UNESP), in Jaboticabal, SP, Brazil (21°14'05"S, 48°17'09"W, and 615 m altitude). Minimum, mean, and maximum temperatures of 3.0 °C, 23.4 °C, and 38.0 °C, respectively, were observed during the experiment.

2.2. Experimental design and genetic material

The experiment was conducted in a completely randomized design with 20 replicates. The treatments consisted of two nematode species (*Meloidogyne incognita and M. javanica*) and six pitaya genotypes (*Selenicereus undatus, S. polyrhizus, S. undatus* subsp. *lithocarpus, S. megalanthus, S. setaceus*, and *S. megalanthus × S. costaricensis* 'Orange'). *Selenicereus undatus* produces spineless fruits with red skin and white pulp; *S. polyrhizus* produces fruits with red skin and red pulp fruit; *S. undatus* subsp. *lithocarpus* produces spineless fruits with yellow skin and white pulp, and is commonly known as Golden pitaya in Brazil; *S. megalanthus* produces spiny fruits with yellow skin and white fruit and is commonly known as Colombian pitaya; *S. setaceus* produces spiny fruits with red skin and white pulp and is commonly known as Cerrado, Tasty, or Baby pitaya, sourced from the São Paulo State Agribusiness Technology Agency (APTA, Colina, SP, Brazil); and *S. megalanthus × S. costaricensis* 'Orange' produces spiny fruits with orange skin and pink pulp, sourced from the Fruit Research Center (Ripado de Fruticultura) of the UNESP/FCAV, in Jaboticabal, SP, Brazil.

Abelmoschus esculentus (Santa Cruz 47) plants were used to assess the inoculum viability of both nematode species. *Crotalaria spectabilis* was used as a resistance standard for both nematode species.

2.3. Implementation and conduction of experiments

The pitaya genotypes were vegetatively propagated to ensure uniformity and precocity (Marques et al., 2012). Cuttings of 20 cm were collected from mature cladodes of mother plants and placed in 600-mL plastic cups for rooting. After two months, seedlings were transplanted into 5-liter pots containing autoclaved substrate (sterilized for 2 h at 120 °C and 1 atm pressure), comprising of a mixture of ravine soil and sand (1:4, v/v).

2.4. Nematode inoculum obtaining and inoculation

Subpopulations of the nematode species were previously multiplied on tomato plants (*Solanum lycopersicum* L. 'Santa Cruz Kada') in a greenhouse. The root-knot nematode species were identified under an optical microscope based on morphological characteristics of the perineal pattern (Taylor and Netscher, 1974), labial region morphology of males (Eisenback et al., 1981), and the esterase isoenzyme phenotype (Esbenshade and Triantaphyllou, 1990), using a vertical electrophoresis system (Mini Protean II, Bio-Rad).

The plants were inoculated 30 days after transplanting the cuttings into pots, when they were producing shoots, except for the control group. The inoculum consisted of a 5-mL suspension containing 5,000 eggs and second-stage juveniles (J2) of each nematode species (*M. incognita* and *M. javanica*). The subpopulation of *M. incognita* was recovered from cotton roots in Barreiras, BA, Brazil, and the subpopulation of *M. javanica* was recovered from okra roots in Piacatu, SP, Brazil.

2.5. Nematode extraction

The plants were removed from the pots 12 months after inoculation. The fresh aerial parts were weighed, and the roots were taken to the Nematology Laboratory (LabNema) for washing, weighing, and nematode extraction. The roots were weighed, crushed in a blender with a 0.5% sodium hypochlorite solution (Hussey and Barker, 1973), and centrifuged (Coolen and D'Herde, 1972) to extract eggs and J2, which were quantified using an optical microscope and a Peters counting chamber (Southey, 1970).

2.6. Variables analyzed

The final population of each nematode species in the roots was determined and used as a nematological variable. The pitaya genotypes were evaluated for each inoculated nematode species using the reproduction factor (RF), calculated according to Oostenbrink (1966) as the ratio of the final population of eggs and J2 in the roots after 12 months of inoculation to the initial inoculated population (Equation 1). The pitaya genotypes were classified based on the reproduction factors for *M. incognita* and *M. javanica* as resistant (RF < 1), susceptible (RF ≥ 1), or immune (RF = 0).

$$\mathrm{RF} = \frac{\text{Final population}\left(\mathrm{FP}\right)}{\text{Initial population}\left(\mathrm{IP}\right)} \tag{1}$$

The reproduction index (RI) was calculated as the ratio of the final population and total number of eggs and J2 for each pitaya genotype to the final population of the genotype with the highest reproduction (*S. megalanthus* × *S. costaricensis* 'Orange'), expressed as a percentage (Equation 2).

$$\mathrm{RI} = \frac{\text{Final test genotype population}}{\text{Final population of greatest reproduction}} \times 100 \tag{2}$$

The pitaya genotypes were classified as susceptible (RI > 50%), slightly resistant (25% ≤ RI ≤ 50%), moderately resistant (11% ≤ RI ≤ 25%), very resistant (1% ≤ RI ≤ 10%), highly resistant (RI < 1%), or immune (RI = 0) (Taylor, 1967).

The shoot and root fresh weights of the plants were measured and compared between nematode-inoculated and non-inoculated treatments to assess potential reductions caused by the nematodes.

2.7. Statistical analysis

The data were subjected to residuals diagnostic analysis to verify the assumptions of analysis of variance. Variables that required transformation were analyzed using the Box-Cox transformation (Hawkins and Weisberg, 2017). The data were then subjected to analysis of variance (ANOVA), with means compared using Tukey's test at the 5% probability level. All analyses were processed using R software (R Core Team, 2023).

3. Results

3.1. Nematological variables

M. incognita and *M. javanica* showed no significant difference in the total number of eggs and second-stage juveniles (J2); however, a significant difference was observed in the number of eggs and J2 per gram of root. All pitaya genotypes were classified as susceptible to *M. incognita* and *M. javanica* based on the reproduction factor (RF), with RF ≥ 1. The nematode species exhibited contrasting reproduction indices (RI), classifying the pitaya genotypes *S. megalanthus* and *S. undatus* as slightly resistant to *M. incognita*, and *S. undatus* subsp. *lithocarpus*, *S. megalanthus* × *S. costaricensis* 'Orange', and *S. polyrhizus* as slightly resistant to *M. javanica* (Table 1).

3.2. Plant developmental variables

The effects of genotype, nematode species, and their interaction were significant for shoot fresh weight, indicating that responses to *M. incognita* and *M. javanica* varied among and within pitaya genotypes (Table 2). As the interaction between genotype and nematode species was significant for shoot fresh weight, these factors were analyzed separately for inoculated and non-inoculated (control) treatments. The effects of genotype and nematode species were significant for root fresh weight, but their interaction was not significant. This indicates that the nematode presence affected root fresh weight accumulation regardless of plant genotype, and the plant genotype affected root fresh weight regardless of nematode presence (Table 2).

The shoot fresh weight accumulation of the genotypes *S. megalanthus*, *S. megalanthus* × *S. costaricensis* 'Orange', and *S. setaceus* was reduced by the presence of *M. incognita*, exhibiting significantly lower shoot fresh weight than the control (Table 3). The shoot fresh weight accumulation of the genotypes *S. undatus* subsp. *lithocarpus*, *S. megalanthus* × *S. costaricensis* 'Orange', and *S. setaceus* was reduced by the presence of *M. javanica*, exhibiting significantly lower shoot fresh weight than the control. These results demonstrate that the nematode presence can stress plants, leading to reduced shoot fresh weight (Table 3).

The greatest root fresh weight accumulations were observed for the pitaya genotypes *S. undatus* subsp. *lithocarpus*, *S. undatus*, and *S. polyrhizus*, regardless of the nematode species (Table 4).

3.3. Frequency of resistant and susceptible plants

Variations in the frequency of resistant and susceptible plants within pitaya genotypes were observed for the two nematode species. The genotypes with the highest proportion of resistant plants were *S. megalanthus*, *S. undatus* subsp. *lithocarpus*, and *S. megalanthus* × *S. costaricensis* 'Orange', with 10% of plants resistant to *M. incognita*. The highest proportions

Table 1. Mean total number of eggs and second-stage juveniles (J2) (TNEJ) and total number of eggs and J2 per gram of roots (TNEJg) for *Meloidogyne incognita* and *Meloidogyne javanica* in pitaya genotypes (*Selenicereus* spp.).

Meloidogyne incognita						
Treatments	**TNEJ**	**TNEJg**	**RF**	**C**	**RI**	**C**
SM	4.52860 (139874.4) a	3.39365 (12058.5) bc	28.0	S	38.3	SR
SUL	4.53435 (50286.5) a	2.90155 (1411.0) c	10.1	S	13.8	MR
SM×SC	4.89910 (365018.4) a	4.00875 (36761.5) a	56.1	S	100.0	S
SU	4.62075 (116093.0) a	3.0975 (4359.0) c	23.2	S	31.8	SR
SS	4.95580 (280421.0) a	3.7531 (17539.9) ab	73.0	S	76.8	S
SP	4.60275 (56735.1) a	3.213 (2535.1) bc	11.4	S	15.5	MR
Test F	1.73^{ns}	7.8059**				
***p* value**	0.1326	< 0.0001				
CV (%)	13.63	19.67				
Meloidogyne javanica						
Treatments	**TNEJ**	**TNEJg**	**RF**	**C**	**RI**	**C**
SM	4.17900 (111668.8) a	2.9485 (2757.0) ab	22.3	S	59.6	S
SUL	4.50515 (69004.4) a	2.9178 (1873.0) ab	13.8	S	36.8	SR
SM×SC	3.96900 (86978.7) a	3.2495 (8096.6) ab	17.4	S	46.4	SR
SU	4.23680 (22559.8) a	2.7358 (792.1) b	4.5	S	12.0	MR
SS	4.50405 (187406.3) a	3.4749 (15173.8) a	37.4	S	100.0	S
SP	4.55145 (80954.5) a	3.1693 (6720.4) ab	16.1	S	43.2	SR
Test F	1.3063^{ns}	2.3032*				
***p* value**	0.2665	0.0494				
CV (%)	19.99	25.3				

SM = *S. megalanthus*; SUL = *S. undatus* subsp. *lithocarpus*; SS = *S. setaceus*; SU = *S. undatus*; SM×SC = *S. megalanthus × S. costaricensis* 'Orange'; SP = *S. polyrhizus*. RI = reproduction index; RF = reproduction factor; C = classification: S = Susceptible, SR = slightly resistant MR = moderately resistant (Taylor, 1967). **, *, and ^{ns} = significant at 1% significance level, 5% significance level, and not significant by F test, respectively. Means followed by the same letter in the columns at not different by Tukey's test (p < 0.05). Values were transformed using Log(x), with original means in parentheses.

Table 2. Analysis of variance of shoot fresh weight (SFW) and root fresh weight (RFW) of pitaya genotypes (*Selenicereus* spp.) inoculated with *Meloidogyne incognita* and *Meloidogyne javanica*.

Source of variation	***Meloidogyne incognita***		***Meloidogyne javanica***	
	SFW	**RFW**	**SFW**	**RFW**
Genotype (G)	795199.8**	5801.0**	792583.7**	4.121.6**
Nematode (N)	350446.8**	8967.0**	556999.0**	12718.0**
G × N	65.383.4**	940.4^{ns}	71.124.6**	384.8^{ns}
CV	24.4	86.1	23.7	75.8

**, *, and ^{ns} = significant at 1% significance level, 5% significance level, and not significant by F test, respectively.

of plants resistant to *M. javanica* were observed in the genotypes *S. megalanthus* and *S. setaceus*, with 30% and 45%, respectively (Figures 1 and 2).

4. Discussion

Although some pitaya genotypes exhibited a higher mean total number of eggs and second-stage juveniles (J2) and a higher number of eggs and J2 per gram of root, all showed reproduction factors (RF) greater than 1.0, regardless of nematode species. Therefore, all pitaya genotypes were susceptible to *M. javanica* and *M. incognita*, enabling nematode multiplication. These results are consistent with other scientific studies, in which pineapple, cowpea, soybean, banana, and pitaya crops were susceptible to *M. javanica* (Costa et al., 1999; Gontijo et al., 2024; Nascimento et al., 2020; Santos et al., 2023; Silva et al., 2023), and rice, hops, melon, passion fruit, and fig crops were susceptible to *M. incognita* (Dutta and Akhil, 2023;

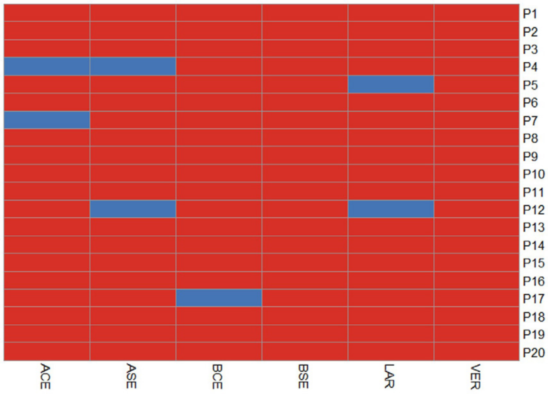

Figure 1. Absolute frequency of plants of pitaya genotypes (*Selenicereus* spp.) within classes of resistance to *M. incognita*. Blue = resistant plants (RF < 1); Red = susceptible plants (RF ≥ 1). P = plant. SM = *S. megalanthus*; SUL = *S. undatus* subsp. *lithocarpus*; SS = *S. setaceus*; SU = *S. undatus*; SM×SC = *S. megalanthus* × *S. costaricensis* 'Orange'; SP = *S. polyrhizus*.

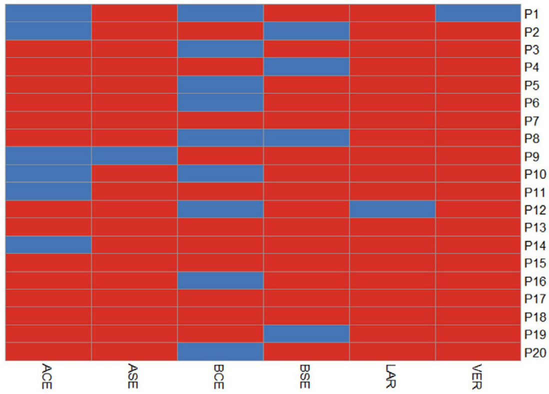

Figure 2. Absolute frequency of plants of pitaya genotypes (*Selenicereus* spp.) within classes of resistance to *M. javanica*. Blue = resistant plants (RF < 1); Red = susceptible plants (RF ≥ 1). P = plant. SM = *S. megalanthus*; SUL = *S. undatus* subsp. *lithocarpus*; SS = *S. setaceus*; SU = *S. undatus*; SM×SC = *S. megalanthus* × *S. costaricensis* 'Orange'; SP = *S. polyrhizus*.

Table 3. Shoot fresh weight of pitaya genotypes (*Selenicereus* spp.) inoculated and non-inoculated (control) with *Meloidogyne incognita* and *Meloidogyne javanica*.

Pitaya genotypes	Control	*M. incognita*	*M. javanica*
SM	375.6 Ca	250.3 Cb	247.3 Ca
SUL	629.2 ABa	617.4 Aa	540.3 ABb
SM×SC	433.8 Ca	290.8 Cb	254.0 Cb
SU	548.1 Ba	588.6 Aa	588.4 Aa
SS	609.5 BCa	446.0 Bb	433.8 Bb
SP	686.8 Aa	631.2 Aa	641.0 Aa

SM = *S. megalanthus*; SUL = *S. undatus* subsp. *lithocarpus*; SS = *S. setaceus*; SU = *S. undatus*; SM×SC = *S. megalanthus* × *S. costaricensis* 'Orange';
SP = *S. polyrhizus*. Means followed by different uppercase letters in row, or different lowercase letters in the columns, are significantly different by Tukey's test (p < 0.05).

Table 4. Root fresh weight of pitaya genotypes (*Selenicereus* spp.) inoculated with *Meloidogyne incognita* and *Meloidogyne javanica*.

Pitaya genotypes	*Meloidogyne incognita*	*Meloidogyne javanica*
SM	29.02 bc	34.65 ab
SUL	53.72 a	46.72 a
SM×SC	18.52 c	16.92 c
SU	40.27 ab	38.47 ab
SS	29.77 bc	28.57 bc
SP	38.50 ab	37.47 ab

SM = *S. megalanthus*; SUL = *S. undatus* subsp. *lithocarpus*; SS = *S. setaceus*; SU = *S. undatus*; SM×SC = *S. megalanthus* × *S. costaricensis* 'Orange'; SP = *S. polyrhizus*. Means followed by different uppercase letters in row, or different lowercase letters in the columns, are significantly different by Tukey's test (p < 0.05).

Ferreira et al., 2015; Gonsaga et al., 2021; Moreira et al., 2017; Zucareli et al., 2020).

The reproduction indices (RI) classifying the pitaya genotypes as slightly or moderately resistant to *M. javanica* and *M. incognita* were similar to those reported for chickpea and melon crops resistant to *M. javanica* (Santos et al., 2021; Silva et al., 2022), and rosemary and *Plectranthus amboinicus* crops resistant to *M. incognita* (Moreira et al., 2017).

Information on genotype resistance serves as a tool to recommend the most suitable genotypes for each cultivation area. The same pitaya genotype may exhibit different responses to each nematode species; *S. setaceus* was the only genotype that remained susceptible to both *M. incognita* and *M. javanica*. These results encourage further studies on nematode parasitism, control, and the possible genetic improvement of pitaya genotypes, enhancing knowledge of pitaya cultivation and promoting sustainable, profitable production.

Effective nematode management requires a combination of several techniques, including biological control, genetic control through resistant plants, crop rotation with non-host plants resistant to the nematode species, and grafting. Together, these techniques provide an effective alternative for controlling nematode population levels, primarily by breaking their developmental cycle, as complete eradication is nearly impossible (Queiroga et al., 2021; Soares and Nascimento, 2021).

Differences in the shoot fresh weight among genotypes for each nematode species may be attributed to the presence of galls on the roots (Kayani et al., 2017), which may have increased root weight in some pitaya genotypes, making them appear superior to their controls. Galls form through cellular hypertrophy and hyperplasia; when nematodes establish their feeding site in the roots, adjacent cells divide and form new tissues. However, shoot fresh weight was generally higher in non-inoculated plants. This result may be associated with the parasitic behavior of nematodes, which feed on plant sap, reducing nutrient availability to plants and thereby decreasing shoot fresh weight in inoculated plants.

The significant differences between inoculated and non-inoculated treatments with *M. incognita* may be attributed to varying resistance levels among the pitaya genotypes. Similar resistance was reported in the literature for passion fruit crops (Rocha et al., 2021). In addition, Santos et al. (2023) reported resistance to *M. incognita* in *S. undatus*.

The variation in resistance to nematodes among pitaya genotypes is important because, once the plant resistant to a nematode species is identified, it can be cloned, allowing the pitaya breeding program can continue, while preserving desirable characteristics through vegetative propagation. Thus, the breeding process can be accelerated by producing large quantities of identical plants in a short period.

This study revealed important information for researchers, consultants, and farmers. However, further research is needed to develop effective nematode control strategies, including breeding programs to identify rootstocks resistant to root-knot nematodes. Furthermore, the results for the pitaya genotypes indicated that they should not be recommended for areas with *M. incognita* and *M. javanica,* even those that were mild or moderately resistant based on the reproduction index (RI).

5. Conclusion

The evaluated pitaya genotypes, *Selenicereus undatus*, *S. polyrhizus*, *S. undatus* subsp. *lithocarpus*, *S. megalanthus*, *S. setaceus*, and *S. megalanthus × S. costaricensis* 'Orange', supported the multiplication of root-knot nematodes *M. javanica* and *M. incognita* and are therefore considered hosts. Further research is needed to identify sources of resistance.

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