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Reaction of potato genotypes to the root-knot nematode *Meloidogyne* spp. in a naturally infested field

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ABSTRACT

The objective of this work was to verify the reaction of potato clones and cultivars to root-knot nematodes in a field area naturally infested by the root-knot nematodes *Meloidogyne incognita* and *M. ethiopica*. Fifteen clones and five potato cultivars were evaluated, in addition to plots with okra and tomato susceptible species, in a field naturally infested with a *Meloidogyne incognita* and *M. ethiopica* population mixture, in an experimental field of Embrapa Hortaliças located in the Federal District, Brazil. The experiment was carried out from April to August 2022, in a randomized complete block design with four replications of five plants per plot. At the planting time, as well as when harvesting the genotypes, soil was collected to determine the initial and final nematode populations. When the plants were harvested, the total number of juveniles extracted from plant tissues (potato tubers and okra roots and tomato) was determined, as well as the calculation of the reproduction factor (RF), and the evaluation of tuber yield of the potato genotypes. Data were submitted to analysis of variance and grouping of means by the Scott-Knott test. The clones C2743-09-09, CH41, F119-12-01, F129-12-08, F63-10-13A, F65-13-06, F88-11-01 and OD38-06, and the cultivars Markies, Agata and Asterix were the least susceptible genotypes to field mix of the root-knot nematodes *M. incognita* and *M. ethiopica*. But combining a lower degree of susceptibility and good tuber productivity, clones MB54-02, F53-11-05, F63-10-13A, F65-13-06, OD38-06 stood out. The commercial cultivars Atlantic and Epagri Catucha presented greater multiplication of nematodes in the field than the other evaluated cultivars.

Keywords: *Solanum tuberosum*, *Meloidogyne incognita*, *Meloidogyne ethiopica*, reproduction factor, yield.

RESUMO

Reação de genótipos de batata ao nematoide das galhas *Meloidogyne* spp. em um campo naturalmente infestado

O objetivo deste trabalho foi verificar a reação de clones e cultivares de batata em área de campo naturalmente infestada pelos nematoides formadores de galhas *Meloidogyne incognita* e *M. ethiopica*. Foram avaliados 15 clones e cinco cultivares de batata, além de parcelas com os padrões de suscetibilidade quiabo e tomate. O experimento foi instalado e conduzido de abril a agosto de 2022 em campo naturalmente infestado com uma mistura populacional de *Meloidogyne incognita* e *M. ethiopica*, localizado na Embrapa Hortaliças, Distrito Federal. O experimento foi instalado em delineamento de blocos ao acaso com quatro repetições e cinco plantas por parcela. No momento do plantio, bem como na colheita dos genótipos, foi realizada coleta de solo para determinação das populações iniciais e finais dos nematoides, e na colheita das plantas avaliado o número total de juvenis extraídos dos tecidos vegetais (tubérculos de batata e raízes de quiabo e tomate), calculado o fator de reprodução estimado (FR), bem como a avaliação da produtividade de tubérculos dos genótipos de batata. Os dados foram submetidos à análise de variância e agrupamento de médias dos tratamentos por teste de Scott-Knott. Observou-se que os clones C2743-09-09, CH41, F119-12-01, F129-12-08, F63-10-13A, F65-13-06, F88-11-01 e OD38-06, e as cultivares Markies, Agata e Asterix, foram os genótipos com menor suscetibilidade à mistura populacional a campo dos nematoides formadores de galhas *M. incognita* e *M. ethiopica*. Entretanto, combinando menor grau de suscetibilidade e boa produtividade de tubérculos são destaque os clones MB54-02, F53-11-05, F63-10-13A, F65-13-06, OD38-06. Verificou-se ainda que as cultivares comerciais Atlantic e Epagri Catucha possibilitaram maior multiplicação dos nematoides a campo do que as demais cultivares avaliadas.

Palavras-chave: *Solanum tuberosum*, *Meloidogyne incognita*, *Meloidogyne ethiopica*, fator de reprodução, produtividade.

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There are about 24 genera of phytonematodes associated with the potato crop worldwide (Bali *et al*., 2021), whose average annual losses are estimated at 11% of production (Akiazi & Deveci, 2022) and may compromise up to 100% of production in severely infested areas (Pinheiro & Lopes, 2011). Among these, the genus *Meloidogyne* stands out, which comprises the root-knot nematodes. This genus is associated with a wide range of hosts, being responsible for economic damage in several crops around the world (Azlay *et al*., 2022).

In Brazil, due to the extent of damage caused to several crops and its wide distribution, *Meloidogyne incognita* and *M. javanica* are considered the most important species. In the potato crop (*Solanum tuberosum*) these species also stand out for their greater occurrence in producing regions of the country (Pinheiro *et al*., 2018). But there are other species associated to the potato crop in Brazil, such as the *Meloidogyne ethiopica* (Lima-Medina *et al*., 2012, 2014).

During the potato growing season, infective second-stage juveniles (J2) hatch from root-knot nematode eggs, invade roots and develop feed sites. Generally, infected potato plants do not show obvious symptoms above ground, but infections can reduce plant vigor (Bali *et al*., 2021) due to less absorption of water and nutrients (Lima-Medina *et al*., 2014). After infection and formation of the feeding site, the J2 develop after three more moults, forming females and males. Females continue to feed and will lay their eggs in masses that protect against desiccation and other weathering. Each female can lay 500 to 1000 eggs during her life cycle, depending on the host, species and environment. The main symptoms refer to the development of protuberances on the tubers, known as galls, in addition to the formation of necrotic spots inside the tuber flesh, making them unsuitable for commercialization, which directly affects potato producers (Macharia *et al*., 2020; Bali *et al*., 2021).

Among the most widespread control methods for phytonematodes are the use of biological products, crop rotation with non-host plants, the use of antagonistic plants (Bali *et al*., 2021), fallow, and the use of genetic resistance when available (Pinheiro *et al*., 2018). It is worth noting that chemical control, although relatively efficient, has a high economic and environmental cost (Bali *et al*., 2021). In most cases, the association of more than one control measure is the best option in the integrated management of nematodes in potato crops (Pinheiro *et al*., 2018).

Although there are no commercial potato cultivars resistant to root-knot nematodes (Macharia *et al*., 2020; Bali *et al*., 2021), there are studies indicating varying levels of susceptibility, and that less susceptible genotypes could be identified. The use of potato cultivars with a lower level of susceptibility to *Meloidogyne* spp. would be an important alternative, due to its lower cost and good efficacy. However, in Brazil, information on the response of potato genotypes to root-knot nematodes is scarce (Lima-Medina *et al*. 2014; Pinheiro *et al*., 2018).

Thus, the objective of this work was to evaluate the reaction of potato clones and cultivars to a population mixture of *Meloidogyne incognita* and *M. ethiopica* in a naturally infested field.

MATERIAL AND METHODS

The experiment was carried out in an experimental field of Embrapa Hortaliças located in Federal District, Brazil. The potato clones BGB476, C2743-09-09, CH04, CH38, CH41, F119-12-01, F129-12-08, F53-11-05, F63-10-13A, F65-13-06, F88-11-01, MB5402, OD38-06, OD80-02 and ORG14599, and the cultivars Markies, Atlantic, Agata, Asterix, and Epagri Catucha were evaluated. The first four cultivars were chosen because they are widely cultivated in the country, so that information is also extremely important for the productive sector, and the last one is a national cultivar released by Epagri, SC, known to be resistant to foliar diseases, and with information in the literature on the degree of resistance to root-knot nematodes (*M. graminicola*, *M. javanica, M. incognita*, *M. hapla*, *M. arenaria*, *M. enterolobii*, *M. paranaensis* and *M. morocciensis*) under Brazilian conditions of field cultivation (Lima-Medina *et al*., 2012).

Type II seed tubers (41 to 50 mm in diameter) were planted on April 18, 2022 in a randomized complete block design experiment with four replications, and plots consisting of a row with five plants. The spacing was 0.30 m between plants and 0.80 m between rows. The field, previously cultivated with okra (*Abelmoschus esculentus*) cultivar Santa Cruz 47, a species known for its susceptibility to root-knot nematodes, was infested by a population mixture of *M. incognita* and *M. ethiopica* with an average of approximately 33.61 2nd stage juveniles (J2) per 150 cm^3 of soil. Plots with okra cultivar Santa Cruz 47 and susceptible tomato cultivar Rutgers, were also randomly entered into the experiment along with the other treatments in the same plot size. Plants of these susceptible species were transplanted to the field on May 2, 2022, five plants per plot for tomato and 15 for okra, and harvested on July 28, 2022.

The identification of root-knot nematode species was performed by extracting *Meloidogyne* females from potato plants at the Nematology Laboratory of Embrapa Hortaliças. The isozyme characterization was carried out according to the methodology adapted from Carneiro & Almeida (2001).

The soil was conventionally prepared with plowing and harrowing. Then, 200 g of NPK 00-20-20 commercial formula were applied per linear meter of furrow (2.5 t/ha) as planting fertilizer. In the heap, 30 days after planting, 24 g of urea per linear meter (300 kg/ha) were applied as cover fertilization. A continuous row of potatoes was planted around the experiments to serve as a border. Irrigation was performed by sprinkling according to the crop's needs throughout the conduct of the experiments. At planting time, five subsamples of soil were collected at equidistant points of each plot, to compose a sample of 1 kg to quantify the initial population (Pi) of nematodes per 150 cm^3 of soil, according to Jenkins (1964).

At the harvest of potato plots, 120 days after planting, the final J2 population of *Meloidogyne* spp. per 150 cm^3 of soil and the total number of juveniles extracted from the entire external surface (±3 mm thick) of 10 potato tubers of commercial size with diameter from 45 to 50 mm, were determined for each plot. Also, the total number of juveniles extracted from the roots of tomatoes and okra were obtained, being the final population for these two species obtained. The extraction method was according to Hussey & Barker (1973). The marketable (diameter >45 mm) and total mass of tubers (t/ha) were accessed. The reproduction factor (RF) was estimated based on Oostenbrink (1966): final population at harvest + total number of juveniles extracted from the outer surface of potato tubers or on the roots of control species / initial population in the soil at planting time. According to this methodology, plants with RF<1.00 are considered resistant, while those with RF ≥1.00 are considered susceptible.

After performing Liliefors normality and Bartlett homogeneity presuppositions tests, data were subjected to analysis of variance and clustering of treatment means by Scott-Knott (1974), using the Genes software (Cruz, 2016). The ratio between the genetic coefficient of variation on the environmental coefficient of variation (CVg/CV) was also calculated according to Cruz *et al*. (2012).

RESULTS AND DISCUSSION

There were significant differences among genotypes for the number of 2^{nd} stage juveniles on the outer surface of the tubers (NTJSET), for the nematode reproduction factor (RF), and for the variables that measure tuber yield. However, there were no significant differences for the initial (IP) and final (FP) population of nematodes in the soil. Although it is difficult to obtain a naturally uniform experimental field of root-knot nematodes, given the intrinsic characteristics of this type of nematode, such as the occurrence and distribution concentrated in spots, the absence of differences in IP in this case is desired. The absence of significant differences for FP in the soil was probably due to the greater proportion of environmental variation compared to the proportion of variance given by the variation of genetic order between treatments according to the mean squares of the analysis of variance. In this case, it is calculated by the ratio between the genetic coefficient of variation on the environmental coefficient of variation (CVg/CV) (Cruz *et al*., 2012). The low CVg/CV ratio for FP reveals that the environmental variance influenced this trait more than the genetic variation for the evaluated genotypes, so that it would not be possible to indicate precisely which genotypes were superior or inferior based only on that criterion.

The environmental coefficients of variation ranged from 56.43% to 88.79% for the nematological variables, and are within the normal range for field experiments with nematodes (Charchar & Moita, 2001, Pinheiro *et al*., 2013, 2018).

We verified that the tomato cultivar Rutgers, used mainly to test the multiplication of the inoculum in the experiment (susceptible), presented the highest average number of juveniles in the root tissue, with 712 individuals (Table 1). The susceptible control of the okra cultivar Santa Cruz 47 (225.00) together with the potato clones BGB476 (195.00), CH04 (150.00), F53-11-05 (150.00), MB54-02 (200.00), OD80-02 (175.00) and the cultivar Atlantic (180.00), also showed a high number of nematodes, on average, in the most superficial portion of the tubers or roots in the case of okra, above 150 individuals.

Considering the multiplication rate, both in soil and in plant tissues, represented by the reproduction factor (RF), it was verified that the potato clones BGB476 (37.86), CH38 (23.04), OD80-02 (17.58), ORG14599 (19.38) and the cultivars Atlantic (25.00) and Epagri Catucha (60.00) allowed a higher nematode multiplication rate, thus being the most susceptible genotypes. The other genotypes showed lower multiplication rates ranging from 0.68 for the clone F119-12-01 to 7.60 for the cultivar Agata, in addition to the okra cultivar with 7.92.

Table 1. Initial and final population of second-stage juveniles, number of juveniles in tuber skin and reproduction factor of *Meloidogyne* ssp. in a naturally infested field, cultivated with twenty potato genotypes. Brasília, Embrapa Hortaliças, 2022.

Clones	[1]IP/	[2]FP	[3]NTJSET	[4]RF
	150 cm³ of soil			
F119-12-01	125.00 a	60.00 a	25.00 c	0.68 b
F88-11-01	55.25 a	240.00 a	65.00 c	5.52 b
F129-12-08	55.00 a	247.50 a	50.00 c	5.41 b
MB54-02	50.00 a	142.50 a	200.00 b	6.85 b
CH04	40.00 a	37.50 a	150.00 b	4.69 b
C2743-09-09	35.50 a	45.00 a	25.00 c	1.97 b
F53-11-05	35.25 a	52.50 a	150.00 b	5.74 b
CH41	35.00 a	120.00 a	100.00 c	6.29 b
OD38-06	30.00 a	52.50 a	100.00 c	5.08 b
F63-10-13A	25.00 a	172.50 a	100.00 c	10.90 b
ORG14599	20.00 a	262.50 a	125.00 c	19.38 a
OD80-02	15.50 a	97.50 a	175.00 b	17.58 a
F65-13-06	15.25 a	75.00 a	25.00 c	6.56 b
BGB476	10.50 a	202.50 a	195.00 b	37.86 a
CH38	5.75 a	82.50 a	50.00 c	23.04 a
Markies	25.25 a	112.50 a	50.00 c	6.44 b
Agata	25.00 a	90.00 a	100.00 c	7.60 b
Asterix	20.00 a	7.50 a	25.00 c	1.63 b
Atlantic	10.50 a	82.50 a	180.00 b	25.00 a
Epagri Catucha	5.75 a	270.00 a	75.00 c	60.00 a
Tomato	70.00 a	150.00 a	712.50 a	12.32 b
Okra	30.00 a	12.50 a	225.00 b	7.92 b
General mean	33.61	118.86 a	131.93	12.66
CV (%)[6]	56.43	75.92	72.57	88.79
CVg/CV[7]	0.41	0.07	0.69	0.51

[1]IP= Initial population of 2nd stage juveniles (J2) per 150 cm³ of soil; [2]FP= Final population of J2 per 150 cm³ of soil; [3]NTJSET= Total number of juveniles extracted from the outer surface of 10 tubers (±3 mm thick) according to Hussey & Barker (1973); [4]RF= Reproduction factor based on Oostenbrink (1966) (final population at harvest + NTJSET) / (initial population at planting). Plants with RF<1.00 = resistant. RF≥1.00 = susceptible. Values in the same column followed by the same letter do not differ by the Scott-Knott test (P<0.05). CV (%): Coefficient of variation in percentage. CVg/CV: ratio between genotypic and phenotypic coefficient of variation.

Considering the genotypes with the lowest amount of nematodes in plant tissues and also with the lowest values of reproduction factor, it can be concluded that the genotypes with the lowest level of susceptibility were clones C2743-09-09 (1.97), CH41 (6.29), F119-12-01 (0.68), F129-12-08 (5.41), F63-10-13A (10.90), F65-13-06 (6.56), F88-11-01 (5.52), and OD38-06 (5.08), and the cultivars Markies (6.44), Agata (7.60), and Asterix (1.63). About the RF, the clone F119-12-01 can be classified as resistant, for having a reproduction factor below unity (0.68). However, as the average initial population of its experimental plots were numerically higher and larger, initial inoculums usually have the opposite effect on the final RF (Patel *et al*., 2020), and, as the RF did not differ statistically from these cited clones, we can consider that it would have the same degree of resistance.

Field evaluations of nematodes have the advantage of providing conditions for the evolution of the population dynamics of these organisms in real cultivation conditions, in addition to also providing the evaluation of other traits such as productivity in the case of species that produce roots and tubers (Silva *et al*., 2011). Thus, the clone MB54-02 was the most productive, with 22.56 t/ha of commercial tubers. In addition, the clones CH38 (12.17), F53-11-05 (11.63), F63-10-13A (13.04), F65-13-06 (10.53), OD38-06 (12.52), and ORG14599 (13.44) showed yields similar to the cultivars Markies (14.65) and Atlantic (12.33), and higher than Agata (6.27) and Asterix (1.63), and the other clones (Table 2).

Table 2. Clustering means of potato clones for tuber yield traits in a field infested with *Meloidogyne* ssp. Brasília, Embrapa Hortaliças, 2022.

Clones	MCT (t/ha)	TMT (t/ha)
MB54-02	22.56 a	24.35 a
ORG14599	13.44 b	14.71 b
F63-10-13A	13.04 b	14.79 b
OD38-06	12.52 b	13.40 b
CH38	12.17 b	12.52 b
F53-11-05	11.63 b	12.10 b
F65-13-06	10.53 b	11.01 b
F129-12-08	9.77 c	11.81 b
BGB476	9.58 c	11.88 b
F88-11-01	8.84 c	10.15 b
CH41	8.15 c	8.86 c
C2743-09-09	7.08 c	7.50 c
OD80-02	6.13 c	7.00 c
CH04	4.26 c	5.96 c
F119-12-01	3.81 c	4.46 c
Markies	14.65 b	15.11 b
Atlantic	12.33 b	12.65 b
Agata	6.27 c	7.81 c
Asterix	5.81 c	6.15 c
Epagri Catucha	3.52 c	4.77 c
General mean	9.80	10.85
CV (%)	20.99	19.45
CVg/CV	0.99	0.94

MCT: mass of commercial tubers; TMT: total mass of tubers. Values in the same column followed by the same letter do not differ according to the Scott-Knott test (P<0.05); CV (%): coefficient of variation in percentage; CVg/CV: ratio between genotypic and phenotypic coefficient of variation.

There are decreases in productivity in potato crops infected with root knot nematodes (Pinheiro & Lopes, 2011; Akiazi & Deveci, 2022), however in this study it was not possible to separate the effect of genotype on yield from the effect of nematodes. It would be possible if there were two identical cultivation conditions and plots with and without nematodes in the soil for all the genotypes. Nevertheless, we can select which ones are more resistant and with higher tuber yield potential. Therefore, the clones that stood out for lower degree of susceptibility (RF) to root-knot nematodes and higher tuber yield were MB54-02 (6.85 and 22.56, respectively), F53-11-05 (5.74 and 11.63), F63-10-13A (10.90 and 13.04), F65-13-06 (6.56 and 10.53), OD38-06 (5.08 and 12.52).

In an experiment of potato genotypes for reaction to root-knot nematodes, Charchar & Moita (2001) evaluated the reaction of 48 potato genotypes to *M. javanica* in a naturally infested field, mostly imported cultivars. Despite observing a RF value of 25 during the rainy season (November to March), the authors classified the Achat cultivar as moderately resistant, since the percentage of infection was 31% lower than the infection of other genotypes.

In a greenhouse experiment, Silva *et al*. (2010) evaluated the reaction of 12 potato genotypes (HPC 7 B, Lady Rosetta, Agata, Cupido, Monalisa, Panda, Itararé, Asterix, Capiro, Atlantic, Mayor, and Canchan) to *M. incognita*, *M. javanica* and *M. enterolobii* (syn. *M. mayaguensis*) in two seasons (July to September 2007 and January to April 2008), and observed that, at 60 days after inoculation, all genotypes presented reproduction of the three species, being that *M. enterolobii* produced the highest number of eggs.

Lima-Medina *et al*. (2012) evaluated in a greenhouse, nine potato cultivars [Epagri Catucha, BRS Clara, PCD 03-11 (current BRSIPR Bel), Eliza, BRS Ana, Cristina (current IPR Cris), SCS Cota, Asterix, and Agata] for reaction to *M. incognita*, *M. graminicola*, *M. arenaria*, and *M. ethiopica.* Assesing 55 cultivars after inoculation, they found that all cultivars were susceptible to *M. incognita*, *M. ethiopica*, and *M. arenaria* (RF>1). For *M. graminicola*, however, only BRSIPR Bel, Asterix, Cristina, Agata and Eliza were resistant (RF<1).

Lima-Medina *et al*. (2014) evaluated potato cultivars for reaction to *M. ethiopica*, and observed that Eliza behaved as moderately resistant;

BRS Ana, BRSIPR Bel, Agata, and Epagri Catucha, as moderately susceptible; BRS Clara, Asterix, IPR Cris, and SCS Cota, susceptible; and Caesar, as highly susceptible.

Lima-Medina *et al*. (2016) evaluated nine potato cultivars in a greenhouse, including Epagri Catucha, Asterix and Agata, regarding their reaction to eight root-knot nematode species, that were *M. javanica*, *M. incognita*, *M. arenaria*, *M. enterolobii*, *M. paranaensis*, *M. hapla*, *M. morociensis*, and *M. graminicola*. They found that all cultivars were susceptible to all *Meloidogyne* species, except *M. graminicola*. The cultivars with the lowest degree of susceptibility to *M. javanica* were Epagri Catucha, Eliza and IPR Cris; to *M. incognita*, Agata; to *M. hapla*, Eliza; to *M. arenaria*, SCS Cota, BRS Clara, Asterix, BRS Ana, Eliza, and Agata; to *M. enterolobii*, BRSIPR Bel and Asterix; to *M. paranaensis*, Epagri Catucha, BRSIPR Bel, Agata, Asterix, SCS Cota, BRS Clara, and BRS Ana; to *M. morocciencis*, Agata; and, to *M. graminicola*, Eliza, IPR Cris and Asterix were immune, and Agata and Epagri Catucha, resistant.

Schafer *et al*. (2017) evaluated three national potato cultivars, BRS Ana, BRSIPR Bel and BRS F63 - Camila and seven clones (F23-11-06, F22-01-08, F189-09-06, F23-24-06, F38-03-07, F32-02-06, and CL02-05) for reaction to *M. javanica*. All genotypes showed susceptibility (RF>1). RF values ranged from 11.30 to 41.30, and were lower for clones F22-01-08 (17.80) and CL02-05 (11.30), and for the three control cultivars BRS Ana (20.30), BRSIPR Bel (20.80) and BRS F63 - Camila (13.30), and higher for F23-11-06 (28.80), F189-09-06 (30.00), F23-24-06 (41.30), F38-03-07 (31.40), and F32-02-06 (36.20).

Pinheiro *et al*. (2018) evaluated, in a field naturally infested with *M. javanica*, the reaction of 12 potato clones, and the control cultivars Agata and Asterix, among them the same clones evaluated in the study reported above, except for clone CL02-05, and also verified that all were susceptible (RF>1). However, in comparison with the coincident clones, they also verified numerically smaller RF for the clone F22-01-08 (4.72), in addition to the cultivars Agata (2.15) and Asterix (5.19), and numerically larger for F23-11-06 (8.78), F189-09-06 (8.53), F23-24-06 (24.22), F38-03-07 (10.50) and F32-02-06 (74.44). The lower RF values for Agata and Asterix also agree with the present study, where lower RF were also observed (7.60 and 1.63, respectively). In that study, the average RF of the genotypes was 13.08, which were very similar to the present study (12.66).

The same authors (Pinheiro *et al*., 2018) evaluated another set of potato clones in the field, but naturally infested with *M. incognita* race 1 and in another agricultural year, coinciding with the evaluation of only clone F22-01-08, and comparing with the cultivar Epagri Catucha. Among the 12 clones, F183-08-01 (current cultivar BRS F183 - Potira) and F50-08-01 (current cultivar BRS F50 - Cecília) had lower mean RF for this nematode (4.41) as compared to the assay with *M. javanica* of the previous year. It was observed that the cultivar Epagri Catucha was among the most susceptible, with RF of 12.72, agreeing with the present work where it numerically presented the highest RF (60.00).

Mao *et al*. (2019) isolated *M. javanica* and *M. incognita* from potato tubers in China and inoculated 28 potato genotypes. The authors found that all genotypes were susceptible with variation in susceptibility levels.

Therefore, based on both national and international literature, as well as on the present study, the most common reaction of potato genotypes to the root-knot nematodes *M. incognita* and *M. ethiopica* has varying levels of susceptibility, and so far, there are no resistant potato genotypes.

It was possible to verify that the clones C2743-09-09, CH41, F119-12-01, F129-12-08, F63-10-13A, F65-13-06, F88-11-01, and OD38-06, and the cultivars Markies, Agata and Asterix have the lowest levels of susceptibility to *M. incognita* and *M. ethiopica* mixture. However, combining a lower degree of susceptibility and good tuber yield, clones MB54-02, F53-11-05, F63-10-13A, F65-13-06, and OD38-06 stand out. It was also verified that the commercial cultivars Atlantic and Epagri Catucha allowed greater multiplication of nematodes in the field compared to the other cultivars.

REFERENCES

AKYAZI, F; DEVECİ, A. 2022. The host status of some commercial potato cultivars and local genotypes to *Meloidogyne incognita* infection. *International Journal of Agricultural and Natural Sciences* 15: 55-60.

AZLAY, L; BOUKHARI, MEM; MAYAD, EH; BARAKATE, M. 2022. Biological management of root-knot nematodes (*Meloidogyne* spp.): a review. *Organic Agriculture*: 1-19.

BALI, S; ZHANG, L; FRANCO, J; GLEASON, C. 2021. Biotechnological advances with applicability in potatoes for resistance against root-knot nematodes. *Current Opinion in Biotechnology* 70: 226-233.

CARNEIRO, RMDG; ALMEIDA, MRA. 2001. Técnica de eletroforese usada no estudo de enzimas dos nematoides de galhas para identificação de espécies. *Nematologia Brasileira* 25: 35-44.

CHARCHAR JM; MOITA, AW. 2001. Resistência de genótipos de batata a *Meloidogyne javanica*. *Pesquisa Agropecuária Brasileira* 36: 535-540.

CRUZ, CD. 2016. Genes software-extended and integrated with the R, Matlab and Selegen. *Acta Scientiarum. Agronomy* 38: 547-552.

CRUZ, CD; REGAZZI, AJ; CARNEIRO, PCS. 2012. *Modelos biométricos aplicados ao melhoramento genético*. 4ª ed. Viçosa: Editora UFV. 514p.

HUSSEY, RS; BARKER, KR. 1973. A comparison of methods of collecting inocula of *Meloidogyne* spp., including a new technique. *Plant Disease Reporter* 57: 1025-1028.

JENKINS, WR. 1964. A rapid centrifugal flotation technique for separating nematodes from soil. *Plant Disease Report* 48: 692-695.

LIMA-MEDINA, I; BELLÉ, C; CASA-COILA, VH; PEREIRA, AS; GOMES, CB. 2016. Reação de cultivares de batata aos nematoides-das-galhas. *Nematropica* 46: 188-196.

LIMA-MEDINA, I; CASA-COILA, VH; GOMES, CB; PEREIRA, AS; NAZARENO, NRX. 2014. Ocorrência de *Meloidogyne ethiopica* no Paraná e reação de cultivares de batata ao nematoide das galhas. *Horticultura Brasileira* 32: 482-485.

LIMA-MEDINA, I; GOMES, CB; SOMAVILLA, L; SIGNORINI, CHB; BRUM, D. 2012. Resistência varietal de cultivares y clones de papa al nematodo del nudo de la raiz (*Meloidogyne* spp.). In: Congreso de la Associación Latinoamericana de la Papa, 25; Encontro Nacional de Produção e Abastecimento de Batata, 14. Uberlândia: Associacion Latinoamericana de la Papa. CD-ROM. 18.

MACHARIA, TN; BELLIENY-RABELO, D; MOLELEKI, LN. 2020. Transcriptome profiling of potato *(Solanum tuberosum* L.) responses to root-knot nematode (*Meloidogyne javanica*) infestation during a compatible interaction. *Microorganisms* 8: 1443.

MAO, Y; HU, Y; LI, C; ZHANG, H; YU, D; LIU, X; YANG, G; WANG, C. 2019. Molecular identification of *Meloidogyne* species isolated from potato in China and evaluation of the response of potato genotypes to these isolates. *Nematology* 21: 847-856.

OOSTENBRINK, M. 1966. Major characteristics of the relation between nematodes and plants. *Mededelingen Landbouw* 66: 1-46.

PATEL, B; PATEL, DB; TAPRE, PV; SINGH, NK; PATEL, R. 2020. Pathogenicity of root-knot nematode (*Meloidogyne incognita*) and determination threshold level in potato (*Solanum tuberosum* L.) crop cv. Lady Rosseta. *International Journal of Bio-Resource and Stress Management* 11: 103-107.

PINHEIRO, JB; CARVALHO, ADF; RODRIGUES, CS; PEREIRA, RB; SUINAGA, FA. 2013. *Reação de clones avançados de batata em campo naturalmente infestado pelo nematoide-das-galhas*. Embrapa Hortaliças. Embrapa. Boletim Pesquisa e Desenvolvimento 99. 18p.

PINHEIRO, JB; LOPES CA. 2011. *Manejo integrado de nematoides em cultivos de batata*, p. 69-94. In: ZAMBOLIM, L (ed). Produção integrada da batata. Volume 2. Viçosa: Universo Agrícola.

PINHEIRO, JB; SILVA, GO; BISCAIA, D; MACÊDO, AG; RAGASSI, CF; SANTIAGO, DC. 2018. Reação de genótipos de batata ao nematoide-das-galhas *Meloidogyne* spp. em campos naturalmente infestados. *Revista Latinoamericana de la Papa* 22: 1-11.

SCHAFER, JT; GOMES, CB; PEREIRA, AS; CRUZ, FF; BARROS, DR. 2017. Resistance of potato genotypes to *Meloidogyne javanica*. *Revista Caatinga* 30: 536-540.

SCOTT, AJ; KNOTT, M. 1974. A cluster analysis method for grouping means in the analysis of variance. *Biometrics* 30: 507-512.

SILVA, AR; SANTOS, JM; HAYASHI, PCR; HAYASHI, E. 2010. Reação de clones e cultivares de batata avaliados em casa de vegetação a *Meloidogyne incognita*, *M. javanica* e *M. mayaguensis* e *in vitro* a *M. javanica*. *Nematologia Brasileira* 34: 48-55.

SILVA, GO; PINHEIRO, JB; VIEIRA, JV; CARVALHO, ADF. 2011. Seleção para resistência de genótipos de cenoura aos nematoides-das-galhas. *Horticultura Brasileira* 29: 335-341.

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