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Reaction of garlic genotypes to *Ditylenchus dipsaci* and aspects related to productivity in a naturally infested area

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ABSTRACT

The stem and bulb nematode, *Ditylenchus dipsaci,* is one of the main problems which affects garlic crop in Brazil; however, information on the host status of the crop to the pathogen is scarce. Thus, the aim of this study was to evaluate the host status of 11 garlic genotypes to *Ditylenchus dipsaci* and their productivity in experiments conducted under controlled conditions and in the field. In a greenhouse, diverse genetic materials were evaluated for nematode reproduction factor (RF). At the same time, the nematode reproduction, damage caused and productivity of these same genotypes were evaluated in an area naturally infested. In the greenhouse, 'AM-PC Farias', 'Quitéria', 'BRS Hozan', 'Peruano', 'Chonan' and 'Moz 114' were resistant; and, under field conditions, in these same genotypes, the nematode showed the lowest rates of reproduction in the soil (RF= 0.2 to 10.77) and in the tissues (1 to 3,893 specimens/plant), and there were the lowest percentages of symptomatic (0 to 48.66%) and dead (4.17 to 19.57%) plants. Higher productivities (4.32 to 11.05 t/ha) and bulb weight (13.12 to 58.63 g) were obtained with 'AM-PC Farias', 'Quitéria' and 'AM-Erenice'; however, only in 'AM-PC Farias' and in 'BRS Hozan' we observed lower population levels of *D. dipsaci* in bulb peels (110 and 0.1 specimens/g, respectively).

Keywords: *Allium* spp., resistance, nematodes, damage.

RESUMO

Reação de genótipos de alho a *Ditylenchus dipsaci* e aspectos relacionados com a produtividade em área naturalmente infestada

O nematoide-do-amarelão-do-alho é um dos principais problemas que afeta a cultura no Brasil, no entanto, informações sobre a resistência da cultura ao patógeno são escassas. Assim, foi objetivo deste estudo avaliar a reação de 11 genótipos de alho a *Ditylenchus dipsaci* e sua produtividade em experimentos conduzidos sob condições controladas e de campo. Em casa de vegetação, os diferentes materiais genéticos foram avaliados quanto ao fator de reprodução (FR) do nematoide. Paralelamente, avaliou-se, em área com solo naturalmente infestado, a reprodução do nematoide, os danos causados e a produtividades desses mesmos genótipos. Em casa de vegetação, 'AM-PC Farias', 'Quitéria', 'BRS Hozan', 'Peruano', 'Chonan' e 'Moz 114' foram resistentes e, em condições de campo, nesses mesmos genótipos, o nematoide apresentou as menores taxas de reprodução no solo (FR= 0,2 a 10,77) e nos tecidos (1 a 3.893 espécimes/planta), menores percentagens de plantas sintomáticas (0 a 48,66%) e mortas (4,17 a 19,57%). Maiores produtividades (4,32 a 11,05 t/ha) e peso de bulbos (13,12 a 58,63 g) foram obtidos com 'AM-PC Farias', 'Quitéria' e 'AM-Erenice', porém, apenas no primeiro e em 'BRS Hozan', foram observados baixos níveis populacionais de *D. dipsaci* nas cascas dos bulbos (110 e 0,1 espécimes/g, respectivamente).

Palavras-chave: *Allium* spp., resistência, nematoides, danos.

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Garlic (*Allium* spp.) is an important spice in Brazilian cuisine. The consumption of garlic is 1.5 kg/inhabitant/year (Resende *et al*., 2016). The states of Rio Grande do Sul (RS) and Santa Catarina (SC) are among the four largest producers of garlic in Brazil, being responsible for almost 25% of the national production (IBGE, 2021). However, several diseases significantly affect the crop yield, just like the infection caused by the stem and bulb nematode *Ditylenchus dipsaci*, which may result in losses of up to 100% (Charchar, 2001; Pinheiro *et al*., 2014).

Ditylenchus dipsaci is difficult to be managed, mainly due to its survival in anhydrobiosis, ensuring viable initial inoculum (Pinheiro, 2017). The life cycle of the nematode varies between 19 and 23 days, under warm temperatures (15 to 20^{0}C), and a single female can produce up to 500 eggs. Thus, in a garlic harvest, we can verify several

nematode generations (Chitambar *et al*., 2018), causing typical symptoms of the disease such as yellowing of the tissues, pseudostem thickening, reduced plant growth, rotting and hollow bulbs (Charchar *et al*., 2003).

Especially in the extreme south of the RS state, this disease caused by *Ditylenchus dipsaci* is a recurring problem due to soil infestation, the use of the same area for cultivation and susceptibility of garlic cultivars that together have a negative impact on production (Araújo Filho *et al*., 2018; Grinberg & Gomes, 2018). The use of resistant materials in the field can guarantee better productivity, in addition to reducing the inoculum potential in cloves, restricting the dissemination of the nematode to other regions (Charchar *et al*., 2003). In studies carried out in Brazil, some garlic genotypes resistant to *D. dipsaci* were verified (Charchar *et al*., 2003). However, these investigations were not conclusive because the tolerance or resistance of garlic to nematode was not evaluated in the field.

In this sense, this study aimed to evaluate the reaction of different garlic genotypes to *D. dipsaci* in a greenhouse; and, investigate the response of these genotypes in relation to the nematode reproduction (plant, bulbs, and in soil), disease progress and productivity under field conditions.

MATERIAL AND METHODS

This study was carried out in a greenhouse, in Pelotas-RS; and at field conditions in a family property located in Quitéria, municipality Rio Grande-RS (32º02'29.7"S; 52º15'15.0"W).

Two experiments were conducted in a greenhouse, in 2018 (Experiment 1) and 2020 (Experiment 2), in which 11 commercial garlic genotypes were evaluated from May to August (Table 1). The authors used nine garlic genotypes (*Allium sativum* = 'Amarante', 'Araguari', 'Cateto Roxo', 'Chonan', 'Gravatá', 'BRS Hozan', 'Moz 114', 'Peruano' and 'Quitéria') from the Active Germplasm Bank of Embrapa Hortaliças and two male garlic genotypes (*A. ampeloprasum* var. *ampeloprasum*, nominated in this study as: 'AM-Erenice' and 'AM-PC Farias'), from rural properties of municipalities of Pelotas and Rio Grande.

We used inoculum of *D. dipsaci* specimens extracted from infected garlic bulbs, previously collected in an infested field of the property where the field studies were conducted. The nematode species were identified by morphometric characterization of 20 males and 20 females, which are within the proposed range for *D. dipsaci* [Males: n = 20; L (mm) = 1.3 ± 0.13; St (µm) = 11.93 ± 0.66; a = 43.8 ± 4.98; b = 6.41 ± 0.76; c = 13 ± 1.10; c' = 4.82 ± 0.50. Females: n = 20; L (mm) = 1.24 ± 0.10; St (µm) = 11.99 ± 0.46; a = 42.04 ± 3.84; b = 6.48 ± 0.54; c = 13.06 ± 0.93; c' = 5.15 ± 0.34; V (%) = 81.81 ± 1.16] according to Sturhan & Brzeski (1991).

The soil used in the greenhouse trials (20±5°C) was classified as sandy loam, being collected at the same area where the field experiments were implanted; (14% clay and 0.6% organic matter), showing the following chemical properties: pH= 6.1; P= 231.2 mg/dm^3; K= 27 mg/dm^3; Na= 14 mg/dm^3; Ca= 1.1 cmolc/dm^3; Mg= 0.7 cmolc/dm ^{3}, base saturation at 48%. First, the soil was sterilized and, subsequently, the soil pH was corrected using limestone and mineral fertilizer (10-20-20) according to recommendation for the crop and need for the volume used (Silva *et al*., 2016). The garlic cloves of each genotype were individually planted in 5 L plastic pots containing 5 L of soil. Both experiments were conducted in a completely randomized design, with six replicates per treatment.

In the experiment conducted in 2018, ten days after emergence, each plant was inoculated with 1 mL aqueous suspension containing 1000 specimens of *D. dipsaci* (IP = initial population), keeping the inoculum between the emerged leaves, according to Plowright *et al*. (2002). Therefore, the pots were kept in a humid chamber for 15 days. In the experiment conducted in 2020, additionally, the authors estimated the percentage of active forms (7.3% mobile specimens) in the nematode suspension used for inoculation in order to compare the data from nematode reproduction in both mobility conditions [total initial population of *D. dipsaci* (TIP) and number of live specimens (NLV)].

One hundred days after inoculation, the plants were harvested for nematological evaluations. Each plant was processed, separating the bulb and shoot parts to extract nematodes by immersing the plant material in the water in a Petri dish for 24 h (IPPC, 2016). Subsequently, the specimens present in the soil were extracted from 250 cm^3 of each pot (Jenkins, 1964) and the total number of nematodes was estimated [final population (FP) = soil specimens + plant material specimens] under stereomicroscope (10 x), IMPAC Tokyo. For each genotype, the nematode reproduction factor was determined (RF = FP/IP), considering as resistant, the ones in which the nematode presented RF<1.0, and susceptible, those which presented RF≥1.0 (Oostenbrink, 1966).

The same genotypes were evaluated in the field naturally infested with *D. dipsaci*, from July, 2019 to January, 2020. This experiment was conducted in a randomized block design with six replicates. Acidity correction and the mineral fertilization were performed according to the recommendation for this crop (Silva *et al*., 2016). After seedbed raising operation, 1 kg soil samples were collected at 0-20 cm depth. Then, the nematodes were extracted (Jenkins, 1964) in order to estimate the IP of each micro-plot/250 cm^3 soil. Each micro-plot consisted of 20 plants in four planting lines, spacing 10 cm for the genotypes *A. sativum* and 12 plants spacing 20 cm for genotypes of *A. ampeloprasum* var. *ampeloprasum.*

At 101 days after planting (DAP), the authors evaluated disease incidence for each micro-plot, considering the plants showing symptoms (leaf yellowing, pseudostem shortening and thickening, and plant rot) and dead plants, whose data were estimated in percentage. Three plants of each micro-plot were randomly collected for detecting and quantifying the nematode. Afterwards, the plants were weighed and fractionated, picking up one 35 g subsample (20 g of bulbs and 15 g of shoot area) in order to extract the

nematodes, following the methodology mentioned above (IPPC, 2016) and to estimate the total population of *D. dipsaci*, per plant and per gram of tissue. Further evaluations of incidence of *D. dipsaci* on garlic were performed at 112, 123, 133, 140, 149 and 158 DAP, according to the cycle of each genotype. Using these data, we calculated the area under the disease progress curve (AUDPC), using software GW Basic 3.20 (Maffia, 1986).

At the end of the cycle of each genotype, the micro-plots were harvested and the bulbs weighed to estimate productivity. Later, one sample weighing approximately 1.0 kg of soil was collected from each micro-plot in the 0-20 cm deep layer in order to extract the nematodes in 250 cm^3 soil (Jenkins, 1964) and estimate the RF, considering only the FP from the soil.

Finally, we quantified the number of *D. dipsaci* in dried bulbs. All bulbs collected per micro-plot were peeled and the peels were chopped and homogenized and used as samples (2.5 g) for nematode extraction (IPPC, 2016). The number of nematodes was estimated using a stereomicroscope (10 x). The reaction of the genotypes was determined according to Oostenbrink (1966).

Obtained data were transformed when necessary, and submitted to variance analysis (ANOVA). When statistical significance between factors was verified, the averages of each treatment were compared with each other using Scott-Knott grouping test ($p<0.05$) with the aid of SASM-Agri Software. The interaction analysis between genotype and evaluation period was performed by Duncan test at 5% probability using SAS 9.4 software.

RESULTS AND DISCUSSION

Considering the results obtained in the greenhouse in 2018 and 2020, the genotypes 'Quitéria', 'Peruano', 'AM-PC Farias', 'BRS Hozan', 'Chonan' and 'Moz 114' behaved as resistant, according to RF *D. dipsaci* values ($0.003<RF<0.883$). On the other hand, 'Amarante', 'Araguari' and 'AM-Erenice' were susceptible ($1.067<RF<12.402$, for TIP and $RF<110.34$, for NEV), being the highest values of RF observed in the last two genotypes considering TIP in the initial nematode population (Table 1). The genotypes 'Cateto Roxo' and 'Gravatá' showed contrasting responses in the evaluated years. Based on NLV to calculate RF of the nematode (experiment 2020), the reaction of the genotypes did not change when compared to TIP. However, in the same garlic genotype, the values of RF were from 10 to 17 times higher when only live specimens of *D. dipsaci* were considered (Table 1).

Evaluating the presence of *D. dipsaci* in the field before harvesting each genotype, the authors verified two different groups related to distribution of disease symptoms and mortality of garlic plants (Table 2). The first group was formed by 'Moz 114', 'AM-Erenice', 'Amarante', 'Araguari', 'Gravatá' and 'Cateto Roxo', in which the authors observed the highest frequencies of symptomatic plants [average value of the group ($\overline{X}$) = 34,88%] and, in the second group, formed by 'BRS Hozan', 'AM-PC Farias', 'Quitéria', 'Peruano' and 'Chonan', we verified the lowest frequencies ($\overline{X}$ = 5.92%). The percentage of dead plants accumulated throughout the crop cycle and symptomatic plants was similar in both groups of genotypes which presented higher ($\overline{X}$ = 27.89%) and lower mortality in the micro-plot ($\overline{X}$ = 6.21%).

Analyzing the evolution of the disease, we observed different groups

Table 1. Reproduction Factor (RF) of *Ditylenchus dipsaci* in garlic genotypes and reaction (R= resistant and S= susceptible), considering the total initial population (TIP) (1000 specimens/plant) and number of live specimens (NLS) (73 specimens/plant), evaluated in a greenhouse. Pelotas, Embrapa ClimaTemperado, 2018 and 2020.

Genotypes	Experiment 1		Experiment 2			
	RF (TIP)	Reaction	RF (TIP)	Reaction	RF (NLS)	Reaction
Araguari	12.402 a	S	2.044 c	S	22.464 c*	S[1]
Amarante	3.143 b	S	1.067 c	S	17.224 c	S
Quitéria	0.883 c	R	0.008 d	R	0.097 d	R
Peruano	0.841 c	R	0.011 d	R	0.121 d	R
Cateto Roxo	0.825 c	R	4.209 b	S	46.249 b	S
Gravatá	0.619 c	R	2.482 c	S	27.271 c	S
AM-PC Farias	0.217 c	R	0.003 d	R	0.036 d	R
AM-Erenice	-	-	10.04 a	S	110.34 a	S
BRS Hozan	-	-	0.03 d	R	0.33 d	R
Chonan	-	-	0.008 d	R	0.093 d	R
Moz 114	-	-	0.003 d	R	0.033 d	R
CV (%)	21.36		34.45		38.9	

*Averages followed by the same letter in the column do not differ from each other, by Scott-Knott grouping test at 5% significance. [1]Resistance reaction/susceptibility according to Oostenbrink (1966). (-) genotype not evaluated.

for AUDPC (Table 2). The greatest value was verified in 'AM-Erenice'. The genotypes Amarante, Araguari, Gravatá and Cateto Roxo showed intermediate AUDPC and, in the third group, formed by 'Moz 114', 'BRS Hozan', 'AM-PC Farias', 'Quitéria', 'Peruano' and 'Chonan', we observed the lowest values that coincided with the same values obtained in the two groups in which the lowest percentage of symptomatic and dead plants was verified, presenting, therefore, the lowest rates of asymptomatic plants.

The highest population levels of *D. dipsaci* per gram of tissue at 101 DAP were observed in 'Gravatá' and 'Moz 114' ($\overline{X}$ = 3358.55 specimens/g tissue), and the lowest in 'Quitéria', 'Peruano', 'AM-PC Farias' and 'BRS Hozan' ($\overline{X}$ = 24.75 specimens/g tissue) (Table 3). Comparing the populational levels, we verified a significant interaction between genotype and evaluation period for number of nematodes per plant at 101 DAP and per bulb at the end of the cycle. Considering the evaluation at 101 DAP (vegetative stage), 'Gravatá' and 'AM-Erenice' showed higher populational levels ($\overline{X}$ = 14104 specimens/plant). In the peels, evaluating at the end of the cycle, 'Gravatá' and 'AM-Erenice', 'Amarante', 'Cateto Roxo' and 'Araguari' showed the highest number of specimens/plant ($\overline{X}$ = 6866.8). Analyzing the period factor within the genotype factor, Gravatá' and 'AM-Erenice' had the highest population level at 101 DAP. The genotypes 'Araguari', 'Quitéria', 'Peruano' and 'AM-PC Farias' had a greater number of specimens in the peels compared with the living tissue of the plant (Table 3).

Higher values of *D. dipsaci* for FP and RF (Table 4) in the soil were found in the micro-plots grown with 'AM-Erenice' and 'Cateto Roxo' ($\overline{X}$ = 249.86). A second group was formed by 'Gravatá', 'Araguari' and 'Amarante' ($\overline{X}$ = 97.89). In genotypes 'Quitéria', 'Chonan', 'Peruano', 'AM-PC Farias', 'BRS Hozan' and 'Moz 114', we observed the lowest values of RF ($\overline{X}$ = 4.49) and the lowest nematode populational levels ($\overline{X}$ = 8.4 specimens/250cm^3). Therefore, 'Moz 114' was the only genotype which showed RF of *D. dipsaci* lower than 1.

Table 2. Incidence of *D. dipsaci* symptoms in different garlic genotypes (not cumulative) and dead plants (cumulative) before harvest and the area under the disease progress curve (AUDPC) under field conditions. Pelotas, Embrapa ClimaTemperado, 2018 and 2020.

Genotypes	Symptoms (%)	Dead plants (%)	AUDPC
Moz 114	48.66 a*	19.57 a*	557.88 c**
AM-Erenice	37.50 a	33.57 a	1942.48 a
Amarante	37.19 a	31.65 a	1127.71 b
Araguari	32.48 a	31.43 a	1042.40 b
Gravatá	29.94 a	25.84 a	880.62 b
Cateto Roxo	23.56 a	25.30 a	881.63 b
BRS Hozan	13.26 b	6.21 b	294.51 c
AM-PC Farias	9.26 b	3.70 b	249.07 c
Quitéria	4.68 b	11.19 b	516.41 c
Peruano	2.38 b	5.79 b	125.25 c
Chonan	0.00 b	4.17 b	134.25 c
CV (%)	46.86	59.47	62.2

*Averages arc sin $\sqrt{(x/100)}$ followed by the same letter do not differ from each other, by Scott-Knott grouping test at 5% significance. **Averages followed by the same letter do not differ from each other, by Scott-Knott grouping test at 5% significance.

Considering the garlic genotypes grown in the area infected with *D. dipsaci* (Table 5), 'AM-PC Farias' was the most productive (11.05 t/ha), showing the highest bulb weight per plant (58.63 g) followed by 'AM-Erenice' with average productivity of 5.9 t/ha and 21.9 g/bulb. A third group was formed by 'Quitéria' and 'Peruano' (4 t/ha and 9.75 to 13.12 g/bulb), and a fourth group formed by 'Cateto Roxo', 'Amarante', 'Araguari', 'Gravatá', 'Moz 114', 'BRS Hozan' and 'Chonan', exhibited the lowest yield (0.4 to 2.8 t/ha and 1.1 to 6.3 g/bulb).

The results of the reaction of garlic genotypes to *D. dipsaci* observed in this study are in accordance with the ones obtained by Charchar (2001) and Charchar *et al*. (2003). In these studies, the authors also verified resistance response of 'Quitéria', 'Peruano' and 'BRS Hozan' to stem and bulb nematode under greenhouse conditions. However, for 'Cateto Roxo' and 'Gravatá', the reaction varied in the two experiments. According to Plowright *et al*. (2002), the population dynamics of *D. dipsaci* can vary depending on the conditions of relative humidity and temperature. Although relative humidity was not measured during these tests, the combination of such factors may have influenced the responses observed in this study.

Considering the nematode mobility in the inoculation of garlic plants, higher multiplication rates were observed when RF was calculated based on the number of mobile specimens of *D. dipsaci*/plant. However, the variation of these IP levels did not affect the reaction of the genotypes. Based on these observations, we believe that a small number of active nematodes is necessary to establish infection in garlic plants, and, thus, to evaluate the resistance of the genotypes to *D. dipsaci* nematode, as already observed by Plowright *et al.* (2002) studying other hosts such as beans, alfalfa, clover and peas. These authors reported that IP from 100 to 200 *D. dipsaci* specimens per plant are sufficient for establishing experiments, number up to three times higher than that verified in the present study (73 active specimens/plant).

Based on the results obtained in the field, we believe that the garlic genotypes in which the highest populational

densities were observed, at 101 DAP, might present lower productivity and lower bulb weight, according to the verified for 'Cateto Roxo', 'Amarante', 'Araguari', 'Gravatá' and 'Moz 114'. The genotype 'AM-Erenice', although showing the second highest productivity, also provided an accentuated multiplication of the nematode in the field. Such result is probably related to the fact that this genotype belongs to another species (*A. ampeloprasum*) which is the same species of 'AM-PC Farias', whose bulbs are larger, maintaining high production when compared to other garlic genetic species (*A. sativum*).

Table 3. Number of *Ditylenchus dipsaci* specimens per gram of tissue (N/g tec) and per plant (N/plant) in garlic genotypes evaluated at 101 days after planting (DAP) and number of nematodes per bulb (peels) in experiment carried out in an area naturally infected with the nematode. Pelotas, Embrapa ClimaTemperado, 2018 and 2020.

Genotype	N/g tec 101 DAP	N/plant 101 DAP	Peels	CV (%)
Gravatá	3962.2 a*	16778 Aa**	8068 Ba**	21.44
Moz 114	2754.9 a	3893 Ab	1671 Ab	34.68
Amarante	2208.8 b	7456 Ab	4114 Aa	49.14
Cateto Roxo	1506.3 b	7740 Ab	7274 Aa	28.06
Araguari	1182.5 b	6342 Ab	10303 Aa	33.55
Chonan	568.7 c	1060 Ac	1179 Ab	35.27
AM-Erenice	564.7 c	11430 Aa	4575 Ba	26.67
Quitéria	81.1 d	361 Bd	1492 Ab	46.33
Peruano	17.1 d	120 Bd	3008 Ab	61.60
AM-PC Farias	0.7 d	10 Bd	110 Ac	62.67
BRS Hozan	0.1 d	1 Ad	0.1 Ac	22.62
CV (%)	39.35	37.61	55.31	

*Averages followed by the same letter do not differ from each other, by Scott-Knott grouping test at 5% significance. **Averages transformed $\sqrt{(x+1)}$ followed by the same lowercase letter, in the column, and uppercase letter, in line, do not differ from each other, by Duncan test at 5% significance.

Table 4. Initial (IP) and final (PF) population of *Ditylenchus dipsaci* in soil and reproduction factor (RF= PF/IP) of the nematode in garlic genotypes, considering only the soil-extracted specimens. Pelotas, Embrapa ClimaTemperado, 2018 and 2020.

Genotypes	IP	FP	RF
	Number of specimens/250 cm³ soil		
AM-Erenice	2.4ns	571.39 a	246.87 a*
Cateto Roxo	1.8	452.83 a	252.84 a
Gravatá	1.6	333.50 b	115.03 b
Araguari	1.8	275.44 b	91.16 b
Amarante	2.2	153.83 b	87.48 b
Quitéria	1.6	21.89 c	10.77 c
Chonan	3	13.50 c	5.75 c
Peruano	1.8	9.17 c	5.72 c
AM-PCF	2.2	3.39 c	2.94 c
BRS Hozan	1.6	2.13 c	1.56 c
Moz 114	2.4	0.33 c	0.2 c
CV(%)	43.09	65.21	62.05

*Averages followed by the same letter do not differ from each other, by Scott-Knott grouping test at 5% significance. nsnot significant at 5%.

The high population density of *D. dipsaci* in garlic tissues recovered at 101 DAP can be attributed to the nematode generation time in the host plant to complete a single cycle. Thus, the genotypes which presented the highest levels in this evaluation ('Moz 114', 'AM-Erenice', 'Amarante', 'Araguari', 'Gravatá' and 'Cateto Roxo') also showed higher percentage of the disease symptoms and a quicker plant death, resulting in higher populational levels in bulb peel harvested at the end of the cycle. Consequently, the lowest values of bulb weight and yield were recorded in these genotypes.

Although the damage threshold of *D. dipsaci* for plants of the Alliaceae family is estimated at approximately 25 specimens/250cm³ of soil (Ives, 2019), lower population levels detected in the field experiment (1.6 to 3 specimens/250 cm³) showed reductions of productivity. Considering the IP extracted from the soil, only genotype 'Moz 114' showed RF lower than 1. However, this genotype showed a high nematode population in its tissues, especially in bulb peels after harvest. This observation should be taken into account in host status evaluations when a high population of *D. dipsaci* in plant and low population in soil is noticed, or vice versa (Ives, 2019).

Based on the lowest values of *D. dipsaci* RF obtained in the greenhouse besides the results in the field, including the lowest nematode population indices in plants, the percentages of symptomatic plants, AUDPC and the RF values of the nematode in soil, the genotypes Quitéria, Peruano, AM-PC Farias and Moz 114 could be recommended for planting in an area infected with *D. dipsaci*. However, considering the production and the low population indices, only 'AM-PC Farias', 'Quitéria' and 'BRS Hozan' could be suggested for planting in infected areas. Although 'BRS Hozan' presented lower than expected productivity, this cultivar has potential for use as a progenitor in

Table 5. Average values of productivity (t/ha) and weight of bulbs (g) per plant of garlic genotypes in the experiment carried out in the field naturally infected with *Ditylenchus dipsaci*. Pelotas, Embrapa ClimaTemperado, 2018 and 2020.

Genotypes	Productivity (t/ha)	Weight of bulbs (g)
AM-PC Farias	11.05 a	58.63 a*
AM-Erenice	5.93 b	21.86 b
Quitéria	4.32 c	13.12 c
Peruano	3.93 c	9.75 d
Gravatá	2.84 d	6.20 d
Cateto Roxo	2.41 d	6.25 d
BRS Hozan	2.17 d	6.29 d
Chonan	1.53 d	4.41 d
Araguari	1.52 d	4.49 d
Amarante	1.14 d	3.19 d
Moz 114	0.38 d	1.09 d
CV (%)	41.67	62.06

*Averages followed by the same letter, in the column, do not differ from each other, by Scott-Knott grouping test at 5% significance.

garlic breeding programs to incorporate resistance to *D. dipsaci* in new genetic materials. In addition, this genotype has partial resistance to garlic rust (*Puccinia allii*) and to purple blotch (*Alternaria porri*) (Embrapa, 2022). However, we should consider that, working with host resistance, the yield should be the main priority (Starr *et al*., 2002).

In crop rotation programs, 'AM-PC Farias', 'Chonan' and 'Peruano' could also be used in infected areas by its lower nematode reproduction and of symptomatic/dead plants as it was observed in greenhouse and field experiments. This management strategy could favor higher levels of suppression of stem and bulb nematode in a short period and, therefore, contribute to the reduction of production losses (Starr *et al*., 2002). In this context, this study represents the first one carried out under field conditions in micro-plots, in Brazil, interrelating all these variables with practical application in the garlic production chain.

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