

Original Research Article

Genetic parameters and population of coriander reaction ~~of coriander~~ to *Meloidogyne incognita* race 1

ABSTRACT

The genetic parameters provide indispensable information about the genetic behavior of the study population regarding the characters evaluated, providing subsidy to the breeder on the decision ~~of about~~ the best selection method ~~to adopt~~ in order to ~~obtain-realize a genetic~~ gain and maintain adequate variability. In this sense, the present study was carried out to verify the reaction and to estimate genetic parameters of a population of coriander composed ~~by of~~ two cultivars (Verdão and HTV Dom Luiz) and 49 half-siblings ~~of progenies of coriander~~ parasitized by *Meloidogyne incognita* race 1. The experiment was conducted in a greenhouse in the Department of Agronomy of the Federal Rural University of Pernambuco. ~~The 51 cultivars and progenies were arranged~~, in a randomized block design with four replicates and ~~an each~~ experimental plot ~~was~~ composed ~~by of~~ eight plants. The sowing was carried out in a tray of ~~expanded-128 cell- expanded~~ polystyrene ~~of 128 cells~~ filled with commercial substrate, 1,000 eggs/cell of the pathogen ~~being were~~ inoculated on the same day of sowing. After 30 days of inoculation, the number of galls was quantified in the root system, the pathogen's eggs were extracted and, after the quantification of the eggs, the reproduction factor was estimated for each genotype. Data ~~from of~~ the three characteristics were compared by Scott-Knott clustering test, ~~they were then~~ classified as resistant ~~and or~~ susceptible, and genetic parameters ~~were~~ estimated. The genotypes differed from each other at 1% probability level for all the characters under study, ~~being possible to select 12 progenies that were resistant to the pathogen. The~~ Heritabilities were high and positive ~~inwith the~~ values of 75.91 for number of galls in the root system and 96.72 for the number of eggs. Based on the phenotypic and genotypic correlations, it was possible to ~~indicate the~~ select ~~desired genotypes in~~ based on the number of galls in the initial selection cycles, making selection and recombination possible in the same cycle. ~~Twelve (12) progenies were selected for their resistance to the pathogen.~~

Keywords: *Coriandrum sativum* L., heritability, correlations, root-knot disease.

1. INTRODUCTION

Coriander is one of the 12 vegetables with the largest participation in the national market with a tendency to increase in the next few years [1]. ~~It is, being extremely widely~~ cultivated in the Northeast region of Brazil [2]. The planted area of about 73,938 hectares and productivity of 15 t/ha, with revenues in the production of seeds and seedlings of \$10.99 and \$243.57 **millions**, respectively [1], reflects the economic importance of the crop in the country due to its market destinations. It ranges from the consumption of its leaves and fruits in **raw state** nature, to raw material for the food, pharmaceutical, alternative medicine [3] and perfume ~~industry-industries~~ [4].

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27 | Several characteristics ~~of the crop~~ are to be improved, ~~in the crop~~, such as ~~its~~ resistance to
28 | early tillage [5], resistance to biotic and abiotic factors [6-7-8], as well as the inherent
29 | ~~characteristics of~~ color, aroma and leaf texture. Among the diseases that affect the culture
30 | ~~there is one caused by a species of the genus *Meloidogyne*, with emphasis on notably *M.*~~
31 | ~~*incognita* race 1, being~~ the most harmful to coriander [9].
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33 | There are studies in the literature evaluating the reaction of cultivars and progenies of
34 | coriander to the attack caused by *M. incognita* race 1 ~~in searching~~ to identify superior
35 | genotypes that can be a source of resistance to be explored in ~~programs of~~ genetic
36 | improvement of the ~~culture crop~~ [10-11- 9]. The evaluation of ~~populations obtained from~~
37 | different cultivars is fundamental, since the increase of genetic variability is a strategy that
38 | must be explored in order to obtain gain from selection.
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40 | The study of genetic parameters of characters related to the infection caused by *M. incognita*
41 | race 1 is fundamental for the genetic improvement of the ~~culturecrop~~, for the genetic
42 | ~~parameter statistics that~~ allow identifying the nature of the action of the genes involved in the
43 | control of the ~~quantitative characterspest~~ and to evaluate the efficiency of different breeding
44 | strategies, obtaining genetic gains and maintaining an adequate genetic basis ~~of the~~
45 | ~~breeding stock~~. Among the genetic parameters, the most important are: additive and non-
46 | additive genetic variances, ~~genetic~~ correlations, and ~~heritability~~ [12]. In this way, the breeder
47 | must choose the best characters to be used in the selective processes, taking into account
48 | information such as the CVg/CVa and heritability, ~~since, a~~ according to Costa et al. [13],
49 | heritability is a genetic parameter of extreme importance to the breeder, the estimation of the
50 | part of the phenotypic variance that is due to genetic effects and making possible the choice
51 | of the selection methods to be applied.
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53 | The objective of this work was to evaluate the reaction and to estimate the genetic
54 | parameters of two cultivars and 49 progenies of C2 half-sibs of coriander, regarding the
55 | parasitism caused by *M. incognita* race 1.
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57 | 2. MATERIAL AND METHODS

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59 | The experiment was conducted ~~under in a~~ greenhouse ~~conditions~~, in the Department of
60 | Agronomy of the Federal Rural University of Pernambuco (UFRPE), located at 8°54'47"S,
61 | 34°54'47"W, 6 m ~~highaltitude~~, in the period from November to December 2017. The monthly
62 | average temperatures recorded by the weather station of Recife Curado (automatic) varied
63 | between 22.3 - 32.2°C, for minimum and maximum ~~temperatures~~, respectively [14]. The
64 | experimental design was a randomized complete block design with four replicates, whose
65 | plot was composed of eight plants.
66

67 | The reactions of two coriander cultivars (Verdão and HTV Dom Luiz) and 49 C2 progenies of
68 | coriander half-siblings inoculated with 1,000 eggs/cell at sowing were evaluated.
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70 | Of the evaluated progenies, 44 were obtained from the Verdão cultivar, by means of the
71 | evaluation of 2,000 plants sown on a tray of ~~expanded-128 cell- expanded~~ polystyrene, ~~of~~
72 | ~~128 cells~~, inoculated with 1,000 eggs/cell of *M. incognita* race 1 at sowing and evaluated
73 | (counting of number of galls) at 30 days after inoculation, ~~selecting p~~ plants with gall
74 | numbers lower than 10 ~~were selected and, which were~~ transplanted to 2 L pots containing a
75 | substrate composed of soil and humus ~~at~~ a ratio of 3:1. The pots were placed in the open
76 | field at a spacing of 30 cm between plants in the row and 1 m between the ~~linesrows~~, so that
77 | recombination occurred among the selected individuals. At harvest, each plant had its fruits
78 | collected individually and stored in properly identified paper bags, corresponding to the half-

79 sib progenies C1. The progenies obtained in the first cycle were again evaluated with
80 inoculation of 1,000 eggs/cell at sowing in a randomized block design with three replicates
81 and ~~the a~~ plot composed ~~by of~~ 8 plants. The selection was carried out between and within
82 the progenies in the same cycle, whose selection and recombination adopted the same
83 criterion as the first selective cycle.

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85 The other 5 progenies were obtained from the HTV Dom Luiz cultivar by the same procedure
86 as the Verdão cultivar, with the exception of the **inoculum -density** (4,000 eggs/cell) and the
87 selection pressure, where the ~~selected~~ plants should have less than 5 galls in the root
88 system ~~to be selected~~. The highest **density** of inoculum in the Dom Luiz HTV cultivar was
89 **used** because it presented greater tolerance to the pathogen when compared to Verdão in
90 previous experiments.

91
92 Sowing was carried out in 128-cell expanded polystyrene trays containing the commercial
93 substrate, placing two coriander **seeds** at a depth of approximately 0.5 cm, and then
94 covering with the substrate. Subsequently, ~~water~~-irrigation and inoculation of 1,000 eggs/cell
95 of *M. incognita* race 1 were performed. Irrigation was carried out daily according to the water
96 requirement, and fertigation was applied three times a week, preventing drainage with
97 ~~sub~~consequent loss of inoculum.

98
99 After 30 days of sowing/inoculation, evaluation was performed. For this, the root system was
100 washed in standing water to remove the substrate. Then, the number of galls was quantified
101 and the eggs were extracted from each individual plant according to methodology proposed
102 by [Hussey and Barker](#) [15] and modified by [Bonetti and Ferraz](#) [16]. The ~~extracted~~ eggs
103 ~~extracted~~ were stored in properly identified containers and placed in a cold chamber until,
104 the count was performed using a microscope ([brand, manufacturer, city, country](#)), increased
105 40X, and Peters' blade.

106
107 After quantification of the number of eggs, the reproduction factor (RF) for each sample was
108 estimated ~~by as~~ the ratio between the final population of the pathogen (number of eggs
109 quantified in the sample) and the initial population of the nematode (1,000 eggs/cell). To
110 classify the reaction of the cultivars and progenies of coriander to the pathogen, the scale of
111 [Oostenbrink](#) [17] was used. Genotypes with $RF < 1$ were considered resistant, and those
112 with $RF > 1$ were considered susceptible.

113
114 The data obtained were transformed by \sqrt{x} to meet the assumptions of the analysis of
115 variance, and were submitted to [this it](#), with subsequent Scott-Knott grouping test at 5%
116 probability, using the SISVAR statistical software [18]. The genetic parameters were
117 estimated by the GENES statistical program [19].

119 3. RESULTS AND DISCUSSION

120
121 There were **highly** significant differences in the number of galls in the root system, number of
122 eggs and reproduction factor ~~at 1% probability~~, among the evaluated genotypes. The
123 coefficients of variation ranged from 11.65% to 16.86% (Table 1). Values of CV between 10
124 and 20% are considered as medium experimental precision [20], which according to
125 [Cargnelutti Filho and Storck](#) [21] are not of concern.

126
127 **Table 1.** Summary of the variance analysis of the number of galls in the root system
128 (NGRS), number of eggs (NE), and the reproduction factor (RF) of two cultivars and 49
129 progenies of coriander inoculated with *Meloidogyne incognita* race 1.

Source of Vvariation	Degree	Square meansQM
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	of Ffreedom	NGRS⁺	NE⁺	RF⁺
Blocks	3	1.31 ^{ns?}	81.43 ^{ns?}	0.08 ^{ns?}
Genotypes	50	1.33 ^{***}	443.63 ^{**}	0.44 ^{**}
Error	150	0.32	14.57	0.02
QV%		16.86	11.65	11.68
Mean		3.36	32.75	1.04

⁺ Data transformed by \sqrt{x}

^{**} Significant at 1% probability; ^{ns} not significant

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For the number of galls in the root system, the means were divided into three groups. In the first group, the means varied between 3.75 –and 6.75; in the second group of 8.00 - 11.25 and in the third group of 11.75 - 24.00 (Table 2). The means obtained in the three groups are inferior to those obtained by Santos et al. [9] evaluating the cultivars Verdão, Tabocas, Tapacurá, Palmeira and HTV Dom Luiz in the treatment that had as levels of the factors container and substrate, tray and Basaplant®. These results showed that it is possible to obtain promising progenies among those evaluated in the present study, based on this characteristic.

Table 2. Scott-Knott grouping test and reaction of two cultivars and 49 coriander progenies to *M. incognita* race 1 indicated by - for the following variables: the number of galls in the root system (NGRS), number of eggs (NE), and reproduction factor (RF)-

Genotypes	NGRS	NE	RF	Reaction*
67	3.75 a	265.25 a	0.27 a	Resistant
DP10	4.00 a	114.75 a	0.12 a	Resistant
58	4.75 a	311.75 a	0.32 a	Resistant
5	5.00 a	418.25 a	0.42 a	Resistant
69	5.50 a	160.75 a	0.16 a	Resistant
18	6.75 a	526.00 a	0.53 a	Resistant
DP11	8.00 b	225.75 a	0.23 a	Resistant
45	8.75 b	1107.50 b	1.11 b	Susceptible
51	9.00 b	857.75 b	0.86 b	Resistant
DP2	9.00 b	732.75 b	0.73 b	Resistant
8	9.50 b	746.00 b	0.75 b	Resistant
Verdão	9.75 b	1328.50 c	1.33 c	Susceptible
29	10.00 b	266.00 a	0.27 a	Resistant
4	10.25 b	2539.25 e	2.54 e	Susceptible
21	10.25 b	629.25 b	0.63 b	Resistant
31	10.25 b	576.00 a	0.58 a	Resistant
1	10.50 b	1159.50 b	1.16 b	Susceptible
40	10.83 b	750.25 b	0.75 b	Resistant
47	11.00 b	1037.50 b	1.04 b	Susceptible
64	11.19 b	487.00 a	0.49 a	Resistant
60	11.25 b	1445.00 c	1.45 c	Susceptible
54	11.25 b	1467.25 c	1.47 c	Susceptible
38	11.75 c	1556.25 c	1.56 c	Susceptible
19	11.75 c	879.75 b	0.88 b	Resistant
16	12.00 c	1902.75 d	1.90 d	Susceptible
15	12.44 c	1601.75 c	1.60 c	Susceptible
14	12.50 c	1564.00 c	1.57 c	Susceptible
49	12.50 c	1817.50 d	1.82 d	Susceptible

DP6	12.75 c	267.25 a	0.27 a	Resistant
HTV Dom Luiz	12.75 c	1711.50 d	1.71 d	Susceptible
33	13.00 c	1705.00 d	1.71 d	Susceptible
57	13.00 c	1542.25 c	1.54 c	Susceptible
3	13.50 c	1328.25 c	1.33 c	Susceptible
23	13.50 c	953.50 b	0.95 b	Resistant
42	13.50 c	1393.25 c	1.40 c	Susceptible
24	13.75 c	1503.00 c	1.50 c	Susceptible
44	13.75 c	1091.00 b	1.09 b	Susceptible
56	14.00 c	2596.25 e	2.60 e	Susceptible
48	14.00 c	2358.50 e	2.36 e	Susceptible
22	14.25 c	676.00 b	0.68 b	Resistant
DP1	14.25 c	1273.25 c	1.28 c	Susceptible
20	14.50 c	820.50 b	0.82 b	Resistant
28	14.75 c	474.50 a	0.48 a	Resistant
46	14.75 c	1394.50 c	1.40 c	Susceptible
32	15.06 c	1348.63 c	1.35 c	Susceptible
12	15.25 c	1838.25 d	1.84 d	Susceptible
34	16.25 c	2337.50 e	2.34 e	Susceptible
53	16.75 c	1783.25 d	1.79 d	Susceptible
50	17.00 c	1945.50 d	1.95 d	Susceptible
52	17.00 c	2169.00 e	2.17 e	Susceptible
30	24.00 c	1876.75 d	1.88 d	Susceptible

147 * Oostenbrink scale (1966), resistant FR_{<1} and susceptible FR_{>1} genotypes.

148 Means followed by the same lower case letter in the column do not differ statistically by the Scott-Knott
149 test at 5% probability.

150

151 For the number of eggs, the means [were varied](#) from 114.75 to 2596.25; forming five groups
152 within this range. The reproduction factor had a [behavior trend](#) similar to the number of eggs,
153 since it [is was](#) directly proportional to this variable. The first group was formed by
154 reproduction factors from 0.12 to 0.58; being all the genotypes classified as resistant and
155 presenting the smallest means, being therefore, those indicated for selection. In the second
156 group, composed of reproductive factors from 0.63 to 1.16, individuals with RF <1 and RF > 1
157 were present. However, because they [were](#) statistically different from the first group, which
158 [presented](#) the lowest means, genotypes with RF <1 will not be selected. In the other three
159 groups, the reproduction factors [were](#) all higher than one, and the selection of such
160 progenies is not recommended.

161

162 The RF values of the progenies of group "a" ($0.12 \leq \text{FRF} \leq 0.58$) [were](#) lower than those
163 obtained for the cultivars Verdão (RF = 1.33) and HTV Dom Luiz (RF = 1.71). These
164 progenies also showed smaller [RFs than](#) those found by [Santos et al.](#) [9], which presented
165 1.54; 1.59; 1.69; 2.01 and 2.42 for the cultivars HTV Dom Luiz, Tapacurá, Verdão, Palmeira
166 and Tabocas, respectively. [Diniz et al.](#) [11] also obtained a superior result to those found in
167 the present study, where the cultivar Verdão showed [a](#) RF = 2.4 when inoculated with 1200
168 eggs of *M. incognita* race 1 at 15 days after sowing and evaluated at 45 days after
169 inoculation. Thus, the progenies belonging to the group "a", presented superior behavior
170 regarding the resistance to *M. incognita* race 1, being promising to give continuity to the
171 program of genetic improvement of the culture.

172

173 As for the genetic parameters, in all analyzed characters there is a greater contribution of the
174 genetic variation to the variation presented by the phenotype, indicating that there is actually
175 genetic variability among the evaluated progenies, simplifying the selection process and
176 making selection possible (Table 3). This fact [is was](#) very important because, according to
177 [Borém and Miranda](#) [22], the greater the proportion of variability resulting from the

178 environment in relation to phenotypic variability, the more difficult it is to perform genotype
 179 selection effectively, reducing the efficiency of the selective process carried out by the
 180 breeder.

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188 **Table 3.** Genetic parameters estimated for the ~~following characters:~~ number of galls in the
 189 root system (NGRS), number of eggs (NE), and reproduction factor (RF).
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Genetic parameters	Characters		
	NGRS	NE	RF
V_g	0.25	107.27	0.107
V_e	0.08	3.64	0.004
V_p	0.33	110.91	0.111
h^2	75.91	96.72	96.70
CV_g	14.97	31.62	31.62
CV_a	16.86	11.62	11.68
CV_g/CV_e	0.89	2.71	2.71

191 Phenotypic variance (V_p), environmental variance (V_e), genetic variance (V_g), heritability (h^2),
 192 coefficient of genetic variance CV_g , coefficient of environmental variance (CV_e), and mean between
 193 coefficient of genetic and environmental variance (CV_g/CV_e).
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195 The coefficients of genetic variation (CV_g) ~~ranged from were 31.62 to~~ 14.97 ~~and 31.62~~ for the
 196 ~~number of galls in the root system and the~~ reproduction factor, ~~and the number of galls in the~~
 197 ~~root system~~, respectively. The coefficient of genetic variation allows inferring about the
 198 genetic variability among the characters, and ~~aiding aids~~ the selection of superior genotypes
 199 for it evidences the levels of genetic variability present in different genotypes, environment,
 200 and characters [23]. Therefore, the estimation of the genetic variance between family means
 201 (progenies) is fundamental and indispensable for the breeder, since the success of a
 202 breeding program depends on the existence of genetic variability in the ~~work base~~
 203 population [12].
 204

205 The heritability presented values from 75.91 (NGRS) to 96.72 (NE), which were considered
 206 high. The attainment of high estimates of heritability indicates that it is possible to select
 207 superior genotypes [5]. Therefore, it is possible to obtain a genetic gain (or resistance to *M.*
 208 *incognita* race 1) with the selection based on ~~both~~ the number of galls in the system, ~~and~~ the
 209 number of eggs, and reproduction factor, ~~based on the data obtained~~.

210
 211 ~~The h~~Heritability values obtained in the present study were higher than those estimated by
 212 Diniz [24] in a study carried out ~~for to~~ evaluating the cultivars Portuguese, Tabocas,
 213 Tapacurá, Verdão, Palmeira, HTV-9299 parasitized by *M. incognita* race 1, where the
 214 estimated heritability were was 48.83 for the number of galls and 70.85 for the number of
 215 eggs. Heritability estimates vary according to several factors such as characteristic,
 216 estimation method,
 217 population diversity,
 218 endogamy level of the population,
 219 evaluated sample size,
 220 number and type of environments,
 221 considered experimental unit considered and precision in the experimental conduction,
 and data collection [22]. Therefore, even by taking into account the same characteristics in the same species, there will be variation in the values of heritability obtained in different populations and experiments. In addition, it will be necessary to estimate such parameter for each working population and to adopt other

222 parameters to complement the information provided by the heritability, aiming at helping the
 223 decision maker of the breeding, with the CVg/CVe ratio being an option to be adopted.

224
 225 As the CVg/CVe ratio was superior to a unit for number of eggs and reproductive factor
 226 (2.71), and close to 1 for the number of galls in the root system (0.89), selection based on
 227 these characters was made possible. This is because, according to Cruz et al. [25], there is
 228 a favorable situation to obtain a genetic gain with the selection when the CVg/CVe ratio
 229 tends to 1.0 or is greater than 1.0 since the genetic variation exceeds the environmental
 230 variation. Thus, as the CVg/CVe and heritability are parameters that indicate the success in
 231 the selection of superior genotypes [26], and both parameters obtained in the present study
 232 were high, it is possible to obtain a genetic gain in the selection of the superior progenies in
 233 the population studied. Moreover, these progenies can be used in the search for genotypes
 234 that may be a source of resistance to *M. incognita* race 1 to be used in coriander breeding
 235 programs for coriander.

236
 237 All genotypes that presented the lowest averages for number of galls in the root system
 238 were in the group of the lowest values of reproduction factor (0.12 - 0.58). Based on the
 239 correlations between the characters under study, it was verified that all are positively related
 240 to each other (Table 4).

241
 242 **Table 4.** Phenotypic, genetic, and environmental correlation coefficients for the following
 243 characters: number of galls in the root system (NGRS), number of eggs (NE) and
 244 reproduction factor (RF)-

Character		NGRS	NE	RF
NGRS	Rp	-	0.71**	0.71**
	Rg	-	0.81**	0.81**
	Re	-	0.23 ^{ns}	0.23 ^{ns}
NE	Rp	-	-	1.0**
	Rg	-	-	1.0**
	Re	-	-	0.99*

246 **S significant at 1% probability by the t test.
 247 ^{ns} not significant.

248
 249 The phenotypic and genetic correlations between the number of galls in the root system with
 250 and the number of eggs and reproductive factor were all highly significant, at 1% probability,
 251 being positive, and strong, in the with a Rg values of 0.81 (NGRS x NE, NGRS x RF) and a
 252 Rp value of 0.71 (NGRS x NE; NGRS x RF) for the genetic and phenotypic correlations,
 253 respectively. High genetic correlation indicates that the characters involved were affected by
 254 the same genes or are closely linked genes [27]. This fact is was important because it has
 255 indicateds that the indirect selection based on the number of galls in the root system, a non-
 256 destructive mode that allows recombination of the selected individuals both within and
 257 between the progenies, may be an option to be adopted in the initial selection cycles.
 258 Therefore, the reproduction factor is could be used as a criterion for selection in more
 259 advanced cycles.

260
 261 The genetic, phenotypic and environmental correlations between the number of eggs and
 262 the reproductive factor were very significant, at 1% probability. All correlations were very
 263 strong and positive as expected, since the reproduction factor is estimated from the number
 264 of eggs, being directly proportional to this. Although these characters were highly
 265 correlated, the use of the reproductive factor was important because it provides information
 266 on the behavior of the pathogen population. This allows the identification of the genotypes
 267 that allow the nematode population increase in the soil, besides allowing the classification of

268 | the genotypes as susceptible and or resistant by-on the scale of [Oostenbrink](#) [17], optimizing
269 | the selective process carried out by the breeder.

270

271 | 4. CONCLUSION

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273 | The inoculation at sowing with 1,000 eggs/cell of *M. incognita* race 1 and evaluation at 30
274 | days after inoculation was efficient in differentiating the evaluated genotypes, promoting
275 | reduction of time and optimization of resources. The selection of superior genotypes, namely
276 | the 12 progenies (67, DP10, 58, 5, 69, 18, DP11, 29, 31, 64, DP6 and 28) indicated for
277 | selection was also made possibly.

278

279 | The high values of heritability and CVg/CVe obtained indicate that the number of galls in the
280 | root system, number of eggs, and reproductive factors can be used to make selection of
281 | promising genotypes resistant to the pathogenpest, allowing gain with the selection and
282 | attainment of superior bred populations.

283

284 | With the strong genetic correlations between the number of galls in the root system and the
285 | reproduction factor, it is possible to indicate the selection based on the number of galls in the
286 | initial cycles of breeding programs in order to obtain genotypes resistant to *M. incognita* race
287 | 1 and selection and recombination between and within progenies in the same selective
288 | cycle. However, it is indispensable to the extraction of eggs and estimation of the
289 | reproduction factor in more advanced cycles in the breeding programs of coriander. The
290 | selection of 12 superior genotypes, namely the progenies 67, DP10, 58, 5, 69, 18, DP11, 29,
291 | 31, 64, DP6, and 28 for future breeding program for resistance to the pest was made.

292

293 | COMPETING INTERESTS

294

295 | Authors have declared that there are no competing interests.

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