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Screening of melon genotypes for resistance to vegetable leafminer and your phenotypic correlations with colorimetry

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ABSTRACT

Melon is one of the most important vegetable crops in the world. With short cycle in a system of phased planting, phytosanitary control is compromised, and a great volume of agricultural chemicals is used to control vegetable leafminer. Genetic control is an ideal alternative to avoid the damage caused by this insect. Thus, the aim of this study was to evaluate *Cucumis* accessions in regard to resistance to leafminer and correlate the variables analyzed. Fifty-four accessions and four commercial hybrids of melon were tested. The study was divided into two experiments: with and with no choice. The following characteristics were evaluated: with choice, in field – subjective score based on the infestation and the number of mines per leaf; and with no choice, in cage – number of mines per leaf, chlorophyll content, and leaf colorimetry. The results showed variability among the accessions and some genotypes showed favorable results for resistance in both experiments. There was correlation between the two variables in the experiment in the field. The accessions CNPH 11-282, CNPH 06-1047, and CNPH 11-1077 are the most recommended for future breeding programs with aim on introgression of resistance to vegetable leafminer in melon.

Key words: *Cucumis melo*, germplasm, *Liriomyza sativae*, Lab system.

INTRODUCTION

Melon (*Cucumis melo* L.) is one of the most important vegetable crops in the world. In 2012, 1.34 million hectares of this crop were harvested, achieving production of approximately 32 million tons (FAO 2015). In Brazil, in 2014, more than 590 thousand tons of fruit were produced on 22 thousand ha (IBGE 2015). The Northeast region was responsible for more than 95% of this production, with the states of Ceará and Rio Grande do Norte as the main producers, composing 82% of production in the region (IBGE 2015). In addition, on a national level, in the last ten years, the export volume of this crop grew more than 38%, climbing from 142.5 thousand tons in 2002 to more than 196.8 thousand tons in 2012 (MDIC 2015).

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Among the commercial types produced, the yellow melon alone occupies more than 50% of the planted area (Costa et al. 2011). In addition, the crop has a short cycle and a phased planting system is used (Sobrinho et al. 2011). Such characteristics hinder phytosanitary control of the crop, increasing the amount of agricultural chemicals necessary to control pests and diseases. Under these circumstances, incorrect management of economically important pests, such as white fly (*Bemisia tabaci* Genn. biótipo B), is likely to have caused reduction in the natural enemies of vegetable leafminer (*Liriomyza sativae* Blanchard) through abusive use of broad spectrum agricultural chemicals, leading to a population explosion of this pest, which in the year 2000 became no longer simply a secondary pest, but achieved the status of the key pest of the crop (Soares Brasil et al. 2012, Guimarães et al. 2005). The insect invades new areas mainly through vegetable commercial transactions, and, currently, nearly the entire planted area in the states of Rio Grande do Norte, Ceará, and Bahia is affected by vegetable leafminer, with observed losses of up to 40% in the 2003 crop season due to attack from this pest (Reitz et al. 2013, Fernandes 2004).

Among possible control measures, genetic control is the ideal alternative for avoiding the damage caused by this insect, and although resistant melon accessions have been reported (Dogimont et al. 1999), the lack of these genotypes is still the main impediment for breeding that seeks commercial varieties resistant to the insect. For Brazil, most of the genotypes used are of cultivars with low adaptation to these regions, often susceptible to local pests (Lopes et al. 2003).

For breeding to be successful, sources of genetic variation are important. Plant germplasm is the basis for plant breeding. Without a broad base composed of different genotypes, breeders may fail in their breeding programs (Pereira et al. 2010).

The Brazilian Crop and Livestock Research Company (Embrapa) currently has an active germplasm bank with more than 500 melon accessions, belonging to diverse botanical varieties of *Cucumis melo*. This collection is the genetic base for breeding programs of the company, and it is widely used in the development of materials resistant to pests and diseases and of new melon cultivars adapted to Brazilian edaphic and climatic conditions.

In this context, the aim of this study was to evaluate a germplasm collection of *Cucumis melo* L. regarding resistance to vegetable leafminer (*Liriomyza sativae*), identify resistant accessions, and correlate the variables analyzed within and between the experiments with and with no choice.

MATERIALS AND METHODS

Fifty-eight melon genotypes were evaluated, of which 49 are melon accessions originating from the Melon Germplasm Bank of Embrapa Vegetable Crops, five are from the Cucurbit Germplasm Bank for the Brazilian Northeast region, and four are commercial hybrids (BRS Araguaia, Estoril, McLaren and Goldex) (Table I). The study was divided into two experiments: with (in the field) and without (in cage) choice. Additionally, the amount of chlorophyll and determined the color of the leaves of melon genotypes, which were correlated with variables related to resistance to vegetable leaf miner.

The initial population of the vegetable leafminer (*Liriomyza sativae*) was obtained in the larval stage from collection made on the Agrícola Famosa farm, municipality of Icapuí, CE, Brazil. Insects in various numbers were released in cages (60 cm x 60 cm base and 50 cm height) containing the commercial hybrid Goldex, where, over the period of two days, the insects were able to oviposit. The plants, after infestation, were isolated up to collection of the pupae in Petri dishes. Upon

TABLE I
Identification and origin of the melon germplasm evaluated for resistance to vegetable leafminer in the field and, or in a cage, Fortaleza, CE, Brazil, 2014.

Identification	Origin	Assay	Identification	Origin	Assay
CNPH 94-001	MGB CNPH[1]	Field / Cage	CNPH 03-966	MGB CNPH	Field / Cage
CNPH 94-002	MGB CNPH	Field / Cage	CNPH 03-972	MGB CNPH	Field / Cage
CNPH 82-004	MGB CNPH	Field / Cage	CNPH 04-980	MGB CNPH	Field / Cage
CNPH 82-006	MGB CNPH	Field / Cage	CNPH 06-1046	MGB CNPH	Field / Cage
CNPH 82-009	MGB CNPH	Field / Cage	CNPH 06-1047	MGB CNPH	Field / Cage
CNPH 82-010	MGB CNPH	Field / Cage	CNPH 08-1053	MGB CNPH	Cage
CNPH 11-196	MGB CNPH	Field / Cage	CNPH 10-1055	MGB CNPH	Field / Cage
CNPH 11-233	MGB CNPH	Field / Cage	CNPH 11-1059	MGB CNPH	Field / Cage
CNPH 94-244	MGB CNPH	Field / Cage	CNPH 11-1061	MGB CNPH	Field / Cage
CNPH 11-247	MGB CNPH	Field / Cage	CNPH 11-1063	MGB CNPH	Field / Cage
CNPH 98-248	MGB CNPH	Field / Cage	CNPH 11-1065	MGB CNPH	Field / Cage
CNPH 94-254	MGB CNPH	Field / Cage	CNPH 11-1066	MGB CNPH	Field / Cage
CNPH 86-277	MGB CNPH	Field / Cage	CNPH 11-1067	MGB CNPH	Field / Cage
CNPH 11-282	MGB CNPH	Field / Cage	CNPH 11-1068	MGB CNPH	Field / Cage
CNPH 11-537	MGB CNPH	Field / Cage	CNPH 11-1069	MGB CNPH	Field / Cage
CNPH 89-574	MGB CNPH	Field / Cage	CNPH 11-1070	MGB CNPH	Field / Cage
CNPH 93-690	MGB CNPH	Field / Cage	CNPH 11-1072	MGB CNPH	Field / Cage
CNPH 93-691	MGB CNPH	Field / Cage	CNPH 11-1074	MGB CNPH	Field / Cage
CNPH 93-693	MGB CNPH	Field / Cage	CNPH 11-1076	MGB CNPH	Field / Cage
CNPH 99-850	MGB CNPH	Field / Cage	CNPH 11-1077	MGB CNPH	Field / Cage
CNPH 00-900	MGB CNPH	Field / Cage	A.05	CGB CPATSA[2]	Field
CNPH 00-902	MGB CNPH	Field / Cage	A.17	CGB CPATSA	Field
CNPH 00-915	MGB CNPH	Field / Cage	A.30	CGB CPATSA	Field
CNPH 00-919	MGB CNPH	Field / Cage	A.41	CGB CPATSA	Field / Cage
CNPH 01-925	MGB CNPH	Field / Cage	A.42	CGB CPATSA	Field
CNPH 01-930	MGB CNPH	Field / Cage	BRS Araguaia	Embrapa	Field / Cage
CNPH 01-933	MGB CNPH	Cage	Estoril	Nunhens	Field / Cage
CNPH 01-960	MGB CNPH	Cage	Goldex	Agristar/Topseed	Field / Cage
CNPH 01-963	MGB CNPH	Cage	McLaren	Seminis	Field / Cage

1/MGB CNPH – Melon germoplasma bank of Embrapa Vegetable Crops. 2/CGB CPATSA - Cucurbit Germplasm Bank of Embrapa Semiarid (CPATSA) in Petrolina, PE, Brazil.

emergence of the first adults, the dishes were placed in the cages for release of the adults, thus contributing to renewal of the individuals raised. Adults were fed in a complementary manner with pure honey.

In the experiment with choice, the accessions were arranged in the field in a completely randomized experimental design, with two replications and six plants per plot. The reaction of the melon genotypes to vegetable leafminer was evaluated under natural field infestation. At 55 days after transplanting, the plants were evaluated through a scoring scale which ranged from 1 to 5, in which: 1 = plant without mines on the leaves; 2 = traces to 25% of leaves attacked; 3 = 25 to 50 % of leaves attacked; 4 = 50 to 75 % of leaves attacked;

5 = 75 to 100 % of leaves attacked. In addition, 58 days after the date of transplanting, three leaves were removed from each plant of the plot and count was made of the number of mines per leaf. The 10th leaf as of the apex of the secondary branch of the melon was defined as the sample leaf for evaluation of pest damage (Braga Sobrinho et al. 2003).

In the experiment with no choice, the material was arranged in cages according to a completely randomized design with six replications, each plant constituting a plot. At 22 days after transplanting, six plants of each genotype were placed in each cage and 36 adults of *Liriomyza sativae* were released for 24 hours. Six days after the infestation, the plants were evaluated through counting the number of mines per leaf.

At 22 days after transplanting, the basic tristimulus values were evaluated in two true leaves of each replication, measured by the colorimeter Konica Minolta CR 400, with reading in CIE system (Lab). In this three-dimensional model, the L stands for the lightness of the color, with 0 producing black and 100 producing a diffuse white. The "a" is the redness vs. greenness, while the "b" is the yellowness vs. blueness. To measure the amount of chlorophyll in the leaves of the genotypes, the portable chlorophyll meter SPAD - 502 (Konica Minolta Sensing) was used. Twenty days after transplanting, measurements were made in all true leaves of each plant.

The data obtained were first analyzed through the Shapiro-Wilk normality test and, after that, the homogeneity of the variances was tested through the Bartlett test. When necessary, pertinent transformations were adopted guided by the optimal Box-Cox transformation. The data were subjected to the Kruskal-Wallis non-parametric test. Estimates of the Pearson correlation coefficients were obtained through analyses of covariance, combining the traits studied in the GENES computational application (Cruz 2013).

RESULTS AND DISCUSSION

In the evaluation with choice, as of the Kruskal-Wallis test of means (Table II), it is possible to observe a difference between the treatments evaluated in relation to the scoring scale. The genotypes CNPH 11-1061, CNPH 11-1063, CNPH 11-1070, and A.05 exhibited higher scores than the genotypes Estoril, CNPH 94-001, CNPH 82-004, CNPH 82-006, CNPH 11-233, CNPH 94-244, CNPH 94-254, CNPH 11-282, CNPH 11-537, CNPH 93-691, CNPH 99-850, CNPH 00-900, CNPH 00-915, CNPH 00-919, CNPH 06-1047, CNPH 11-1072, and CNPH 11-1077, suggesting greater susceptibility of those genotypes to the insect. The genotype CNPH 11-1072 exhibited the lowest score, differing statistically from the accessions CNPH 82-009, CNPH 11-247, CNPH 98-248, CNPH 89-574, CNPH 93-690, CNPH 93-693, CNPH 00-902, CNPH 01-925, CNPH 01-930, CNPH 03-966, CNPH 04-980, CNPH 10-1055, CNPH 11-1059, CNPH 11-1061, CNPH 11-1063, CNPH 11-1065, CNPH 11-1066, CNPH 11-1068, CNPH 11-1069, CNPH 11-1070, CNPH 11-1076, A.05, A.17, and A.42.

The two commercial hybrids adopted as controls ('Goldex' and 'McLaren') did not differ from the other treatments. The presence of the antixenotic effect may explain this result. Another theory to explain this result would be that of optimal foraging, where the female tends to prefer hosts that ensure performance gains in adults, even if these hosts are inadequate for the development of their offspring (Scheirs and De Bruyn, 2002). The hypothesis that oviposition in less adequate hosts may be a strategy of the species for selection of more vigorous individuals cannot be ruled out. In an experiment carried out by Lima (2012), a proven antixenotic effect for oviposition by *L. sativae* was observed for the McLaren hybrid. The referred investigation did not include the commercial hybrid Goldex in the evaluation, which could also have

TABLE II
Mean values of variables of the evaluation of melon germplasm for resistance to vegetable leafminer with and with no choice, Fortaleza, CE, Brazil, 2014.

Identification	SSF[1]		MLF[2]		MLC[3]	
CNPH 94-001	1,55	d-f*	0,25	a-c	7,90	j-q
CNPH 94-002	1,83	a-f	0,08	c	8,27	i-p
CNPH 82-004	1,42	d-f	0,17	a-c	18,79	a-c
CNPH 82-006	1,67	b-f	0,31	a-c	11,87	d-l
CNPH 82-009	2,08	a-c	0,47	ab	2,94	w-y
CNPH 82-010	1,83	a-f	0,19	a-c	11,92	d-k
CNPH 11-196	1,80	a-f	0,20	a-c	2,84	w-y
CNPH 11-233	1,67	b-f	0,25	a-c	8,71	i-p
CNPH 94-244	1,67	b-f	0,14	a-c	11,89	d-i
CNPH 11-247	2,00	a-d	0,61	a	21,38	a-d
CNPH 98-248	2,00	a-c	0,19	a-c	1,16	y
CNPH 94-254	1,67	b-f	0,08	bc	4,04	t-y
CNPH 86-277	1,75	a-f	0,06	c	12,39	b-h
CNPH 11-282	1,67	b-f	0,08	c	2,63	xy
CNPH 11-537	1,50	d-f	0,36	a-c	12,76	b-g
CNPH 89-574	1,92	a-d	0,61	a	14,08	a-f
CNPH 93-690	1,92	a-d	0,25	a-c	4,93	p-x
CNPH 93-691	1,58	b-f	0,14	a-c	3,07	v-y
CNPH 93-693	2,08	a-c	0,22	a-c	14,37	a-f
CNPH 99-850	1,67	b-f	0,39	a-c	8,76	h-o
CNPH 00-900	1,72	b-f	0,15	a-c	7,96	k-r
CNPH 00-902	2,08	ab	0,24	a-c	11,51	d-l
CNPH 00-915	1,58	b-f	0,18	a-c	12,25	d-i
CNPH 00-919	1,58	c-f	0,14	bc	6,94	n-u
CNPH 01-925	1,98	a-d	0,27	a-c	6,08	o-w
CNPH 01-930	2,17	ab	0,28	a-c	11,03	f-n
CNPH 01-933	-		-		13,05	d-i
CNPH 01-960	-		-		6,40	o-w
CNPH 01-963	-		-		1,66	xy
CNPH 03-966	1,85	a-e	0,13	bc	7,44	m-t
CNPH 03-972	1,83	a-f	0,51	ab	3,53	v-y
CNPH 04-980	2,00	a-d	0,00	c	6,50	o-v
CNPH 06-1046	1,80	a-f	0,13	bc	7,01	n-u
CNPH 06-1047	1,28	ef	0,06	c	20,80	a-c
CNPH 08-1053	-		-		1,87	xy
CNPH 10-1055	2,00	a-d	0,56	ab	11,00	e-m
CNPH 11-1059	2,08	a-c	0,64	a	21,94	ab
CNPH 11-1061	2,33	a	0,42	a-c	15,33	d-j
CNPH 11-1063	2,42	a	0,47	a-c	9,36	g-o
CNPH 11-1065	2,17	ab	0,67	a	18,60	a-f

TABLE II (continuation)

Identification	SSF[1]		MLF[2]		MLC[3]	
CNPH 11-1066	2,30	ab	0,31	a-c	11,90	f-n
CNPH 11-1067	1,79	a-f	0,21	a-c	4,14	s-y
CNPH 11-1068	2,00	a-d	0,42	a-c	19,59	a-d
CNPH 11-1069	2,08	ab	0,37	a-c	15,22	c-i
CNPH 11-1070	2,37	a	0,31	a-c	19,15	a-e
CNPH 11-1072	1,00	f	0,03	c	4,44	r-y
CNPH 11-1074	1,83	a-f	0,47	a-c	9,41	g-o
CNPH 11-1076	2,20	ab	0,61	a	14,43	e-m
CNPH 11-1077	1,75	b-f	0,06	c	4,75	q-y
A.05	2,50	a	0,17	a-c	-	
A.17	2,00	a-d	0,67	a	-	
A.30	1,80	a-f	0,27	a-c	-	
A.41	1,75	a-f	0,50	a-c	7,71	l-s
A.42	2,00	a-d	0,68	a	-	
BRS Araguaia	1,83	a-f	0,11	bc	3,68	u-y
Estoril	1,58	b-f	0,19	a-c	9,58	g-o
Goldex	1,83	a-f	0,47	ab	24,25	a
McLaren	1,83	a-f	0,22	a-c	4,97	q-x
P valor (χ^2)	<0,001		<0,001		<0,001	

1SSF = subjective score and 2MLF = mines per leaf, both in the experiment with choice (field); 3MLC = mines per leaf in the experiment with no choice (cage). *Mean followed by the same letter, in column, do not differ among themselves by Kruskal-Wallis test.

shown this effect.In regard to the number of mines per leaf, the genotype CNPH 11-1072 exhibited the second lowest mean value, confirming the result found in subjective analysis (scoring scale). The accessions CNPH 94-002, CNPH 86-277, CNPH 11-282, CNPH 04-980, CNPH 06-1047, and CNPH 11-1077, as well as the genotype CNPH 11-1072 differed from the genotypes CNPH 82-009, CNPH 11-247, CNPH 89-574, CNPH 03-972, CNPH 10-1055, CNPH 11-1059, CNPH 11-1065, CNPH 11-1076, A.17, A.42, and Goldex. The hybrid McLaren did not differ from any treatment, matching the genotypes that were less attacked. As previously stated, this genotype has a proven antixenotic effect for oviposition (Lima 2012).

Analysis of the variables of mine counting on the leaves and weekly evaluation through the scoring scale shows that, in addition to the genotype CNPH 11-1072, the accessions CNPH 11-282, CNPH 06-1047, and CNPH 11-1077 differed from the other ones, with the greatest number of mines and with the highest subjective scores. In contrast, the genotypes CNPH 11-1059 and CNPH 11-1076 appear as susceptible to the two characteristics evaluated, indicating the lack of resistance factors of the antixenosis type.

In the experiment with no choice, the genotypes CNPH 82-004, CNPH 11-247, CNPH 89-574, CNPH 93-693, CNPH 06-1047, CNPH 11-1059, CNPH 11-1065, CNPH 11-1068, and CNPH 11-1070 did not differ for the variable of number of mines per leaf; and the commercial hybrid Goldex was the genotype with the greatest number of mines per leaf (Table II). The genotypes BRS Araguaia, CNPH 82-009, CNPH 11-196, CNPH 98-248, CNPH 94-254, CNPH 11-282, CNPH

93-691, CNPH 01-963, CNPH 03-972, CNPH 08-1053, CNPH 11-1067, CNPH 11-1072, and CNPH 11-1077 were the least attacked genotypes, not differing among themselves. The genotypes CNPH 11-282, CNPH 11-1072, and CNPH 11-1077 did not differ from the least attacked accession (CNPH 98-248) (Table II). These results show that the lower oviposition of *L. sativae* shown in these genotypes under free choice conditions continued even when the insect does not have the chance of choosing, thus characterizing stability of resistance of the genotype to the insect. Complementary investigations are necessary to ascertain the causes of resistance.

In contrast, the genotype CNPH 11-1065 appears among those most attacked in the field and in the laboratory, suggesting the absence of resistances of the antixenosis type. The genotype CNPH 11-1076, susceptible in the two variables analyzed in the field, does not appear among those most attacked in the laboratory, but its leaves were more infested than twenty of the genotypes tested.

Although such results suggest that these genotypes (CNPH 11-1065 and CNPH 11-1076) do not have resistance of the antixenosis type, that does not mean that they may not express some level of resistance of another nature. In a similar way, the accessions studied whose results indicate resistance factors of the antixenosis type may also have antibiosis and/or tolerance to the insect under study, since there are reports of the simultaneous occurrence of tolerance and of other types of resistance (Oliveira et al. 2011, Santos et al. 2010, Silva and Bleicher 2010).

The genotype CNPH 06-1047, which was less oviposited in the field experiment for the variable of number of mines per leaf, was one of the most oviposited in the experiment in cages. A possible explanation for this result would be a probable emission of substances repellent to *L. sativae*, making the insects move away from this treatment, resulting in less oviposition. In contrast, in the confinement test, since there was no choice, the flies oviposited even though being initially repelled, which indicates the absence of substances inhibitory to oviposition. This same accession was evaluated by Dogimont et al. (1999), who reported the presence of a dominant gene conferring resistance of the antibiosis type to the fly *Liriomyza trifolli*, although resistance of the antixenosis type may perform a relevant role in expression of resistance to the insect in the adult phase (Dogimont et al. 1995).

Chlorophyll variable and colorimetric axes (Table III) were analyzed exclusively in relation to the correlations between them and with variables related to resistance to vegetable leafminer in melon germplasm.

There was a significant positive correlation between the variables of mines per leaf and the subjective score, both from the experiment with choice (Table IV), indicating that the fly attacks the melon plant leaves in a uniform manner. For Nunes et al. (2008), knowledge of the nature and intensity of the correlations among the traits of interest is fundamental because when there is significant correlation between two traits, it is possible to obtain gain indirectly in one of them by means of selection of the other. Thus, for the variables under study, it is possible to carry out selection of plants attacked to a greater or lesser degree by the vegetable leafminer from the subjective score attributed to the plants.

The number of mines per leaf in the field correlated positively with the number of mines per leaf in the cage. This correlation reveals that the genotypes little attacked in the field, where choice was possible on the part of the insect, remained little attacked in the cages where there was confinement and, consequently, the impossibility of choice of host, suggesting the presence of resistance of the antibiosis type in these accessions.

The L axis, indicative of the lightness (color) of the sample, showed negative correlation with the

TABLE III
Mean values of the chlorophyll contents and of the colorimetric parameters for the 54 genotypes evaluated in cages, Fortaleza, CE, Brazil, 2014.

Identification	Chlorophyll	CIE system (Lab)		
		L	a	b
CNPH 94-001	33.13	42.90	-15.75	20.82
CNPH 94-002	41.35	37.58	-14.32	17.49
CNPH 82-004	32.12	36.64	-14.45	19.78
CNPH 82-006	32.97	40.41	-16.73	23.12
CNPH 82-009	39.48	41.44	-15.25	19.09
CNPH 82-010	37.72	41.08	-15.15	19.61
CNPH 11-196	36.53	44.21	-18.35	24.59
CNPH 11-233	35.17	43.67	-17.00	23.21
CNPH 94-244	35.10	35.59	-13.05	15.79
CNPH 11-247	31.40	35.27	-14.83	19.93
CNPH 98-248	37.22	33.49	-14.36	18.76
CNPH 94-254	35.23	37.53	-15.14	18.85
CNPH 86-277	30.75	42.66	-17.34	22.91
CNPH 11-282	32.42	36.83	-16.56	23.45
CNPH 11-537	32.00	34.83	-14.51	18.10
CNPH 89-574	37.73	31.78	-12.72	14.96
CNPH 93-690	35.82	36.12	-15.88	20.71
CNPH 93-691	34.50	44.28	-18.07	24.33
CNPH 93-693	40.20	35.42	-14.22	16.50
CNPH 99-850	35.85	36.80	-15.47	17.72
CNPH 00-900	36.57	39.10	-15.10	19.65
CNPH 00-902	30.57	36.62	-16.10	21.29
CNPH 00-915	33.15	43.31	-16.34	20.95
CNPH 00-919	33.72	42.29	-16.35	21.46
CNPH 01-925	35.92	39.53	-12.69	15.79
CNPH 01-930	34.70	45.69	-17.45	23.45
CNPH 01-933	32.98	39.00	-14.99	19.57
CNPH 01-960	33.05	42.96	-17.44	22.88
CNPH 01-963	38.32	32.45	-14.84	18.86
CNPH 03-966	29.88	45.52	-17.81	25.09
CNPH 03-972	37.32	36.38	-15.83	20.97
CNPH 04-980	40.06	40.70	-14.41	18.81
CNPH 06-1046	37.74	39.85	-14.02	18.59
CNPH 06-1047	36.27	37.19	-14.56	18.91
CNPH 08-1053	37.93	32.92	-14.75	19.09
CNPH 10-1055	32.77	35.15	-14.70	18.10
CNPH 11-1059	36.18	35.96	-15.40	20.76
CNPH 11-1061	34.05	35.05	-16.98	23.52
CNPH 11-1063	32.97	37.65	-16.25	21.07

TABLE III (continuation)

Identification	Chlorophyll	CIE system (Lab)		
		L	a	b
CNPH 11-1065	37.35	36.11	-16.05	20.80
CNPH 11-1066	24.45	39.93	-18.27	25.70
CNPH 11-1067	35.20	46.42	-18.58	25.37
CNPH 11-1068	32.82	40.00	-17.89	25.24
CNPH 11-1069	33.96	37.86	-13.77	18.30
CNPH 11-1070	31.92	39.78	-15.45	19.89
CNPH 11-1072	37.24	35.10	-15.72	20.30
CNPH 11-1074	32.40	38.33	-15.71	20.09
CNPH 11-1076	33.28	33.36	-13.52	15.99
CNPH 11-1077	37.42	42.73	-17.81	23.44
A.41	37.75	37.48	-12.55	14.95
BRS Araguaia	33.86	42.60	-17.37	23.39
Estoril	38.07	30.31	-11.45	14.75
Goldex	34.82	32.65	-15.17	19.57
Mc Laren	42.52	35.87	-12.01	14.42
Average	35.07	38.41	-15.49	20.20
Standard deviation	3.18	3.90	1.70	2.96
CV (%)	9.05	10.16	10.94	14.65
$IE_{95\%}$	0.87	1.07	0.46	0.81

TABLE IV

Phenotypic correlations among the variables used in evaluation of melon germplasm in regard to resistance to vegetable leafminer, Fortaleza, CE, Brazil, 2014.

Parameter	b	a	L	Chlorophyll	MLC	MLF
SSF[1]	0.07	-0.08	-0.05	-0.14	0.22	0.52**
MLF	-0.16	0.13	-0.38**	-0.09	0.45**	
MLC	-0.08	0.11	-0.32*	-0.26		
Chlorophyll	-0.55**	0.51**	-0.21			
L	0.65**	-0.67**				
a	-0.97**					

1SSF = subjective score and 2MLF = mines per leaf, both in the experiment with choice (field); 3MLC = mines per leaf in the experiment with no choice (cage). ** and * indicate significant correlations at 1% and 5% probability, respectively, by the t test.

variables of mines per leaf in the field and mines per leaf in the cage. It is possible that this greater lightness is related to greater contents of leaf waxes. Nevertheless, subsequent studies are necessary that relate the lightness of the leaf and the wax contents. Bernays and Chapman (1994) report that physical factors may be cited among the causes of resistance by antixenosis, such as light radiation emitted by the organs and the morphological factors, such as thickness of the epidermis and amount of wax present in the leaves. These authors affirm that some kale cultivars produce a large amount of wax and that in many brassicas this characteristic confers an important factor of resistance. Costa et al. (2014) found the greatest waxiness among the accessions studied in the clone of collard greens UFLA-6, with the greatest resistance to green aphid.

There was no significant correlation between the variables related to insect infestation (subjective

score, mines per leaf in the field, and mines per leaf in the cage) and the chlorophyll contents found in the leaves, leading one to believe that the vegetable leafminer does not have a preference for leaves with greater or lesser amounts of chlorophyll. Lima (2010), working with shaded coffee plants, suggests that greater leaf chlorophyll contents favor infestation by the coffee leaf miner.

Correlations of this type, with measurements of chlorophyll contents only after infestation, do not provide information about possible physiological responses of the plant to insect attack. Measurements of these contents are necessary at two different times, before and after infestation of the pest. According to Al-Khateeb and Al-Jabr (2006), high infestations of vegetable leafminer reduce the chlorophyll content, the photosynthetic rate, and yield of cucumber. More recently, Lima (2012) affirms that the amount of chlorophyll in the leaves is an adequate parameter for studies of melon tolerance to *L. sativae*. The author observes, for most of the accessions studied, a reduction in the amount of chlorophyll in the leaves after attack of the insect; nevertheless, he found a genotype that did not undergo reduction in the chlorophyll contents after these attacks, which is a strong indication of plant tolerance to the insect.

Correlations were not observed between the colorimetric axes a and b, and the variables in regard to leafminer infestation (subjective score, mines per leaf in the field, and mines per leaf in the cage), indicating that color is not an important factor for host selection by *Liriomyza*. Coelho (2008), in spite of affirming that leaf coloring of the melon genotypes has a direct influence on the attractiveness of *B. tabaci* biotype B, also did not detect significant correlation between these variables.

Positive and negative correlation were found between the chlorophyll content and the a and b parameter, respectively. The L factor (lightness) correlated positively with parameter a and negatively with parameter b, showing a tendency of the greener and yellower accessions to exhibit greater lightness.

There was a strong negative correlation between parameters a and b, which are related to green and yellow coloring, respectively. According to Vieira et al. (2010), chlorophyll of type b, present in all higher plants, is a pigment that has yellowish green coloring, and, according to Martinazzo et al. (2007), the a/b chlorophyll ratio in general tends to decrease with the reduction in lightness intensity due to a greater proportion in relation to chlorophyll b in a shaded environment. Considering that the leaves evaluated in regard to colorimetry were grown in a greenhouse, a greater concentration of this pigment may explain such negative correlation.

CONCLUSIONS

There is wide genetic variation among the melon genotypes evaluated in regard to resistance to vegetable leafminer. The melon accessions CNPH 11-282, CNPH 11-1072, and CNPH 11-1077 are those most recommended for future breeding studies with a focus on introgression of resistance to *L. sativae* in melon. Some genotypes maintained their resistance performance in both assays, with choice and with no choice. In this evaluated germplasm, the lighter leaves are less oviposited by vegetable leafminer.

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