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PEST MANAGEMENT

Plant Resistance to the Moth *Tuta absoluta* (Meyrick) (Lepidoptera:Gelechiidae) in Tomato Cultivars

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Keywords

Tomato moth, integrated pest management, plant susceptibility, trichomes

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Abstract

The resistance of 11 tomato cultivars (Ps-6515, Berlina, Poolad, Petoprid-5, Zaman, Matin, Golsar, Sandokan-F1, Golshan-616, Sadeen-95 and Sadeen-21) to the tomato moth, *Tuta absoluta* (Meyrick) (Lepidoptera:Gelechiidae) was investigated under field conditions. A randomized complete block design was used with three replications. Data analysis indicated that there were significant differences ($P<0.05$) among cultivars regarding leaflet damage, leaf damage, overall plant damage, number of mines per leaf, number of holes on the stem, and fruit. Our findings revealed that the cultivars Berlina, Golsar, Poolad, and Zaman were less suitable cultivars, suggesting that they are more resistant to the tomato moth than the other cultivars. The high density of leaf trichomes present in the cultivars Berlina, Zaman, and Golsar can be one of the possible causes of resistance to *T. absoluta*. Knowledge of the extent of susceptibility or resistance of cultivars to a pest on a crop is one of the fundamental components of integrated pest management (IPM) programs for any crop.

Introduction

The tomato moth, *Tuta absoluta* (Meyrick) (Lepidoptera:Gelechiidae), is a devastating insect pest affecting tomato production in Iran and many other countries (Baniameri & Cheraghian 2011, Gharekhani & Salek-Ebrahimi 2014). The larvae produce galleries in the leaves, stems, terminal buds and fruits. The main damage is caused through larvae feeding on the parenchyma between the epidermal layers of the leaves, reducing the photosynthetic capacity of the plant with subsequent reduction of the yield (Desneux *et al* 2010, 2011). Under heavy infestation, the yield loss between 80–100% is common (Gebremariamd 2015).

In many agronomic and vegetable cropping systems, the primary strategy employed to control this pest involves the use of chemical insecticides. However, it has serious problems such as destruction of natural enemy populations (Campbell *et al* 1991), build-up of insecticide residues on tomato fruits (Walgenbach *et al* 1991) and in the environment, and, especially, evolution of *T. absoluta* resistance to many of the active ingredients available on the market (Siqueira *et al* 2000a, b, Lietti *et al* 2005, Silva *et al* 2011, Campos *et al* 2015, Roditakis *et al* 2015).

One of the important control methods for sustainable management of *T. absoluta* to minimize development of pesticide resistance is the use of resistant host plants. The use of resistant plants can be a useful component of an integrated pest management (IPM) system that could affect pest population density, herbivore damage, and decrease pesticide applications in agricultural ecosystems. In addition, in many cases, even partial resistant cultivars are useful to enhance the effects of beneficial natural enemies (Hare & Andreadis 1983, Bong *et al* 1991, Cogni *et al* 2002, Kaplan 2007, Kaplan & Thaler 2010). Plant resistance to a pest can be caused by antixenosis, a mechanism employed by the host plants, deters the insects from oviposition, feeding, seeking shelter, and colonization (Oyetunji *et al* 2014); antibiosis, which has a direct influence on the life history of a pest (Ofomata *et al* 2000, Li *et al* 2004); and tolerance, the plant's capacity of keeping its production under attack for herbivore insect (Vargas 1970, Stowe *et al* 2000, Stevens *et al* 2008). Many researchers have investigated the resistance of host plants to tomato moth (Gilardón *et al* 2001a, Leite *et al* 2001, Suinaga *et al* 2004, Silva 2009, Gharekhani & Salek-Ebrahimi 2014). In this study, we present data on susceptibility of 11 tomato genotypes to *T. absoluta*. The data obtained from these experiments are used to understand the mechanism of population build-up of this pest on different tomato genotypes to develop a comprehensive pest management program for tomato.

Material and Methods

The experiment was performed in a field in the Faculty of Agriculture, Persian Gulf University, Bushehr province, Borazjan region, Bondarooz (Southern Iran) (29°12′54.1″ N, 51°13′57.1″ E, and elev. 99 m) from February 2014 to June 2015. Eleven cultivars of tomato were used in this study, including five cultivars Ps-6515, Berlina, Poolad, Petoprid-5, Zaman from FALAT Co., Iran; two cultivars Matin and Golsar from GOLSAM Co., Iran; and four cultivars Sandokan-F1, Golshan-616, Sadeen-95 and Sadeen-21 from BEHTA Co., Iran. The tomato seeds were planted in plastic transplant trays containing peat moss soil and perlite on November 2014. With the appearance of the first true leaves, the seedlings were transplanted into the main field. The evaluation of the resistance was performed in a randomized block design with three replications. A total of 20 plants per cultivar were planted in each replicate plot (plot area = 24 m^2) in two 150-cm spaced rows. The space between plants in each row was 50 cm, and the space between plots was 150 cm. The cultivars were exposed to the natural infestation by indigenous population of tomato leaf miner in the field.

Leaflet damage, leaf damage, and overall plant damage caused by the insect were evaluated at days 20, 40, and 60 after infestation. Five plants were randomly selected in each plot and marked notes and the different characteristics on these plants were measured. Leaflet and leaf damage was evaluated based on the percentage of leaflet or leaf area affected by *T. absoluta*. In this case, three leaves were selected from the upper third of each of the five selected plants and the damaged area of each whole leaf and its leaflets was recorded. The overall plant damage estimates were also performed for each of the five selected plants. In addition, the number of mines per leaf, holes on the stem, and holes per fruit were assessed at the last sampling date. The number of mines per leaf was counted on three leaves selected from the upper third of each of the five randomly selected plants. The number of holes on the stem and the number of holes on the fruit were evaluated by performing a direct counting of these features throughout the stem and five fruits from each of these five selected plants, respectively. In addition,

Table 1 The mean percent of leaflet damage, leaf damage, and overall plant damage in tomato cultivars submitted to infestation of *Tuta absoluta* in different evaluation periods.

Cultivar	Leaflet damage			Leaf damage			Overall plant damage		
	Sampling time			Sampling time			Sampling time		
	20	40	60	20	40	60	20	40	60
PS6515	11.33 ± 3.36a	30.00 ± 5.47a	53.67 ± 7.30b	11.33 ± 3.40a	36.67 ± 6.00a	63.67 ± 8.00bc	12.67 ± 3.50a	36.00 ± 6.00a	55.67 ± 7.40a
Berlina	3.00 ± 1.73d	8.67 ± 2.94d	14.33 ± 3.80f	3.33 ± 1.80e	11.00 ± 3.30e	20.67 ± 4.50 g	7.33 ± 2.70bcd	15.67 ± 4.00bc	26.33 ± 5.10c
SandocanF1	9.33 ± 3.05ab	33.67 ± 5.80a	58.33 ± 7.60ab	9.67 ± 3.10abc	34.00 ± 5.80ab	67.00 ± 8.20abc	10.00 ± 3.20abc	31.33 ± 6.00ab	48.00 ± 7.00ab
Matin	11.33 ± 3.36a	33.00 ± 5.74a	65.00 ± 8.00a	12.33 ± 3.50a	33.67 ± 5.80ab	71.00 ± 8.40ab	12.33 ± 3.50ab	31.33 ± 6.00ab	50.00 ± 7.00a
Sadeen95	7.00 ± 2.64bc	21.00 ± 4.58b	36.67 ± 6.00d	6.67 ± 2.60bcde	22.33 ± 4.70 cd	43.67 ± 6.60de	7.33 ± 2.70bcd	22.67 ± 4.70abc	37.00 ± 6.00abc
Zaman	5.67 ± 2.38 cd	14.33 ± 3.78c	24.00 ± 4.90e	6.00 ± 2.50bcde	17.66 ± 4.20de	35.67 ± 6.00ef	5.33 ± 2.30 cd	13.67 ± 4.00c	25.67 ± 5.00c
Petopride5	10.67 ± 3.26a	34.00 ± 5.83a	63.00 ± 7.90a	10.33 ± 3.20ab	36.33 ± 6.00a	74.67 ± 8.60a	9.00 ± 3.00abcd	30.67 ± 5.50ab	49.67 ± 7.00a
Golsar	3.67 ± 1.90d	10.67 ± 3.26 cd	19.00 ± 4.30ef	4.33 ± 2.10de	15.00 ± 3.90e	29.33 ± 5.40 fg	4.67 ± 2.10d	16.00 ± 4.00bc	27.00 ± 5.20c
Golshan616	9.33 ± 3.05ab	24.33 ± 4.90b	45.00 ± 6.70c	9.33 ± 3.00abc	27.33 ± 5.20bc	58.00 ± 7.60c	10.67 ± 3.30ab	23.33 ± 4.80abc	37.67 ± 6.10abc
Poolad	5.00 ± 2.24 cd	13.00 ± 3.60 cd	22.00 ± 4.70ef	5.67 ± 2.30cde	17.33 ± 4.20de	30.33 ± 5.50f	7.33 ± 2.70bcd	19.67 ± 4.40bc	28.67 ± 5.30bc
Sadeen21	8.00 ± 0.00abc	20.67 ± 4.54b	37.33 ± 6.10d	8.33 ± 2.90abcd	24.33 ± 4.90 cd	46.67 ± 6.80d	8.00 ± 2.80abcd	16.67 ± 4.00bc	28.67 ± 5.30bc

Means followed by the same letters in columns do not differ by the Duncan test (α = 0.05).

Table 2 The mean number of mines on the leaf, number of holes on the stem, and number of holes on the fruit of tomato cultivars submitted to infestation of *Tuta absoluta*.

Cultivar	Number of mines on the leaf	Number of holes on the stem	Number of holes on the fruit
PS6515	6.47 ± 2.50a	3.67 ± 1.90a	11.67 ± 3.40ab
Berlina	3.27 ± 1.80b	1.33 ± 1.00c	4.07 ± 2.00e
SandocanF1	5.20a ± 2.30b	2.80 ± 1.60abc	11.00 ± 3.30ab
Matin	5.73 ± 2.40a	3.13 ± 1.70ab	9.67 ± 3.10bc
Sadeen95	4.60 ± 2.10ab	2.33 ± 1.50abc	6.87 ± 2.60cde
Zaman	3.20 ± 1.80b	1.33 ± 1.10c	5.53 ± 2.30de
Petopride5	6.13 ± 2.50a	3.33 ± 1.80ab	13.00 ± 3.60a
Golsar	3.53 ± 1.80b	1.40 ± 1.10c	5.20 ± 2.30de
Golshan616	4.67 ± 2.10ab	2.40 ± 1.50abc	7.67 ± 2.70 cd
Poolad	3.47 ± 1.80b	1.40 ± 1.10c	7.00 ± 2.60cde
Sadeen21	3.47 ± 1.80b	1.90 ± 1.10c	8.67 ± 2.90bc

Means followed by the same letters in columns do not differ by the Duncan test (α = 0.05).

three leaves were selected from the upper third of each of the five randomly selected plants for counting the density of total trichomes and type VI glandular trichomes on the leaves. Then, three leaflets separated from each leaf and trichomes were counted using a stereomicroscope (×40) on three 2-cm^2 regions of each leaflet. The total number of trichomes and type VI glandular trichomes were also counted on different 2-cm^2 sections of the stem.

The normality of data was assessed with Shapiro-Wilk's test (Proc Univariate, SAS Institute (2003), Cary, NC, USA). Data which needed to be normalized were transformed before being analyzed. The percentage data were subjected to arcsin square root transformation; however, no count data transformation was performed before analysis because there was no evidence of non-normality within these data. Analysis of variance was performed using the general linear model (GLM) procedure in the SAS software and means were compared using Duncan's multiple range test. Total damage index for each cultivar was presented as thesum of the indices gained for different evaluated traits. Index for each trait was calculated by dividing the lowest recorded number in a certain cultivar to the greatest recorded number for that trait in all cultivars. Pearson's correlations (5% significance) were used to evaluate the relationships between traits. Data were then subjected to stepwise regression with overall plant damage at 60 day as the dependent variable. Cultivar comparison and selection was accomplished by cluster analysis according to Ward's method using SAS software.

Results and Discussion

According to data of leaflet damage and leaf damage, and overall plant damage, we found that the cultivars Berlina, Golsar, Poolad, and Zaman more effectively avoided damage caused by *T. absoluta* in the three evaluation periods (Table 1). In contrast, Matin, Petopride5, SandocanF1, and PS6515 showed significantly greater damage rates than other evaluated cultivars (Table 1). There were also significant differences in the number of mines on the leaf ($F = 3.33$, df = 10,

Table 3 Estimates of damage indices for different plant parts at day 60 after infestation and total damage index for tomato cultivars submitted to infestation of *Tuta absoluta*.

Cultivar	Leaflet damage index	Leaf damage index	Plant damage index	Number of holes on the stem index	Number of mines on the leaf index	Number of holes on the fruit indx	Total damage index
PS6515	0.78	0.84	0.80	0.78	0.74	0.67	4.60
Berlina	0.21	0.28	0.38	0.28	0.37	0.23	1.75
SandocanF1	0.84	0.88	0.70	0.60	0.60	0.63	4.24
Matin	0.94	0.93	0.72	0.66	0.66	0.56	4.47
Sadeen95	0.53	0.57	0.53	0.49	0.53	0.40	3.44
Zaman	0.35	0.47	0.37	0.28	0.37	0.33	2.15
Petopride5	0.91	0.98	0.71	0.70	0.70	0.75	4.76
Golsar	0.27	0.39	0.39	0.30	0.40	0.30	2.05
Golshan616	0.65	0.76	0.54	0.51	0.53	0.44	3.05
Poolad	0.32	0.40	0.41	0.30	0.40	0.40	2.23
Sadeen21	0.54	0.61	0.41	0.30	0.40	0.50	2.76

Table 4 Average densities (number/2 cm^2) of total trichomes and type VI glandular trichomes on the leaf and stem for the plants used in the bioassay.

Cultivar	Leaf		Stem	
	Total trichomes	Type VI glandular trichomes	Total trichomes	Type VI glandular trichomes
PS6515	38.27 ± 6.20 cd	28.67 ± 5.30c	64.70 ± 8.00a	20.00 ± 4.47abc
Berlina	55.33 ± 7.40ab	34.70 ± 5.90b	78.30 ± 8.80a	18.00 ± 4.24 cd
SandocanF1	43.00 ± 6.50c	29.33 ± 5.40c	70.40 ± 8.40a	19.70 ± 4.43bc
Matin	36.40 ± 6.00 cd	23.70 ± 4.80c	84.10 ± 9.20a	16.00 ± 4.00d
Sadeen95	60.4 ± 7.70a	37.70 ± 6.10a	87.7 ± 9.30a	21.70 ± 4.65ab
Zaman	50.13 ± 7.00b	34.33 ± 5.80b	101.7 ± 10.00a	21.33 ± 4.62ab
Petopride5	26.80 ± 5.10e	17.70 ± 4.20e	86.8 ± 9.30a	22.00 ± 4.69ab
Golsar	55.33 ± 7.40ab	37.70 ± 6.10a	110.00 ± 10.40a	22.33 ± 4.72a
Golshan616	42.27 ± 6.50c	30.70 ± 5.50c	94.50 ± 9.70a	20.00 ± 4.47abc
Poolad	34.33 ± 5.90d	23.33 ± 4.80d	72.30 ± 8.50a	16.70 ± 4.08d
Sadeen21	38.20 ± 6.20 cd	25.67 ± 5.00d	69.30 ± 8.30a	18.00 ± 4.24 cd

Means followed by the same letters in columns do not differ by the Duncan test (α = 0.05).

20, $P = 0.0107$), number of holes on the stem ($F = 3.37$, df = 10, 20, $P = 0.0110$), and fruit ($F = 9.10$, df = 10, 20, $P < 0.0001$) caused by *T. absoluta* among the tomato cultivars (Table 2). The lowest number of mines on the leaf and holes on the stem were observed in the cultivars Berlina, Zaman, Golsar, Poolad, and Sadeen21. The cultivars Berlina, Zaman, Golsar, and Poolad also had the lowest number of holes on the fruit (Table 2).

Total damage index for evaluated tomato cultivars has been presented in Table 3. Based on the results, the cultivars Berlina, Golsar, Zaman, Poolad, and Sadeen21 with the lowest total damage index (1.75, 2.05, 2.15, 2.23, and 2.76, respectively) were the most resistant cultivars against *T. absoluta*. The greatest total damage index was obtained for the cultivars Petopride5, PS6515, Matin, and SandocanF1 (4.76, 4.6, 4.47 and 4.24, respectively) sustained less damage from pest (Table 3).

Genetic variability is one of the characteristics of the germplasm bank subsamples that gives higher or lower susceptibility to pest insects (Fernandes *et al* 2012). So, observed differences between the levels of damages caused by *T. absoluta* on different tomato cultivars in the present study may have occurred because of genetic variability among them. Resende *et al* (2006), Gonçalves *et al* (2008), Oliveira *et al* (2009), Gonçalves Neto *et al*. (2010), Maciel *et al* (2011), and Gharekhani & Salek-Ebrahimi (2014) have also observed resistance to *T. absoluta* as non-preference and antibiosis in some evaluated tomato cultivars.

The genetic diversity of tomato cultivars may display inappropriate morphophysiological features to oviposition of *T. absoluta* adults and/or restrict the larvae feeding (Sobreira *et al* 2009). Trichome density is the most important structural feature of plants known to confer resistance to insect pests (Sharma *et al* 2009, He *et al* 2011). In the present study,

Table 5 Estimates of Pearson's correlations among the evaluated characteristics in tomato cultivars submitted to infestation of *Tuta absoluta*.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
(1) Total number of trichomes on the stem	–	–	–	–	–	–	–	–	–
(2) Number of Type VI glandular trichomes on the stem	0.19	–	–	–	–	–	–	–	–
(3) Total number of trichomes on the leaf	0.32	0.30	–	–	–	–	–	–	–
(4) Number of type VI glandular trichomes on the leaf	0.30	0.30	0.91*	–	–	–	–	–	–
(5) Number of mines on the leaf	0.04	0.09	−0.40*	−0.40*	–	–	–	–	–
(6) Number of holes on the stem	0.02	0.1	−0.40*	−0.40*	0.10*	–	–	–	–
(7) Number of holes on the fruit	−0.10	−0.03	−0.63*	−0.61*	0.75*	0.74*	–	–	–
(8) Leaflet damage	−0.17	−0.02	−0.58*	−0.58*	0.76*	0.76*	0.82*	–	–
(9) Leaf damage	−0.14	0.04	−0.58*	−0.56*	0.73*	0.73*	0.82*	0.97*	–
(10) Overall plant damage	−0.07	0.08	−0.42*	−0.40*	0.10*	0.10*	0.73*	0.78*	0.76*

*Significant at 5% by the *t* test.

Table 6 Results of stepwise multiple regression analysis between overall plant damage at day 60 (y) and the evaluated characteristics.

Variable	Parameter estimate	Model R-square	C(p)	*F* value
Number of mines on the leaf	8.85	0.92	2.30	360.29*
Total number of trichomes on the stem	−0.06	0.93	0.40	5.04*

*Significant at $P \leq 0.05$.

significant differences were observed in the total number of trichomes on the leaf ($F = 21.47$, df = 10, 20, $P < 0.0001$), number of type VI glandular trichomes on the leaf ($F = 46.58$, df = 10, 20, $P < 0.0001$), and number of type VI glandular trichomes on the stem ($F = 7.54$, df = 10, 20, $P < 0.0001$) among the cultivars (Table 4). However, differences in the total number of trichomes on the stem were not significant ($P > 0.05$) (Table 4). The cultivars with more total trichome density on the leaf were Sadeen95, Berlina, and Golsar. The most density of type VI glandular trichomes on the leaf was observed in Sadeen95 and Golsar (Table 4). Golsar, Sadeen95, Zaman, Petopride5, PS6515, and Golshan616 had the greatest number of type VI glandular trichomes on the stem. The lowest total number of trichomes and also type VI glandular trichomes on the leaf was observed in Petopride5. The cultivars Matin, Poolad, Berlina, and Sadeen21 had the lower number of type VI glandular trichomes on the stem (Table 4).

Pearson's correlations revealed that the total number of trichomes on the leaf had negative and significant correlations with the overall plant damage ($r = -0.42$), leaf damage ($r = -0.58$), leaflet damage ($r = -0.58$), number of mines on the leaf ($r = -0.40$), number of holes on the stem ($r = -0.40$), and number of holes on the fruit ($r = -0.63$) (Table 5). Person's correlation estimates between type VI glandular trichomes on the leaf with overall plant damage ($r = -0.40$), leaf damage ($r = -0.56$), leaflet damage ($r = -0.58$), number of mines on the leaf ($r = -0.40$), number of holes on the stem ($r = -0.40$), and number of holes on the fruit ($r = -0.61$) were also negative and significant (Table 5). These results suggest trichomes may have direct negative influence on both larval feeding and oviposition by insects (Handley *et al* 2005), result in the lowest number of larvae and consequently lower damage to leaves and plants. Gilardón *et al* (2001a) and Neves *et al* (2003) also reported significant positive correlation between the density of trichomes on the leaves and resistance to *Tuta* species, as well as its relation to trichomes type VI. Thus, the high density of leaf trichomes present in the cultivars Sadeen95, Berlina, and Golsar can be one of the possible causes of resistance to *T. absoluta* known as the antixenosis mechanism. Oliveira *et al* (2009) also observed that the HGB 1497 subsample of *Solanum lycopersicum* L. presented resistance by antixenosis to the tomato plant miner *T. absoluta*. The high density of trichomes on tomato leaves can be extremely important for a cultivar to avoid the presence of *T. absoluta*. In addition, different metabolites are secreted from trichomes on the stems and leaves of the tomato plants, which cause different resistance against *T. absoluta* (Gilardón *et al* 2001b). Compounds such as tridecan-2-one and undecan-2-one, especially secreted by type VI glandular trichomes on the tomato leaves, perform as physical and chemical barriers for

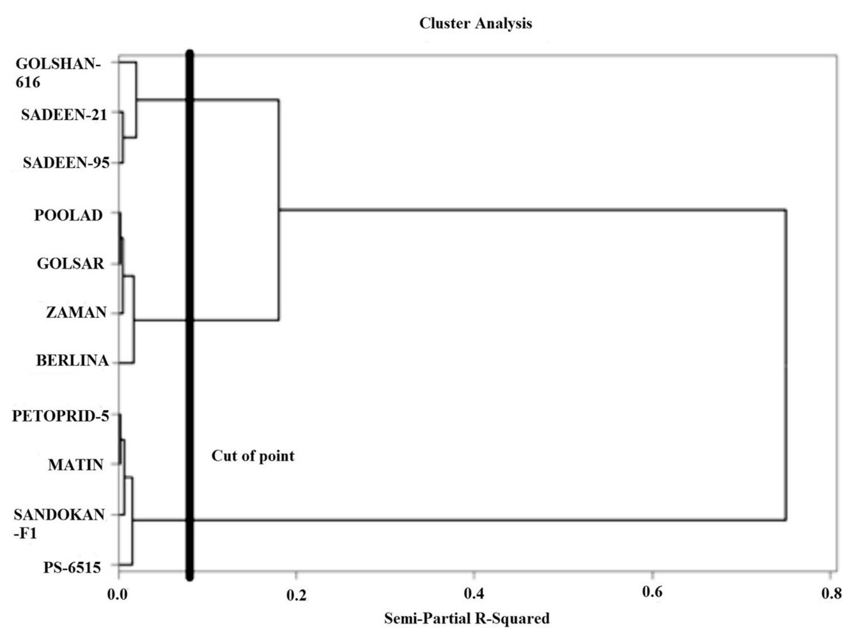

Fig 1 Dendrogram of 11 tomato cultivars for six studied variables using hierarchical cluster analysis (Ward's method).

insects and pathogens (Farrar & Kennedy 1991, Eigenbrode & Espelie 1995, Justus *et al* 2000, Picoaga *et al* 2003). Such features can be used in plant breeding programs aimed at resistance to pests with selections toward genes that express a higher number of trichomes. An exception was Poolad with a low number of trichomes on the leaf (Table 4), which showed high resistance to *T. absoluta* (Tables 1, 2 and 3). Also, Sadeen95 with the most density of its trichomes (Table 4), showed partially resistance to the pest (Tables 1 and 3). This result can be explained by the presence and role of other potential resistance factors such as allelochemicals that confer resistance to *T. absoluta* as shown by Leite *et al* (1999) and Suinaga *et al* (2004).

Person's correlation estimates between leaf and leaflet damage with the number of mines on the leaf, number of holes on the stem, and fruit were positive and significant (Table 5). Overall plant damage also had positive and significant estimates of correlation with leaf damage ($r = 0.76$), leaflet damage ($r = 0.78$), number of mines on the leaf ($r = 0.10$), number of holes on the stem ($r = 0.10$), and number of holes on the fruit ($r = 0.73$) (Table 5). The number of holes on the fruit had positive and significant correlations with the number of mines on the leaf ($r = 0.75$) and number of holes on the stem ($r = 0.74$) (Table 5). The number of holes on the stem had positive and significant correlation with the number of mines on the leaf ($r = 0.10$) (Table 5).

Stepwise regression is an automated tool used in the exploratory stages of model building to identify a useful subset of predictors. The process systematically adds the most significant variable or removes the least significant variable during each step. In order to remove the effect of non-effective characteristics in the regression model on grain yield, stepwise regression was used. The results of the stepwise regression analysis are presented in Table 6. The number of mines on the leaf (x_4) was the variable that best explained overall plant damage at day 60 after infestation (y) as shown by stepwise regression (Table 6). The total number of trichomes on the stem (x_1) was the second variable that exerted influence on overall plant damage. Parameter estimates showed that the number of mines on the leaf had positive significant effect, while the number of trichomes on the stem negatively affected overall plant damage at day 60 (Table 6).

The results of cluster analysis separated 11 evaluated tomato cultivars in three distinctive categories including Petopride5, Matin, SandokanF1, and PS6515 as susceptible; Golshan616, Sadeen21, and Sadeen95 as partially resistant; and Berlina, Zaman, Golsar, and Poolad as resistant cultivars (Fig 1).

Conclusions

Significant differences in relative resistance of the studied tomato cultivars demonstrate that the ones have potential for use in backcrosses in processing tomato breeding programs. However, our results are preliminary and require future studies for identifying the other resistance factors, other than trichome density, associated with these cultivars. Also, additional analyses with molecular markers will be needed for indicating the probable genetic variation between these tomato cultivars.

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References

Baniameri V, Cheraghian A (2011) The current status of *Tuta absoluta* in Iran. International Symposium on Management of *Tuta absoluta* (tomato leafminer(. Agadir, Morocco, November 16–18, 2011

Bong CFJ, Sikorowski PP, Davis FM (1991) Effects of a resistant maize genotype and cytoplasmic polyhedrosis virus on growth and development of the corn earworm (Lepidoptera:Noctuidae). Environ Entomol 20:1200–1206

Campbell CD, Walgenbach JF, Kennedy GC (1991) Effect of parasitoids on Lepidopterous pests in insecticide-treated and untreated tomatoes in western North Carolina. J Econ Entomol 84:1662–1667

Campos MR, Silva TB, Silva WM, Silva JE, Siqueira HA (2015) Spinosyn resistance in the tomato borer *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae). J Pest Sci 88(2):405–412

Cogni R, Freitas AVL, Amaral Filho BF (2002) Influence of prey size on predation success by *Zelus longipes* L. (Het., Reduviidae). J Appl Entomol 126:74–78

Desneux N, Wajnberg E, Wyckhuys KA, Burgio G, Arpaia S, Narváez-Vasquez CA, González-Cabrera J, Ruescas DC, Tabone E, Frandon J, Pizzol J, Poncet C, Cabello T, Urbaneja A (2010) Biological invasion of European tomato crops by *Tuta absoluta*: ecology, history of invasion and prospects for biological control. J Pest Sci 83:197–215

Desneux N, Luna MG, Guillemaud T, Urbaneja A (2011) The invasive South American tomato pinworm, *Tuta absoluta*, continues to spread in Afro-Eurasia and beyond: the new threat to tomato world production. J Pest Sci 84:403–408

Eigenbrode SD, Espelie KE (1995) Effects of plant epicuticular lipids on insect herbivores. Annu Rev Entomol 40:171–194

Farrar RR, Kennedy GG (1991) Relationship of leaf lamellar-based resistance to *Leptinotarsa decemlineata* and *Heliothis zea* in a wild tomato, *Lycopersicon hirsutum* f. *glabratum*, PI 134417. Entomol Exp Appl 58:61–67

Fernandes ME, Fernandes FL, Silva DJ, Picanço MC, Jhamc GN, Carneiro PC, Queiroz RB (2012) Trichomes and hydrocarbons associated with the tomato plant antixenosis to the leafminer. An Acad Bras Cienc 84(1):201–210

Gebremariamd G (2015) *Tuta absoluta*: a global looming challenge in tomato production, review paper. J Biol Agric Healthc 5(14):57–62

Gharekhani GH, Salek-Ebrahimi H (2014) Evaluating the damage of *Tuta absoluta* (Meyrick) (Lepidoptera:Gelechiidae) on some cultivars of tomato under greenhouse condition. Arch Phytopathol Plant Protect 47(4):429–436

Gilardón E, Pocovi M, Hernández C, Collavino G, Olsen A (2001a) Role of 2-tridecanone and type VI glandular trichome on tomato resistance to *Tuta absoluta*. Pesq Agrop Brasileira 36:929–933

Gilardón E, Pocovi M, Hernández C, Olsen A (2001b) Role of tomato leaf glandular trichomes on oviposition of *Tuta absoluta*. Pesq Agrop Brasileira 36:585–588

Gonçalves Neto AC, Silva VF, Maluf WR, Maciel GM et al (2010) Resistência à traça-do-tomateiro em plantas com altos teores de acilaçúcares nas folhas. Hortic Bras 28:203–208

Gonçalves LS, Rodrigues R, Amaral AT Jr, Karasawa M et al (2008) Comparison of multivariate statistical algorithms to cluster tomato heirloom accessions. Genet Mol Res 7:1289–1297

Handley R, Ekbom B, Agren J (2005) Variation in trichome density and resistance against a specialist insect herbivore in natural populations of *Arabidopsis thaliana*. Ecol Entomol 30:284–292

Hare JD, Andreadis TG (1983) Variation in the susceptibility of *Leptinotarsa decemlineata* (Coleoptera: Chrysomelidae) when reared on divergent host plants to the fungal pathogen, *Beauvaria bassiana*, in the field and laboratory. Environ Entomol 12:1892–1897

He J, Chen F, Chen S, Lv G, Deng Y, Fang Z, Guan Z, He C (2011) *Chrysanthemum* leaf epidermal surface morphology and antioxidant and defense enzyme activity in response to aphid infestation. J Plant Physiol 168:687–693

Justus KA, Dosdall LM, Mitchell BK (2000) Oviposition by *Plutella xylostella* (Lepidoptera:Plutellidae) effects of phylloplane waxiness. J Econ Entomol 93:1152–1159

Kaplan I (2007) Leafhopper-induced plant resistance enhances predation risk in a phytophagous beetle. Oecologia 152:665–675

Kaplan I, Thaler JS (2010) Plant resistance attenuates the consumptive and non-consumptive impacts of predators on prey. Oikos 119:1105–1113

Leite GLD, Picanço M, Della Lucia TM, Moreira MD (1999) Role of canopy height in the resistance of *Lycopersicon hirsutum* f. *glabratum* to *Tuta absoluta* (Lep., Gelechiidae). J Appl Entomol 123:459–463

Leite GL, Picanço M, Guedes RN, Zanuncio JC (2001) Role of plant age in the resistance of *Lycopersicon hirsutum* f. *glabratum* to the tomato leafminer *Tuta absoluta* (Lepidoptera:Gelechiidae). Sci Hortic 89:103–113

Li Y, Hill CB, Hartman GL (2004) Effect of three resistant soybean genotype on the fecundity, mortality, and maturation of soybean aphid (Homoptera: Aphididae). J Econ Entomol 97:1106–1111

Lietti MM, Botto E, Alzogaray RA (2005) Insecticide resistance in Argentine populations of *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae). Neotrop Entomol 34(1):113–119

Maciel GM, Maluf WR, Silva VF, Gonçalves Neto AC (2011) Híbridos pré-comerciais resistentes a *Tuta absoluta* obtidos de linhagem de tomateiro rica em acilaçúcares. Hortic Bras 29:151–15

Neves LGN, Leale NR, Rodrigues R, Pereira NE (2003) Genetic parameters and correlation among progenies of *Lycopersicon esculentum* x L. *hirsutum* f. *glabratum* for resistance to tomato pinworm. Hortic Bras 21:456–458

Ofomata VC, Overholt WA, Lux SA, Huis AV, Egwuatu RI (2000) Comparative studies on the fecundity, egg survival, larval feeding, and development of *Chilo orichalcociliellus* (Lepidoptera:Crambidae) on five grasses. Ann Entomol Soc Am 93:492–499

Oliveira FA, da Silva DJ, Leite GL, Jham GN, Picanço M (2009) Resistance of 57 greenhouse-grown accessions of *Lycopersicon esculentum* and three cultivars to *Tuta absoluta* (Meyrick) (Lepidoptera:Gelechiidae). Sci Hortic 119(2):182–187

Oyetunji OE, Nwilene FE, Togola A, Adebayo KA (2014) Antixenotic and antibiotic mechanisms of resistance to African rice gall midge in Nigeria. Trends Appl Sci Res 9:174–186

Picoaga A, Cartea ME, Soengas P, Monetti L, Ordás A (2003) Resistance of kale populations to lepidopterous pests in northwestern Spain. J Econ Entomol 96:143–147

Resende JTV, Maluf WR, Faria MV, Pfann AZ (2006) Acylsugars in tomato leaflets confer resistance to the south American tomato pinworm, *Tuta absoluta* Meyr. Sci Agric 63:20–25

Roditakis E, Vasakis E, Grispou M, Stavrakaki M, Nauen R, Gravouil M, Bassi A (2015) First report of *Tuta absoluta* resistance to diamide insecticides. J Pest Sci 88(1):9–16

SAS Institute (2003) The SAS system for windows, release 9.0. SAS, Institute, Cary

Sharma HC, Sujana G, Rao DM (2009) Morphological and chemical components of resistance to pod borer, *Helicoverpa armigera* in wild relatives of pigeonpea. Arthropod-Plant Interact 3:151–161

Silva VF (2009) Resistência a artrópodos-praga em genótipos de tomateiro ricos em zingibereno e/ou acilaçúcares [Resistance to arthropod pests in zingiberene and/or acylsugars rich tomato genotypes]. Doctoral Thesis (in Portuguese), Universidade Federal de Lavras, Lavras, 62 p

Silva GA, Picanço MC, Bacci L, Crespo ALB, Rosado JF, Guedes RNC (2011) Control failure likelihood and spatial dependence of insecticide resistance in the tomato pinworm, *Tuta absoluta*. Pest Manag Sci 67(8): 913–920

Siqueira HÁ, Guedes RN, Picanço MC (2000a) Insecticide resistance in populations of *Tuta absoluta* (Lepidoptera:Gelechiidae). Agric For Entomol 2:147–153

Siqueira HÁ, Guedes RN, Picanço MC (2000b) Cartap resistance and synergism in populations of *Tuta absoluta* (Lepidoptera: Gelechiidae). J Appl Entomol 124:233–238

Sobreira FM, Sobreira FM, Andrade GS, Almeida GD, Matta FP (2009) Sources of resistance to tomato leafminer in cherry tomato. Sci Agrár 10(4):327–330

Stevens MT, Kruger EL, Lindroth RL (2008) Variation in tolerance to herbivory is mediated by differences in biomass allocation in aspen. Funct Ecol 22:40–47

Stowe KA, Marquis RJ, Hochwender CG, Simms EL (2000) The evolutionary ecology of tolerance to consumer damage. Annu Rev Ecol Evol Syst 31:565–595

Suinaga FA, Picanço MC, Moreira MD, Semeão AA, Magalhães ST (2004) Resistência por antibiose de *Lycopersicon peruvianum* à traça do tomateiro. Hortic Bras 22:281–285

Vargas H (1970) Observaciones sobre la biología y enemigos naturales de la polilla del tomate, *Gnorimoschema absoluta* (Meyrick) (Lepidoptera:Gelechiidae). Idesia 1:75–110

Walgenbach JF, Leidy RB, Sheets TJ (1991) Persistence of insecticides on tomato foliage and implications for control of tomato fruit worm (Lepidoptera:Noctuidae). J Econ Entomol 84:978–986