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MORPHOAGRONOMIC CHARACTERIZATION OF TOMATO LINES (*Solanum lycopersicum* L.) RESISTANT TO BEGOMOVIRUS

Caracterización morfoagronómica en líneas de tomate (*Solanum lycopersicum* L.) con resistencia a begomovirus

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ABSTRACT. The present work was developed to evaluate the in order to characterize morphoagronomically the phenotypic variability in 16 tomato cultivars, including 15 cultivars are resistant to begomovirus from Taiwan and the analysis of these cultivars to the circulating virus isolated in Cuba. For this, 20 morphoagronomic characters related to the plant were evaluated, the fruit and the phonological stages. In addition, begomovirus resistance was evaluated by the severity of the disease caused by infection of TYLCV-IL under uncontrolled conditions. For the morphoagronomic viewpoint, a phenotypical variability regarding morphoagronomic characteristic was detected, grouping the cultivars into four main groups. Except for the susceptible control, all the evaluated cultivars were asymptomatic to the virus, confirming the prospects for their use in plant breeding programs for obtaining new hybrids and cultivars resistant to begomovirus.

Key words: agronomic characteristics, geminivirus, yield, disease resistance

RESUMEN. El presente trabajo se realizó con el objetivo de caracterizar morfoagronómicamente la variabilidad fenotípica existente en 16 cultivares de tomate, de ellos 15 son cultivares con resistencia a begomovirus procedentes de Taiwán y el análisis del comportamiento de estos cultivares ante el aislado viral circulante en Cuba. Para ello se evaluaron 20 caracteres morfoagronómicos relacionados con la planta, el fruto y las fases fenológicas del cultivo. Se estudió asimismo, la resistencia a begomovirus, mediante la evaluación de la severidad de la enfermedad provocada por la infección de TYLCV-IL en condiciones no controladas. Se pudo detectar la existencia de variabilidad genética dentro de la colección en cuanto a características morfoagronómicas, lo que permitió agrupar a los cultivares en cuatro grupos fundamentales. A excepción del control susceptible, los cultivares evaluados fueron asintomáticos ante el virus, lo que confirma las perspectivas de su utilización en los programas de mejoramiento del cultivo para la obtención de híbridos y nuevos cultivares resistentes a begomovirus.

Palabras clave: características agronómicas, geminivirus, rendimiento, resistencia a la enfermedad

INTRODUCTION

Tomato (*Solanum lycopersicum* L.) is very common all over the world and has become a crop of great economic importance (1). The cultivation has gained popularity, especially in recent years with the discovery of the antioxidant and anticancer activity of lycopene (2, 3). Therefore, its production and consumption are constantly increasing, being the seventh crop in world importance, reaching in 2013 a production of more than 163 million tons and a cultivated area of almost 5,1 million hectares (4).

In Cuba the yields achieved are low, as in the vast majority of tropical countries. This is due to the negative effect of climatic factors and the high incidence of pests in the culture (5, 6).

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Among the main pests that affect tomato in Cuba, which cause yield losses of up to 100%, are commonly known as "geminiviruses" (7). The Geminiviridae family constitutes one of the families of viruses that infect plants, with DNA as genetic material. Among the genera that comprise it, Begomovirus is one of that affect the most, it is transmitted by the whitefly *Bemisia tabacci* (Genn.) (8-10).

The use of resistant cultivars, combined with biological control in the Integrated Pest Management strategy, could contribute to reduce the percentage of infected plants and, consequently, the incidence of the disease (11, 12). In this sense, the identification of new sources of resistance to the pathogen and its incorporation into commercial cultivars are investigations that deserve to be prioritized (13-15).

Taking into account current trends in genetic improvement for the disease and in Cuba with few begomovirus resistant cultivars, it is necessary to identify new cultivars with genes and resistance mechanisms that can be used by the genetic improvement cultivation program, in the subsequent development of commercial hybrids, lines and cultivars with a more durable resistance. This, in addition, will allow drawing strategies of a greater durability before the threat of emergence of virus mutants, recombinations among viral species and emergencies of new species.

This is why, based on the use of natural sources of resistance and considering the high incidence and prevalence of begomovirus in the country, the present work was developed with the objective of characterizing morphoagronomically the phenotypic variability in 15 tomato cultivars with resistance to Begomoviruses from Taiwan and the behavior analysis of these cultivars before the TLCVL circulating in Cuba under uncontrolled conditions.

MATERIALS AND METHODS

The morphoagronomic characterization of 16 tomato cultivars (Table I) was performed in the central area of the National Institute of Agricultural Sciences (INCA), located at km. 3 ½ of the San José to Tapaste road, San José de las Lajas municipality, Mayabeque province, located at 23° 00 'north latitude and 82° 12' west longitude at 138 m.a.s.l.

The behavior of the climatic variables of maximum, average and minimum temperature, as well as of the relative humidity and the precipitations that affected during the experiment development were taken from the Meteorological Station of Tapaste. Cultural attention in all cases was made according to the Technical Instructions for Organoponics and Intensive Gardens, established for the tomato (16).

Table I. Cultivars of tomatoes studied and genes of resistance to pathogens

	Abbreviations	Cultivar	Genes
1	*TY*52	*TY*52	*Ty*-1
2	CLN2498F1	CLN2498F1-68-15-22-17-19-12-17-8-0	*Ty*-2
3	CLN3024F2	CLN3024F2-104-48-1-18-0	*Ty*-1, *Ty*-2
4	CLN3205F1	CLN3205F1-32-7-13-22-6-26-26	*Ty*-3
5	CLN3212F1	CLN3212F1-21-31-11-27-3-11-25	*Ty*-5
6	CLN3150F1	CLN3150F1-4-8-8-26-4-5	*Ty*-2, *Ty*-5
7	CLN3126A	CLN3126A-10-23-8-11-1-13-7	*Ty*-2
8	CLN3109F1	CLN3109F1-26-35-11-2-29-10-11-0	*Ty*-2
9	CLN3447F2	CLN3447F2-66-2-15-0	*Ty*-2, *Ty*-5
10	CLN3070F1	CLN3070F1-8-7-27-29-9-4-10-19-14	*Ty*-2, *Ty*-3
11	CLN3078F1	CLN3078F1-12-34-27-9-410-19-14	*Ty*-2, *Ty*-3
12	CLN3078F1B	CLN3078F1-12-34-29-7-8-5-0	*Ty*-2, *Ty*-3
13	CLN3241F1	CLN3241F1-34-28-2-20-528-27	*Ty*-2, *Ty*-3, *Ty*-5-*Ph*-2, *I*-2
14	CLN3125F2	CLN3125F2-21-4-13-1-0	*Ty*-2, *Ty*-3, *I*-2
15	CLN2819F1	CLN2819F1-2-1-4-25-6-13-13-21-4-4-0	*Ty*-2, *Ty*-3, *Ty*-5
16	C-28	Campbell-28	Susceptible.

Ty-1, Ty-2, Ty-3 and Ty-5 genes, related to begomovirus resistance; I-2, related to resistance to race 2 of *Fusarium oxysporium* f. sp. *Lycopersicum*; Ph-2, related to resistance to *Phytophthora infestans*

The study was carried out with 16 cultivars; 15 tomato cultivars with different sources of resistance to begomovirus from Taiwan, belonging to the Germplasm Bank of the Fundamental Research Institute of Tropical Agriculture (INIFAT) and Campbell-28, a susceptible begomovirus (Table I).

For this purpose, seeds of the 16 cultivars were planted in a ball of 196 alveoli, containing a substrate composed of Red Ferralitic compacted soil, filter cake: zeolite, in a 1:2:1 proportion, the capacity of each alveolus being 30 cm^3. At 21 days after germination the seedlings were sown, of 10 plants per cultivar in open-air asbestos cement beds containing a mixture of Ferralitic Red Compacted soil (Ferralsol eutric), according to the new Soil Genetic Classification (17) and filter cake, in a 3:1 ratio. A planting distance of 0,90 x 0,25 m and a Completely Randomized Design was used. The planting was carried out in the optimum period of cultivation, on December 10th, 2014, while the transplant was carried out on January 6th, 2015.

The morphoagronomic characters were evaluated in 10 plants, the flowers or fruits by accession, at different times of their development, according to the characterization proposed by the descriptor of the International Institute of Plant Genetic Resources (18), according to which the characters related to the mature fruit when they are commercially mature. The evaluations were as follows: days at flowering and ripening; abscission layer; type of growth and inflorescence; foliage density; chiseling and compactness of the fruits; stem scar and pistillate; color of the immature and mature fruit; longitudinal and equatorial diameters; fruit shape, shoulder of the fruit and terminal form of fruit bloom; average mass of fruits; number of locules and yield per plant.

For the analysis of the quantitative traits, a simple classification ANOVA, fixed effects model was performed and the means were test by the Duncan Multiple Ranges test for a 5 % statistical significance (19).

The data were submitted to Principal Component Statistical Analysis, where the autovectors were selected with values equal to or greater than 0,50 on the main axes. Prior to performing multivariate analyzes, qualitative and quantitative determinations were standardized to ensure that all variables had the same weight Statistic (20).

In this way the qualitative characters encoded in binary form were assigned values of 0 and 1, where generally zero coincided with the absence of the character and 1 with the presence. The qualitative characters that suppose different expression degrees, were codified giving zero value to the lowest degree of expression and one to the greater and fractional values to the intermediate grades (example: stem scar : small 0, mean ½, large 1).

Finally the quantitative traits were treated in a similar way, with a score of zero to the minimum value and one to the maximum, the intermediate values being coded using the following formula: V (0-1) = (V (real) - V (minimum))/(Range), where: V (0-1): is the new value between 0-1; V (real) and V (minimum) are the values of the quantitative character and their minimum value, respectively; (Range) is the range of character variation. In addition, a cluster analysis (hierarchical clusters) was carried out, based on a matrix of Euclidean distances. The analyzes were performed using the statistical package SPSS version 21.0, on Windows (21).

Evaluation of the disease severity caused by TYLCV

To evaluate the disease severity in the 16 cultivars studied the four-degree scale was used (22), following a sampling dynamics of the plants at 15 and 30 days after transplantation (DAT). Observations were made during the early hours of the morning (8: 00-9: 00 am).

According to the severity scale for TYLCV used, 0: plant without symptom; 1: plant with symptoms of light yellowing in the margin of leaflets of apical leaves; 2: plant with symptoms of yellowing and minor frizzle of apical leaflets; 3: plant with large range of yellowing symptoms, frizzling and chopping, with some reduction in size, but the plant continues to grow; 4: plant with symptoms of severe yellowing and growth retardation, frizzling and chopping, stops the growth of the plant.

RESULTS AND DISCUSSION

Morphoagronomic characterization of the cultivars studied

The results of the morphoagronomic characterization, taking into account the 20 characters analyzed, allowed verifying the phenotypic variability in the 16 tomato cultivars evaluated in terms of characteristics related to plant, fruit and phenological phases (Tables II, III, IV and V).

Table II. Vegetative-floral characteristics of the analyzed cultivars

Code	Growth type	Type of inflorescence	Density of foliage	Abscission layer
TY52	Determined	Simple	Intermediate	Present
CLN2498F1	Determined	Compound	Intermediate	Present
CLN3024F2	Determined	Simple	Intermediate	Present
CLN3205F1	Semidetermined	Simple	Intermediate	Present
CLN3212F1	Determined	Simple	Scarce	Present
CLN3150F1	Determined	Simple	Scarce	Present
CLN3126A	Determined	Simple	Intermediate	Present
CLN3109F1	Determined	Simple	Intermediate	Present
CLN3447F2	Semidetermined	Simple	Intermediate	Present
CLN3070F1	Determined	Simple	Intermediate	Present
CLN3078F1	Determined	Simple	Dense	Present
CLN3078F1B	Determined	Simple	Dense	Absent
CLN3241F1	Semidetermined	Simple	Scarce	Absent
CLN3125F2	Semidetermined	Simple	Intermediate	Present
CLN2819F1	Semidetermined	Simple	Scarce	Present
C-28	Determined	Simple	Intermediate	Present

Table II shows the phenotypic differences related to vegetative-floral characteristics, with the exception of 'CLN3205F1', 'CLN3447F2', 'CLN3241F1', 'CLN3125F2' and 'CLN2819F1', which presented semidetermined growth. Depending on the growth type, cultivated tomatoes are used for one or the other purpose (23). Also, a predominance of the simple inflorescences was observed, however, the cultivar CLN2498F1 showed double inflorescences.

Most of the cultivars had intermediate foliage density (10 cultivars), although two cultivars ('CLN3078F1' and 'CLN3078F1B') had abundant foliage density, while another four presented sparse foliage and their fruits, therefore, they were more exposed to adverse environmental conditions. The presence of abscission layer in the fruits predominated, except in the cultivars 'CLN3078F1B' and 'CLN3241F1', which lacked this character, associated with the presence of the *j*-2 gene, of the pedicel binding, which gives these cultivars very favorable characteristics for the industry (24, 25).

Table III shows the duration of the phenological phases, days at flowering and at maturity. The most precocious cultivar was 'TY52', because it presented a period of germination-less maturation (85 days). On the contrary, 'CLN3212F1' and 'CLN3126A' were found to be the later, with periods of 96 and 95 days, respectively. Similar behavior was observed in the germination-flowering period.

Table III. Days to flowering and ripening in the 16 tomato cultivars

Code	Days to flowering (DAT)	Days to maturation (DAT)
TY52	42	85
CLN2498F1	45	86
CLN3024F2	45	88
CLN3205F1	47	90
CLN3212F1	52	96
CLN3150F1	49	94
CLN3126A	52	95
CLN3109F1	46	88
CLN3447F2	47	90
CLN3070F1	52	94
CLN3078F1	52	94
CLN3078F1B	47	92
CLN3241F1	47	92
CLN3125F2	47	89
CLN2819F1	50	94
C-28	45	91

Diversity in the duration of the different phenological phases in the culture have been reported, in addition, by different authors (6, 26, 27).

Table IV shows some of the evaluations carried out on the fruits. Only two cultivars of the studied ones presented green shoulders in their fruits 'CLN3024F2' and 'CLN3126A'. At present, plants with these characteristics have some acceptance in the market, as long as it is not very pronounced, as in these cases, and it is not linked to other genes present in many wild species, which transmit unpleasant tastes to the cultivated tomato (2. 3). However, the absence of green shoulder in fruits is related to a uniform distribution of color in the fruit, which is of great importance because of the great acceptance on the market of cultivars with these characteristics for fresh consumption (28).

Different forms of the fruit were distinguished: squashed, elongated round, and cylindrical cordiform and ellipsoid. The fruits presented, in general, smooth surfaces, with the exception of 'CLN3212F1' and 'C-28', which presented light ribbed. Today there is a preference for smooth fruits in the market (29).

Similarly, other indicators, such as the shape of the pistillate scar, the stem scar and the terminal shape of the fruits, were shown to be variable. In general, fruits with flattened base predominated and pistilar and peduncular scars on tip and median, respectively. Although fruits of medium and soft compactness prevailed, cultivars such as CLN3109F1 and CLN3447F2 were presented with compact fruits, a very useful feature for the industry (Table IV). It is noteworthy that the only character that remained homogeneous was the color of ripe fruits.

In general, Table V shows a high variability in the quantitative traits analyzed, which is evidenced by the highly significant differences found in the average mass of the fruits, the equatorial, polar diameter and yield per plant (Table V). The average mass of the fruits was between 47,5 and 123,5 g, while yield varied between 0,62 and 1,92 kg plant^{-1}, being the cultivar CLN3109F1, the one with the highest yield. Similar differences in mean mass and yield were found when evaluating various tomato cultivars introduced in Ghana (6, 11) and Cuba (26); as well as in local cultivars of Turkey and Iran (27). It is noteworthy that the low yields found in TY52, CLN3447F2, could be due, among other factors, to its susceptibility to *Phytophthora infestans* (data not shown).

The analysis of Principal Components (PCA) (Table VIa and b), based on the divergence found, showed that 54 % of the total variability in the three main axes is extracted in the formation of the groups.

Table IV. Characteristics of the fruit of the cultivars under study

Code	LOC	FF	CFI	CFM	PH	ACO	COM	FTF	CPI	CPE
TY52	2	CO	VC	RN	SH	AA	CB	PD	PU	ME
CLN2498F1	2	CO	VM	RN	SH	AA	CB	PD	PU	PE
CLN3024F2	1	CO	VM	RN	CH	AA	CB	PT	PU	GR
CLN3205F1	1	AP	VM	RN	SH	AA	CB	PT	PU	PE
CLN3212F1	2	EL	VC	RN	SH	AL	CM	ID	IG	GR
CLN3150F1	1	RA	VC	RN	SH	AL	CM	PD	PU	ME
CLN3126A	2	RA	VM	RN	CH	AA	CM	PD	ET	ME
CLN3109F1	1	RA	VM	RN	SH	AA	CD	PD	PU	ME
CLN3447F2	1	CO	VC	RN	SH	AA	CD	PD	PU	ME
CLN3070F1	2	RA	VC	RN	SH	AA	CB	PD	PU	ME
CLN3078F1	1	RA	VM	RN	SH	AA	CB	PD	PU	ME
CLN3078F1B	1	CO	VM	RN	SH	AA	CB	PD	PU	ME
CLN3241F1	1	CO	VM	RN	SH	AA	CD	PT	PU	ME
CLN3125F2	2	CO	VM	RN	SH	AA	CM	PT	PU	GR
CLN2819F1	1	CO	VM	RN	SH	AA	CB	PD	PU	GR
C-28	2	AP	VM	RN	SH	AL	CB	PD	IG	GR

LOC (number of loci): 1 (of 2-3 loci), 2 (of 4 to 7 loci); FF (fruit shape): AP (crushed), RA (elongated round), CO (cordiform), CI (cylindrical), EL (ellipsoid); CFI (immature fruit color): VC (light green), VM (medium green); PH (shoulder presence): SH (without shoulders), CH (light); ACO (fruit harvested): AA (absent), AL (light); COM (fruit compactness): CB (soft), CM (medium), CD (hard); FTF (terminal form of fruit flowering): ID (indented), PD (flattened), PT (pointed); CPI (pistillar scar shape): PU (dot), ET (star), IG (irregular); CPE (pedicle scar shape): PE (small), Intermediate (medium), GR (large)

Table V. Mean values of the quantitative traits in the analyzed tomato cultivars

Code of the line	Weight of the fruit (g)	Yield (kg/plant)	Equatorial diameter(cm)	Longitudinal Diameter (cm)
TY52	47,50 h	0,692 f	4,30 f	4,68 d
CLN2498F1	83,2 ef	1,496 abcd	5, 12 cd	6,14 a
CLN3024F2	98,00 cde	1,311 bcde	5,40 bc	6,02 a
CLN3205F1	70,20 fg	1,104 def	4,60 ef	6,16 a
CLN3212F1	123,50 a	0,814 ef	7,10 a	5,52 bc
CLN3150F1	82,80 ef	1,817 ab	5,10 cde	5,42 c
CLN3126A	75,40 fg	0,937 ef	5,18 cd	5,52 bc
CLN3109F1	108,00 bc	1,917 a	5,42 bc	6,20 a
CLN3447F2	64,00 g	0,616 f	4,82 de	4,70 d
CLN3070F1	99,50 cd	1,041 def	5,48 bc	5,98 ab
CLN3078F1	73,60 fg	1,318 bcde	5,06 cde	5,28 c
CLN3078F1B	85,00 def	1,245 cde	5,56 bc	6,26 a
CLN3241F1	119,90 ab	1,770 abc	5,70 b	6,30 a
CLN3125F2	85,7 def	1,075 defg	5,54 bc	5,88 ab
CLN2819F1	106,60 bc	1,027 defg	5,88 b	5,96 ab
C-28	104,86 bc	1,324 bcde	5,90 b	4,82 d
x	89,26***	0,665***	1,887***	1,543***

For each variety different letters indicate significant differences (p <0.05), according to Duncan's test

According to this analysis (Table VIb), in axis 1, the modalities of variables corresponding to the average mass of the fruits, equatorial diameter, foliage density, fruit picking, fruit shapes and pistillar scars and peduncular, as well as days to flowering and ripening; while in axis 2 it is explained by the modalities corresponding to the yield, longitudinal diameter, abscission layer, color of the immature fruit and terminal form of the fruit flowering. Also, the third component is explained by the type of growth and inflorescence.

The clustering analysis using a matrix of Euclidean distances showed the formation of four well differentiated groups (Figure).

Group I consisted of the cultivars CLN3205F1, CLN3241F1, CLN3125F2 and CLN2819F1. These presented semidetermined growth, simple inflorescences and smooth fruits, without shoulders, with 2-3 loculi inside generally and high values of equatorial diameters. In the immature state, the fruits were medium green and had pistilar scar in the shape of a point.

Cultures that integrated group II (CLN2498F1, CLN3024F2, CLN3126A, CLN3109F1, CLN3078F1 and CLN3078F1B) showed intermediate or dense foliage, determined growth type, abscission layer. They presented smooth fruits, of average green color in immature state, with 2-3 loci and medium size.

The three cultivars that integrated group III (TY52, CLN3447F2 and CLN3070F1) presented simple inflorescences and density of the intermediate foliage. The immature fruits were light green, without shoulders, with mean SD and pointed tip. Yields of these cultivars presented low percentages.

On the other hand, the group IV was integrated by the cultivars CLN3212F1, CLN3150F1 and C-28 that presented determined growth, fruits without shoulders, slightly ribbed, with average longitudinal diameters. These cultivars showed yields close to the mean value.

Although the results indicate that the 16 cultivars could be classified, the continuous nature of the present variability did not allow a clear definition of the characteristics of the different groups, so that although a certain characteristic predominated in a group, in occasions there were cultivars that did not present it, an example of this in group I is the type of growth that although predominates fruits with 2-3 locules, the cultivar CLN3125F2, presented between 4-7 locules. These results correspond to what has been reported by several authors (28), who, when evaluating morphoagronomically a tomato collection in Kenya through Principal Component Analysis, did not achieve a precise definition of the different groups, and attribute this result to the high variability present in the germplasm under study.

Table VIa. Percentage of variability explained by Principal Component Analysis, according to the first three components

Components	% Variability	% Accumulated
1	25,086	25,086
2	16,375	41,461
3	13,453	54,914

Table VIb. Contribution of the different variables to the variability in the first three components of the Principal Component Analysis

	Component		
	1	2	3
Average mass of fruits	0,538	0,733	0,156
Yield	-0,131	0,600	0,543
Equatorial Diameter	0,773	0,457	0,054
Longitudinal diameter	-0,223	0,743	0,342
Growth type	-0,245	0,359	-0,711
Type of inflorescence	-0,262	-0,115	0,637
Density of foliage	-0,508	-0,283	0,125
Abscission layer	0,153	-0,585	0,017
Color of the immature fruit	-0,461	0,553	0,123
Shape of the shoulder of the fruit	0,014	-0,013	-0,092
Ribbed of fruits	0,712	-0,116	0,146
Terminal shape of the fruit bloom	-0,676	0,390	-0,390
Blosson scar	0,793	-0,089	0,030
Pedicle scar	0,530	0,161	-0,397
Shape of the fruit	0,551	-0,042	0,384
Number of loculi	0,310	-0,471	0,121
Fruit compactness	0,171	0,332	-0,128
Flowering days	0,621	0,099	-0,164
Days to maturation	0,708	0,196	-0,242

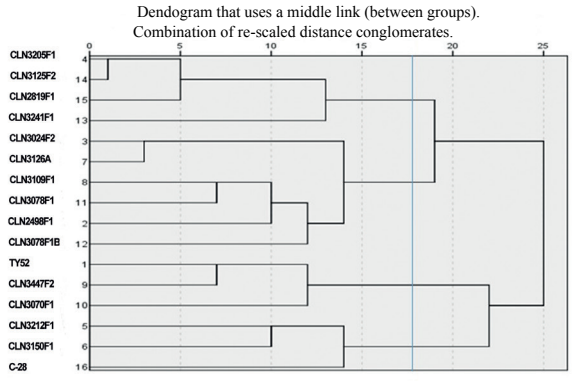

Figure. Grouping of the 16 tomato cultivars, using a matrix of Euclidean distances

These results showed that the tomato cultivars introduced from Taiwan adapted to the edaphoclimatic conditions of Cuba, being able to produce fruits in the desired amounts under these conditions. Also, the existence of a wide genetic variability from the morphoagronomic point of view in the evaluated cultivars was corroborated. Thus, it is convenient to use these cultivars, for a better use of genetic variability, especially as tolerance sources to begomovirus, since they present introgressed, at least one resistance gene to TYLCV, from wild species. These cultivars could be used as potential progenitors in the breeding programs of this vegetable.

Evaluation of the disease severity caused by TYLCV

Table VII shows the average values of severity detected in the cultivars, based on the sampling dynamics performed in the optimal period of planting (15-30 DAT). As shown in the Table, the plants of the 15 cultivars from Taiwan were asymptomatic. Its apical leaflets maintained the dark green color, characteristic of the leaves of the healthy plants. This absence of symptoms was maintained throughout the sampling dynamics.

Table VII. Mean values of severity expressed by the cultivars under study under uncontrolled conditions at 15 and 30 DAT

Code	Severity (15 DAT)	Severity (30 DAT)
TY52	0	0
CLN2498F1	0	0
CLN3024F2	0	0
CLN3205F1	0	0
CLN3212F1	0	0
CLN3150F1	0	0
CLN3126A	0	0
CLN3109F1	0	0
CLN3447F2	0	0
CLN3070F1	0	0
CLN3078F1	0	0
CLN3078F1B	0	0
CLN3241F1	0	0
CLN3125F2	0	0
CLN2819F1	0	0
C-28	1	3

However, after only 15 DAT, the cultivar 'Campbell 28' used as a susceptible control, showed symptoms of infection, light, almost imperceptible yellowing in the margins of leaflets of the apical leaves, which corresponded to a maximum value of 1 on the severity scale. These symptoms were more intense and showed a progressive increase until reaching grade 3 (severity value), at 30 DAT. The rapidity in the appearance of symptoms confirmed the absence of barriers to resistance to TYLCV in this cultivar, which is activated at the early stages of inoculation and acts at different levels in the cell, between cells and at long distance, by the conductive tissues (30).

As for the susceptible control, the results obtained in Campbell 28 corroborated the high susceptibility of this, during the evaluation-selection of hybrids and new lines resistant to TYLCV-IL [CU], adapted to the conditions of the Cuban tropic (14, 31).

The results obtained in the evaluations of 'TY52' corresponded to those described by other authors in the different studies (14, 30), aimed at the search for resistance to TYLCV isolates from Cerdeña and Israel. The resistant character of 'TY52' was exposed by Hurtado (14), describing the presence of the Ty-1 gene, and its relation to the movement impediment of the virus at short distance (cell-cell).

It is interesting that of the 16 cultivars studied, two of them (CLN3241F1, CLN2819F1) present three resistance genes, Ty-2, Ty-3, Ty-5; while another six (CLN3024F2, CLN3150F1, CLN3447F2, CLN3070F1, CLN3078F1, CLN3078F1B) present two TYLCV resistance genes. Due to the great variability of existing viral species, the incorporation of several genes/alleles has been recognized as one of the most interesting and appropriate strategies in the search for a broad and stable resistance to these diseases. Indeed, nowadays, the pyramiding of resistance genes in a line or cultivar has become a potent strategy to increase the durability and stability of begomovirus resistance (15, 31, 32).

Preferably, these resistance genes must operate at different stages of the infective process and, thus, only the occurrence of several simultaneous mutations will cause the resistance to break (33, 34). This diversification would cause the pathogen to confront simultaneously several resistance genes, being more effective to plant in the same region, cultivars with different resistance genes, or to separate them in the time, sowing them during different periods[A]. However, it should be noted that the severity evaluations to TYLCV were performed in the optimum period, where the incidence of the pest is lower.

However, most of the cultivars classified as resistant during the optimum planting period maintain this condition in the spring-summer planting period, which demonstrates, in general, the resistance stability to the Cuban isolate of TYLCV (14). In this sense, differences in the symptomatology of tomato plants are observed when tests or resistance tests are performed at different times of the year (22), observing a greater aggressiveness during the spring-summer planting period. It is noteworthy that in this period the populations of the vector insect are higher, the conditions for the development of the crop are less favorable and the affectations, in general, more evident (7).

At present, there are few sources of resistance used in commercial cultivars for the control of TYLCV. In a diallel study based on the combination of various sources of resistance to begomovirus, it was evidenced that the genetic improvement programs of tomato, for resistance to these pathogens, have been based on the use of the resistance that comes from the wild species *S. chilense*, *S. peruvianum* and *S. habrochaites* for presenting the highest levels of resistance since there are few sources of resistance in commercial cultivars for the control of TYLCV (35). However, we continue to look for new sources of resistance to TYLCV (31, 36, 37).

On the other hand, identification of resistant cultivars in which several resistance genes are involved will allow strategies to be introduced for introduction into elite begomovirus-susceptible cultivars (14, 15), which will condition positive epidemiological impacts on the management of viral species present in Cuba, thus limiting the dispersions of these under field conditions. The use of these cultivars in the breeding programs for begomovirus resistance represents a considerable advance, since in future work with these cultivars we could implement selection for resistance assisted by DNA markers, using the RCP technique, instead of inoculations with the pathogen. Also, with these cultivars one could exploit the advantages in gene piramidation to guarantee a more durable resistance (15, 31).

[A]Dueñas, H. F. *Identificación y aprovechamiento de fuentes de resistencia en tomate (Solanum lycopersicum L.), frente a begomovirus que afectan al cultivo*. Tesis de Doctorado, Instituto Nacional de Ciencias Agrícolas, 2012, Mayabeque, Cuba, 100 p.

CONCLUSIONS

In the cultivars evaluated there is morphoagronomic variability, which allowed them to be differentiated into four fundamental groups. The most variable characters were: the average mass of the fruits; The equatorial and longitudinal diameters and yield per plant.

Tomato cultivars from Taiwan were asymptomatic to the virus, confirming the prospects of their use in crop breeding programs to obtain hybrids and new cultivars resistant to begomoviruses.

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