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Original article

Agronomic indicators and genetic parameters in six tomato (*Solanum lycopersicum* L.) cultivars

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ABSTRACT

In order to evaluate agronomic indicators and estimate genetic parameters, six tomato cultivars were established in two locations, using a randomized complete block design with four replications. Eight morphoagronomic variables were evaluated, including agricultural yield. The data were processed with the Statistica statistical package, which was used to perform two-factor analysis of variance, double classification and random effects, the latter to decompose the total phenotypic variance. Multiple comparison of means was performed through Tukey's test $p \leq 0.05$. Simple correlation analysis was also performed among the variables evaluated. The results showed significant effects of genotype-environment interaction in 75 % of the variables under study. Coefficients of environmental variation were high for all traits and heritability estimates, in a broad sense, were very low. Simple correlations were high and positively significant between the characters fruit mass per plant and fruit number per plant, fruit diameter and fruit mass per plant, yield and fruit number per plant, yield and fruit mass per plant, and yield and fruit diameter.

Key words: variance, genotypes, broad heritability, genetic variability

INTRODUCTION

Tomato is the most cultivated and important vegetable in the world; fresh and industrial consumption are the two main production destinations [(1)]. Its demand is continuously increasing and with it its cultivation, production and trade [(2)]. The fruit is an essential component of the diet of millions of people [(3)].

In Cuba, this crop requires cultivars adapted to tropical climate conditions. The availability of Cuban cultivars with this characteristic constitutes an advantage over imported cultivars for extending planting and harvesting dates [(4)].

The knowledge of the relation between variables and genetic parameters in any specie, facilitates the selection process of new genotypes in plant improvement schemes. Morphoagronomic characterization has been essential for the identification of desirable traits in individuals destined to be released directly as cultivars or used as gene donors [5].

Variability based on morphological and agronomic traits is a fundamental tool in breeding schemes and efficient germplasm conservation [6]. Therefore, the aim of this work was to evaluate agronomic indicators and estimate genetic parameters in six tomato cultivars.

MATERIALS AND METHODS

In the period from November/2015 to April/2016, tomato cultivars Vyta, INCA-9-1, L-10-3, Criollo Quivicán, L-316 and Buena Ventura were evaluated in two locations in Granma province. These were established in a Pelic Vertisol soil [7] at the Basic Unit of Cooperative Production (UBPC) Tamara Bunke, in Río Cauto municipality and in a Fluvisol Fluffy soil (7) at the Agricultural Experimental Station of the Agricultural Research Institute ″Jorge Dimitrov″, in Bayamo municipality. The climatic data (Table 1) were taken from the register of the Provincial Meteorological Center of Granma.

Table 1. Climatic data during the experimental period in the two locations under study

Locality	Months	Precipitations (mm)	Climate temperature Average temperature (ºC)	Relative Humidity (%)
Río Cauto	November	25,4	24,9	82
	December	4,0	24,6	85
	January	12,6	24,5	79
	February	10,0	25,4	78
	March	10,0	26,3	79
Bayamo	November	75,2	25,3	80
	December	84,2	25,2	87
	January	6,3	24,6	98
	February	87,3	23,5	96
	March	47,2	25,7	96

Soil preparation for the experiments was carried out with animal traction in the traditional way; the tasks performed were: plowing, crossing, raking and furrowing. For fertilization, an organic source derived from sheep manure was used, incorporated at the time of transplanting, at a rate of 5 t ha^{-1}. Cultural attentions in all cases were carried out according to the Technical Instructions for Organoponics and Intensive Orchards, established for tomato [8].

In both locations, transplanting from seedbed to field was used as a method of sowing, with postures 25 days after sowing in the seedbed. At both sites, a planting frame of 1.40 x 0.25 m was used, in 28 m^2 plots, distributed in a randomized block design with four replications. Each plot consisted of four furrows of five meters long, using 22.4 m^2 as the useful plot, composed of the two central furrows, minus 50 cm at the ends, to avoid edge effects.

The following variables were evaluated: number of primary branches per plant; plant height (cm); number of fruits per cluster; number of fruits per plant; fruit mass per plant (kg); average fruit mass (kg); fruit diameter (cm) and yield (t ha^{-1}).

The statistical package Statistica was used. A two-factor analysis of variance was performed and the multiple comparison of means was carried out using Tukey's test for $p \leq 0.05$.

For each variable, the coefficient of variation was estimated using the following expression:

$$CV = \frac{S}{X} 100$$

where:

CV: coefficient of variation (%)

S: standard deviation

X: mean value of the variable.

Genetic, environmental and genotypic variances were estimated by analysis of variance according to the following equations:

Genetic variance (σ^2_G) = CMG- CMe/r

Environmental variance (σ^2_A) = $CM_e + CM_L + CM_{GL}$

Phenotypic variance (σ^2_F) = $\sigma^2_G + \sigma^2_A$

where:

CM_G= cultivar mean square

CM_e= mean square of the error

CM_L= mean square of locations

CM_{GL}= mean square of the G x L interaction.

Broad sense heritability was determined by the expression:

$H^2 = \sigma^2_G / \sigma^2_F$

An analysis of simple correlations between the evaluated variables was also performed.

RESULTS AND DISCUSSION

The factorial analysis of variance showed significant differences in the cultivar x locality interaction for most of the traits evaluated (Table 2), except for the variables fruit mass per plant and yield, which only showed statistical significance in the individual factors (cultivars and localities). The significant interaction indicates that at least one of the cultivars evaluated performed better or adapted better in a specific location or environment [(9)], which could be due to the edaphoclimatic differences between the locations under study and the existence of genetic diversity among the genotypes evaluated [(10)].

The environmental fluctuations make necessary the formation of new genotypes, for which the knowledge of the interaction genotype by environment allows determining genetic parameters that sometimes can be used as selection criteria in the improvement programs of this crop [11].

Table 2. Mean squares, standard errors (SE) and coefficients of variation (CV) in morphoagronomic characters in tomato crop

SV	NBP	PH	NFB	NFP	MFP	AFM	FD	YLD
L	189,06*	8,7	0,003	1584,04*	3,822*	477,93*	1766,95*	45,833*
V	40,80*	216,7*	0,688*	238,68*	0,174*	177,10*	88,96*	121,74*
VxL	70,83*	236*	0,647*	281,18*	0,055	514,90*	102,07*	58,08
SE	13,372	22,2	0,067	30,18	0,032	26,70	5,13	26,62
CV (%)	35,53	13,39	18,05	34,39	29,71	27,38	36,59	35,72

SV: Sources of variation, L: locations, V: cultivars, VxL: interaction cultivars by location, NBP: number of branches per plant, PH: plant height (cm), NFB: number of fruits per bunch, NFP: number of fruits per plant, MFP: mass of fruits per plant (kg), AFM: average fruit mass (kg), FD: fruit diameter (cm), YLD: Yield (t ha^{-1})

Most of the variables evaluated showed coefficients of variation ranging from 27 to 37 %, with fruit diameter having the highest coefficient. Plant height and number of fruits per bunch were less than 20 %. If the coefficient of variation is greater than 20 %, it is considered that the character under study is variable [11]. This is important to be taken into account in breeding programs, since the greater the variability of the trait in the population under study, the greater the probability of success expected from the selection.

In studies carried out in areas of the National Institute of Agricultural Sciences, a wide morphoagronomic variability was found in the evaluation of 20 tomato accessions [12]. In breeding programs, having a high variability of characters facilitates the selection of new genotypes.

The effects of the cultivar x location interaction on variables evaluated are shown in Table 3. In the number of branches per plant, the C5xL2 interaction statistically outperformed the rest of the interactions. The C6xL2 interaction showed no significant differences with the C4xL1 interaction, but differed statistically from the others, which, in turn, showed no significant differences between them.

Table 3. Cultivar x location interaction effects in six tomato cultivars grown in two locations in Granma province

Cultivar	Locality	Variables					
		NBP	HP	NFB	NFP	AFM	FD
C1	L1	11,5 c	69,37 bc	2,73bc	34,6 bc	35,43 cd	4,53 d
C1	L2	11,7 c	63,23 bcd	2,40 cd	37,1 b	54,67 ab	5,31 abc
C2	L1	16,0 c	67,83 bc	2,87abc	28,9 bc	36,57 cd	4,75 bcd
C2	L2	16,4 c	61,43 cd	3,4 ab	55,4 a	28,73 d	4,41 de
C3	L1	11,7 c	67,30 bc	2,53 c	31,43 bc	28,88 d	4,49 de
C3	L2	13,4 c	51,57 d	2,50 cd	31,5 bc	50,40 abc	5,36 ab
C4	L1	18,7 bc	69,70 bc	2,73bc	26,3 bc	41,10 bcd	4,77 bcd
C4	L2	14,1 c	85,20 a	2,60 c	55,7 a	40,03 bcd	3,75 e
C5	L1	11,5 c	61,83 bcd	2,53 c	19,3 c	53,32 ab	5,34 abc
C5	L2	28,0 a	75,33 ab	3,5 a	39,8 ab	36,13 cd	4,58 cd
C6	L1	14,3 c	67,93 bc	2,67bc	26,3 bc	33,48 d	4,11 de
C6	L2	19,0 b	61,30 cd	1,77 d	26,9 bc	62,53 a	5,96 a
SE		0,304	0,392	0,021	0,457	0,431	0,001

C1: Vyta, C2: Inca-9-1, C3: L-10-3, C4: Criollo Quivicán, C5: L-316, C6: Buena Ventura, L1: Río Cauto, L2: Bayamo, NBP: number of branches per plant, PH: plant height (cm), NFB: number of fruits per branch, NFP: number of fruits per plant, AFM: average fruit mass (kg), FD: fruit diameter (cm). Means with equal letters in the same column do not show significant differences between them for p≤0.05

In plant height, the C4xL2 interaction showed the highest value with no significant difference with the C5xL2 interaction. The latter also statistically exceeded the value of the C2xL2, C3xL2 and C6xL2 interactions. The rest of the means showed no significant differences among them.

The highest number of fruits per bunch corresponded to the interaction C5xL2 with no significant differences with C2xL1 and C2xL2. The latter outperformed C1xL2, C3xL1, C4xL2, C5xL1 and C6xL2. C3xL1, C4xL2 and C5xL1 were also superior to C6L2.

Regarding the number of fruits per plant, C2xL2 and C4xL2 interactions were outstanding, with no differences with C5xL2. The C5XL2 and C1xL2 interactions were also statistically superior to C5xL1.

In relation to the average fruit mass, the average expressed by the C6xL2 interaction stood out, with no statistical differences with the values achieved by the C1xL2, C3xL2 and C5xL1 interactions. It was also observed that the values of the interactions C1xL2 and C5xL2 statistically exceeded C1xL1, C2xL1, C2xL2, C3xL1, C5xL2 and C6xL1. The value shown by the C3xL2 interaction also exceeded the values expressed by the C2xL2, C3xL1 and C6xL1 interactions.

The largest fruit diameter was reached by the C6xL2 interaction without significant differences with the averages expressed by the C1xL2, C3xL2 and C5xL1 interactions. The lowest value corresponded to the C4xL2 interaction, without statistical differences with the averages of the C2xL2, C3xL1 and C6xL1 interactions.

The differential behavior of genotypes, through variable environmental conditions, is important in the genetic improvement of crops, because it is present during the selection and recommendation process [13,14]. On the other hand, it allows the selection of the variety to sow in a determined agroecological region, which is a central aspect in the production technology of any crop, since it contributes to the efficiency with which the available resources are used [15]. In this sense, the evaluation of genetic materials in different environments and the measurement of the genotype-environment interaction, gives an idea about the phenotypic stability of genotypes before environmental fluctuations [16].

In terms of fruit mass per plant and yield (Table 4), the Vyta cultivar did not show significant differences with the INCA-9-1 and Criollo Quivicán cultivars. It did outperform the others, which, in turn, did not differ from each other. This cultivar has shown good adaptability to the soil and climatic conditions of the Granmense territory, since, as can be seen, the yield achieved here exceeds the 12.6 t ha^{-1} published by ONEI [17] as the average for the province. It also behaved among the highest yields in a study conducted in four locations in Granma province [14].

Table 4. Behavior of average fruit mass per plant and yield in six tomato cultivars evaluated in two locations in Granma province

Cultivars	Average fruit mass per plant (kg)	Yield (t ha^{-1})
Vyta	1,61 a	44,41 a
INCA-9-1	1,35 ab	36,05 ab
L-10-3	1,24 b	34,16 b
Criollo Quivicán	1,54 ab	40,55 ab
L-316	1,22 b	33,65 b
Buena Ventura	1,22 b	33,30 b
SE	0,014	0,429

SE: standard error, means with equal letters in the same column do not show significant differences between them for $p \leq 0.05$

The mass of fruits per plant, expressed by the cultivars in the two localities, are higher than the range indicated in some research [18], whose authors indicated values between 5 and 500 g.

When evaluating the average behavior of these variables in the two locations under study, it was observed that the highest values were expressed in L2 (Table 5). Hence the importance of evaluating the varieties at the local level, in order to select those that can express a greater productive potential, according to their responses in specific environments.

Table 5. Behavior of fruit mass per plant and yield in six tomato cultivars evaluated in two localities in Granma province

Localities	Mass of fruits per plant (kg)	Yield (t ha^{-1})
L1	1,04 b	25,74 b
L2	1,69 a	48,31 a
SE	0,014	0,429

SE: standard error, means with equal letters in the same column do not show significant differences between them for $p \leq 0.05$

The highest heritability values were for fruit mass per plant and yield with values of 0.07 and 0.11, respectively. These values, like the others, are low, indicating that these characteristics are essentially due to environmental effects, which will not enhance that these characters can be recombined and inherited in the following generations [19].

The coefficients of environmental variation (CVA) were higher than the coefficients of genetic variation (CVG) for all the traits evaluated (Table 6). This explains the low values estimated from the ratio between both coefficients (CVG/CVA), and it is inferred that the behavior of the studied traits was mainly due to environmental conditions. When the CVG/CVA ratio tends to one or is higher than one, the genetic variation is greater than the environmental variation, which contributes favorably to a selection process [20].

Table 6. Genetic parameters in morphoagronomic traits in tomato crop

Variance	NBP	%	HP	%	NFB	%	NFP	%	MFP	%	AFM	%	FD	%	Yld	%
σ^2L	6,568	16,8	0	0	0	0	72,381	38,9	0,209	77,9	0	0	75,771	96,3	51,4003	51,86
σ^2V	0	0	0	0	0,0067	2,53	0	0	0,0200	7,45	0	0	0	0	10,6091	10,70
σ^2VL	19,153	48,99	71,287	76,27	0,1942	73,20	83,6669	44,93	0,0072	2,68	62,7326	85,90	32,3127	3,19	10,4869	10,58
σ^2 e	13,372	34,20	22,183	23,73	0,0644	24,27	30,1758	16,20	0,0321	11,95	26,7009	14,10	5,1326	0,51	26,6239	26,86
h^2a	0,00		0,00		0,0257		0,00		0,0745		0,00		0,00		0,11	
CVG	0,00		0,00		0,00		0,00		0,01		0,00		0,00		0,29	
CVA	1,28		0,33		0,02		2,98		0,18		0,64		16,93		2,11	
CVF	2,52		1,40		0,10		5,41		5,41		2,14		23,69		2,68	
CVG/CVA	0,00		0,00		0,00		0,00		0,00		0,00		0,00		0,14	

NRP: number of branches per plant, AP: plant height (cm), NFR: number of fruits per bunch, NFP: number of fruits per plant, MFP: mass of fruits per plant (kg), AFM: average fruit mass, FD: fruit diameter (cm), Yld: yield (t ha^{-1}), L: locality, V: cultivar, VxL: cultivar by locality interaction, h2a: broad sense heritability (%),CVG: coefficient of genetic variation, CVA: coefficient of environmental variation (%),CVF: coefficient of phenotypic variation (%)

In the simple correlations between the evaluated traits, 50 % of the related pairs were significant (Table 7). High and positive correlations were found for the pairs of characters fruit mass per plant and number of fruits per plant (r=0.63), fruit diameter and fruit mass per plant (r=0.78), yield and number of fruits per plant (r=0.64), yield and fruit mass per plant (r=0.98) and yield and fruit diameter (r=0.83).

Table 7. Phenotypic correlations between agronomic traits in tomato

Variable	NBP	PH	NFB	NFP	MFP	AFM	FD
NRPP							
HP	0,23						
NFPB	0,32	0,26					
NFP	0,24	0,37*	0,37*				
PFP	0,31	0,09	-0,04	0,63*			
PPF	0,07	-0,32	-0,56*	-0,41*	0,41*		
FD	0,42*	-0,20	-0,10	0,40*	0,78*	0,47*	
Yld	0,32	0,07	-0,05	0,64*	0,98*	0,39*	0,83*

:: Significant coefficients, NBP: number of branches per plant, PH: plant height (cm), NFR: number of fruits per cluster, NFP: number of fruits per plant, MFP: mass of fruits per plant (kg), AFM: average fruit mass (kg), FD: fruit diameter (cm), Yld: yield (t ha^{-1})

On the other hand, correlations were low and positive between fruit diameter and number of branches per plant (0.42), number of fruits per plant and plant height (0.37), number of fruits per plant and number of fruits per bunch (r=0.37), average fruit mass and fruit mass per plant (r=0.41), fruit diameter and number of fruits per plant (r=0.40), fruit diameter and average fruit mass (r=0.47), yield and average fruit mass (r=0.39). Low and negative correlations were found between average fruit mass and number of fruits per bunch and number of fruits per plant with values of r=-0.69 and r=-0.41, respectively.

The correlation coefficient between average fruit mass and fruit diameter, although significant, was lower than that indicated by other authors (21), who reported a coefficient of 0.69 between these two variables. These authors also indicated positively significant coefficients between these variables and yield, which coincides with the results obtained in this research.

CONCLUSIONS

- In the total phenotypic variation, the environmental contribution was high and heritability estimates, in a broad sense, were low for the traits evaluated.
- Fruit mass per plant, fruit diameter and number of fruits per plant were the variables that most positively influenced yield.

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