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Relative importance of traits for the diversity of tomato crop

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ABSTRACT

Seed collections are an alternative for conserving plant genetic resources. The characterization of plant species contained in the collections has been carried out with the help of tables of botanical, morphological, and agronomic descriptors, which are mainly used without parameters referring to their effective contribution to variability, causing an increase in time and labor in the characterization of plants. This study aimed to evaluate the relative importance of the morphoagronomic traits in 85 low-growing tomato accessions from the collection of the Federal University of Goiás and estimate the descriptors that most help in the dissimilarity of the accessions and thus remove the redundant descriptors. The experimental design consisted of three complete randomized blocks, 85 plots (each plot corresponding to a different accession), and 12 plants per plot. The evaluations used adapted morphological descriptors described in the MAPA guidelines for distinguishability, homogeneity, and stability trials. 56.4% of the selected morphoagronomic descriptors are essential in the characterization study since they significantly contribute to the discrimination of genetic divergence between low-growing tomato accessions. Discarding 43.6% of the descriptors does not cause loss of information, reduces costs, and streamlines the management of the classification of the collection.

Keywords: *Solanum lycopersicum*, Accessions, Characterization.

Importância relativa dos caracteres para diversidade da cultura do tomateiro

RESUMO

As coleções de sementes são uma alternativa para a conservação dos recursos genéticos vegetais. A caracterização das espécies vegetais contidas nas coleções vem sendo executada com ajuda de tabelas de descritores botânicos, morfológicos e agronômicos, que em sua maioria são utilizados sem parâmetros referentes a sua contribuição efetiva para a variabilidade, ocasionando aumento de tempo e mão-de-obra no momento da caracterização das plantas. O objetivo deste trabalho foi de avaliar a importância relativa dos caracteres morfoagronômicos em 85 acessos de tomate rasteiro da coleção da Universidade Federal de Goiás-UFG, bem como, estimar os descritores que mais auxiliam na dissimilaridade dos acessos e desta maneira retirar os descritores redundantes. O delineamento experimental foi constituído por 3 blocos completos casualizados, 85 parcelas (sendo cada parcela correspondendo a um acesso diferente) e 12 plantas por parcela. As avaliações utilizaram descritores morfológicos adaptados descritos nas orientações para execução dos ensaios de distinguibilidade, homogeneidade e estabilidade do MAPA. Dos descritores morfoagronômicos selecionados, 56,4% são essenciais no estudo de caracterização por apresentarem contribuições importantes na discriminação da divergência genética entre acessos do tomateiro rasteiro. O descarte de 43,6% dos descritores não ocasiona perda de informação, diminui os custos e dinamiza o manejo da classificação da coleção.

Palavras-chave: *Solanum lycopersicum*, Acessos, Caracterização.

1. Introduction

Tomato (*Solanum lycopersicum* L.) is a nightshade plant native to the Andean region (Lin et al., 2014), located in northern Peru and southern Ecuador. It is admitted that its domestication did not occur in the region of origin but Mexico (Schwarz et al., 2013). This domestication process brought the loss of genetic variability and the narrowing of the genetic base of cultivated tomatoes (Martins et al., 2011).

Species collections are an alternative for the conservation of plant genetic resources. The main reason for establishing and maintaining these collections is to store, make available, and provide information about a given accession (sample of representative germplasm of an individual or population, registered in a collection), with the identification of traits of importance for plant breeding programs (EMBRAPA, 2016). They represent food security, assuring the current and future generations of food supply.

The agronomic characterization of accessions from the collection helps in the better knowledge of each trait and in the selection of parents for crossings aiming to develop new improved lines (Amorim et al., 2008). The characterization of the plant species contained in the collection has been carried out with the help of tables of botanical, morphological, and agronomics descriptors, which most of the time are used without parameters referring to their effective contribution to the variability, causing this way, an increase in time and labor in the characterization of plants (Oliveira et al., 2006). Therefore, discarding redundant descriptors reduces data collection activity and avoids ambiguity in their evaluation (Pereira et al., 1992).

The cluster analysis method is presented as a way to group and describe a cluster of individuals. It simultaneously considers the set of descriptors evaluated as a whole. Thus, multivariate analyses are useful tools for identifying descriptors with more information and ruling out traits that little or do not contribute to the total variation (Cruz, 2016). This study aimed to evaluate the relative importance of morphoagronomic traits in 85 low-growing tomato accessions from the Horta collection of the horticulture sector of the Federal University of Goiás – UFG, estimate the descriptors that most help in the dissimilarity of the accessions, and eliminate redundant descriptors.

2. Material and Methods

The study was conducted in the Horta area, in the experimental station of the UFG, in Goiânia, at 16º45’26” S, 49º26’15” W, and 898 meters altitude, in the state of Goiás. According to the Koppen classification, the climate is defined as humid tropical, characterized by rainy summers with high temperatures and dry winters, with an average annual rainfall of 1,575 mm. The climatic data referring to the period when the study was carried out are shown in Figure 1.

The seeds were manually sown in polystyrene trays with 450 cells, filled with a substrate based on coconut fiber, husk, and peat, then covered with vermiculite. Then, they were packed with polyethylene film (Stretch) to maintain a constant temperature and relative humidity, stimulating uniform seed germination. The trays were placed in agricultural greenhouses with footbaths, antechambers, screens with a maximum mesh size of 0.239 mm, and floating irrigation, as established by the Ministry of Agriculture, Livestock, and Food Supply (Ministério da Agricultura, Pecuária e Abastecimento - MAPA). Soil preparation was carried out with a tractor and rotary tiller. Beds 1.0 m wide and 0.20 m high, with a spacing of 1.0 m between beds, were prepared. NPK formulation 04-30-10 at a dose of 1500 kg was used in the fertilization, divided into four applications, providing 60 kg of N, 450 kg of P, and 150 kg of K.

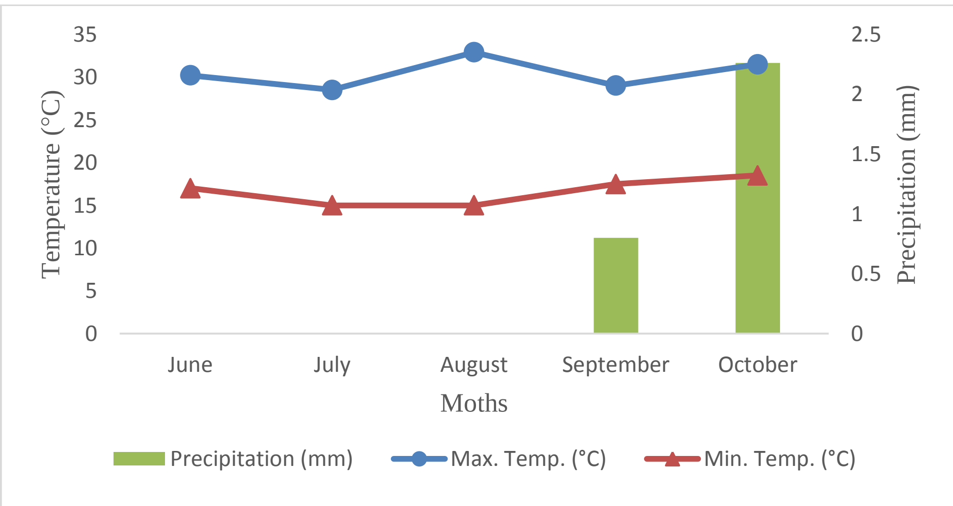

Figure 1. Temperature (°C) and accumulated precipitation (mm) during the experimental period. Goiânia (GO), 2019.

Table 1a. Descriptors for industrial tomato, 2019 (adapted MAPA).

Trait	Trait Description	Description	Performing the analysis
1. Seedling: anthocyanin pigmentation in the hypocotyl	Absent Present	A P	-
2. Plant: growth habit	Determined Undetermined	D U	-
3. Stem: anthocyanin pigmentation in the upper third	Absent Present	A P	-
4. Stem: internode length	Short Medium Long	S M L	By measuring, with the aid of a tape measure, the length between the third and fourth internodes of the central branch, starting from the root.
5. Leaf: position (in the middle third of the plant)	Top Medium Low	T M L	-
6. Leaf: length	Short Medium Long	S M L	-
7. Leaf: width	Narrow Medium Wide	N M W	-
8. Leaf: shape	Type 1 Type 2 Type 3	1 2 3	By removing a leaf from the middle third of the plant, placing it on graph paper, and photographing it. Subsequently, the distribution of leaves in the most suitable formats (types 1, 2, and 3) was carried out, characterizing them from the form of insertion of the leaflet into the leaf. Type 1 is characterized by a leaf with insertion from the first leaflet (from top to bottom) to the right side, type 2 has an insertion from the leaflet (from top to bottom) to the left side, and type 3 is characterized by a leaf with parallel leaflet insertion.
9. Leaf: limbo division	Pinnate Bipin	P B	-
10. Leaf: green color intensity	Light Medium Dark	L M D	Through color palettes that was created based on the hexadecimal code, which each color intensity receives a name (code); in this way, there is no possibility of similar colors being confused (Gremillion, 2012).
11. Leaf: presence of bubbles	Absent Present	A P	-
12. Inflorescence: type	Mostly Uniparous Mostly Multiparous	U M	-
13. Flower: fasciation (first flower of the inflorescence)	Absent Present	A P	-
14. Flower: coloring	Yellow Orange	Y O	-
15. Peduncle: abscission	Absent Present	A P	-
16. Peduncle: length (from the abscission zone to the calyx)	Short Medium Long	S M L	-
17. Fruit: size (longitudinal and transversal)	Small Medium Large	S M L	-
18. Fruit: length/diameter ratio	Small Medium Large	S M L	-
19. Fruit: shape in longitudinal section	Wide Transverse Elliptical Transverse Elliptical Circular Rectangular Cylindrical Elliptic Cordiform Obovoid Ovoid Piriformis Pitanga	WTE TE C R CL E CO O OV P PT	-

Table 1b. Descriptors for industrial tomato, 2019 (adapted MAPA)

1. Fruit: rib (rib-shaped protrusion) in the peduncular zone	Absent Present	A P	-
2. Fruit: depression in the peduncular zone	Absent Present	A P	-
3. Fruit: peduncular scar diameter	Small Medium Large	S M L	-
4. Fruit: pistillate scar shape	Shape 1 Shape 2 Shape 3 Shape 4	1 2 3 4	-
5. Fruit: pistillate tip shape	Reentrant Pointed Plane	R P PL	-
6. Fruit: diameter of the placental zone	Small Medium Large	S M L	Using a digital caliper, measuring the distance (mm) from the inner wall of the pericarp to the placental column.
7. Fruit: pericarp thickness	Fine Medium Thick	F M T	It was carried out with a digital caliper, measuring the diameter (mm) from the outer wall to the inner wall of the pericarp.
8. Fruit: predominant number of locules	Two Three Four Multilocular	T TH F M	-
9. Fruit: green shoulder (before maturation)	Absent Present	A P	-
10. Fruit: intensity of green coloration before maturation	Faint Medium Strong	F M S	Through color palettes. This palette was created based on the hexadecimal code, an international code in which each color intensity receives a name (code); in this way, there is no possibility of similar colors being confused (Gremillion, 2012).
11. Fruit: external coloration at maturation	Crem Yellow Orange Rosy Red Brown	C Y O R RE B	-
12. Fruit: intensity of red color at maturation	Faint Medium Strong	F M S	Through color palettes like in number 29.
13. Fruit: internal coloring (pulp) at maturation	Crem Yellow Orange Rosy Red Brown	C Y O R RE B	-
14. Fruit: intensity of the red coloration of the pulp at maturation	Faint Medium Strong	F M S	Through color palettes like in number 29..
15. Fruit: firmness	Soft Medium Firm	S M F	By submitting the fruits to pressure at a point in the median region, measuring the resistance of the pulp to penetration, using a digital penetrometer model PTR-300, brand Instrutherm and obtaining the values expressed in Newton (N).
16. Cycle up to flowering: first open flower	Premature Medium Late	P M L	
17. Cycle up to maturation	Premature Medium Late	P M L	
18. Fruit yield	Low Medium High	L M H	By weight (kg/plant) and the number of plants.
19. Average number of fruits per plant	Low Medium High	L M H	-
20. Soluble solids	Low Medium High	L M H	By transferring a drop of fruit juice to the prism of a digital refractometer, model HI 96801 from Hanna Instruments, and then reading it, expressed in Brix.

The seedlings were transplanted by hand 35 days after sowing (DAS), with a spacing of 0.40 m between plants and 1,0 m between rows. The water supply was carried out through a drip irrigation system, obeying the water requirement and parameters for the irrigation management of the crop. Weeding was carried out weekly to avoid competition with weeds. To identify the rate of insect infestation for decision-making on the application of pesticides, insecticidal baits were placed throughout the experiment. Phytosanitary control was carried out whenever necessary to maximize fruit production (Fontes & Silva, 2002).

The plant material mentioned was characterized by morphological traits included in the guidelines of distinguishability, homogeneity, and stability (DHE) test by MAPA, which were modified. Also, three traits were inserted by the authors. The randomized block design with three replications was used. Eighty-five (85) low-growing tomato accessions were evaluated. Each plot consisted of twelve plants, and the two central plants of each plot were assessed. The descriptors analyzed are shown in Table 1a and 1b. For the quantitative traits of each individual, the differences between the varieties were analyzed, as well as the metric data of the descriptors most affected by the environment.

For the evaluation of genetic diversity among the accessions, analysis of variance (ANOVA) was performed first, and then the clustering of means for each trait, with the data being submitted to the Scott-Knott test with a probability of 5%. The multivariate analyzes performed were the Tocher cluster, considering the generalized Mahalanobis distance and the relative importance of traits as a measure of dissimilarity, using the method of Jolliffe (1972) and canonical variables. All genetic and statistical analyzes were processed through the Computer Program in Genetics and Statistics – GENES Program (Cruz, 2016).

3. Results and Discussion

The results presented were divided between qualitative and quantitative descriptors. Table 2 shows the qualitative descriptors, the phenotypic classes, the number of accessions, and the percentage frequency of accessions in each of the classes. The descriptors initially discarded for not being able to differentiate the accesses are those that presented a frequency of 100%. Thus, it was suggested in this study to discard nine descriptors because they have a lower potential for discrimination: plant – growth habit, leaf – limb division, inflorescence - type, flower - fasciation (first flower of the inflorescence), flower – color, fruit - depression in the peduncular zone, fruit – green shoulder (before ripening), fruit - external coloring at ripening, and fruit – internal coloring (pulp) at ripening. So, the reduction in the number of qualitative descriptors was 40.91%.

There are few works in the literature that use the analysis of the multivariate method to discard descriptors in tomatoes. Afonso et al. (2014), in a study of the selection of morphoagronomic descriptors in banana plants, through the multivariate method, using the frequency for discarding qualitative data, suggested that 21.42% of the number of qualitative descriptors should be discarded. These values were lower than those discarded in this study, which was 40.91% of the number of qualitative descriptors used.

Table 3 presents the quantitative descriptors, their division into groups, amplitude, and the number of accessions. The descriptor fruit – shape in the longitudinal section presented the highest number of groups, eleven; the other descriptors presented only three groups. The descriptor average number of fruits per plant showed the highest amplitude of 75.83, and the descriptor peduncle – length had the smallest amplitude of 0.43. The maximum, minimum, and average values and coefficients of phenotypic variation of each quantitative descriptor are shown in Table 4. It can be seen that the coefficients of variation assumed quite variable percentages among the traits, with the lowest values recorded for cycle up to maturation and cycle up to flowering, which were below 8%. On the other hand, the highest percentage occurred in the trait fruit diameter of the peduncular scar, with a value above 118%.

The cycle up to maturation ranged from 100 to 113 days, with an average of 110.95 days. This trait is of significant importance, considering that it has a significant influence on the decision-making process of choosing the most suitable plant due to the rainy and sanitary periods. It is worth mentioning that this trait mainly depends on the environmental factor, as plants subjected to stress tend to reduce the cycle. The standard deviation of 21.42 of the yield variable allowed estimating a variation between the PXT-651 and PXT-610, responsible for the lowest and highest yields (39,12 and 162,97 t ha^{-1}), respectively.

The peduncle length presented average values of 0.51 mm and varied from 0.00 to 1.31 mm. The high value detected in the CV (%) may be related to the circumstance that these accessions are in an uncontrolled environment, where there is interference from the environment, such as temperature and light intensity changes. Another reason that may have increased the CV value is the small number of plants evaluated per plot.

Table 2. Qualitative descriptors, description of traits, number of accessions, and percentage frequency of 85 low-growing tomato accessions. Goiânia – GO. 2019.

Descriptor	Feature Description	Number of	Frequency
Seedling: anthocyanin pigmentation in the hypocotyl	Absent	7	0.03
	Present	248	0.97
Plant: growth habit	Determined	255	100
	Undetermined	0	-
Stem: anthocyanin pigmentation in the upper third	Absent	169	0.66
	Present	86	0.34
Leaf: position (in the middle third of the plant)	Top	35	0.14
	Medium	100	0.39
	Low	120	0.47
Leaf: form	Type 1	60	0.23
	Type 2	84	0.33
	Type 3	111	0.44
Leaf: limbus division	Pinnate	255	100
	Bipin	0	-
Leaf: intensity of green coloring	Clear	161	0.63
	Average	62	0.24
	Dark	32	0.13
Leaf: presence of bubbles	Absent	241	0.94
	Present	14	0.06
Inflorescence: type	Mostly Uniparous	255	100
	Mostly Multiparous	0	-
Flower: fasciation (first flower of the inflorescence)	Absent	255	100
	Present	0	-
Flower: coloring	Yellow	255	100
	Orange	0	-
Peduncle: abscission	Absent	7	0.03
	Present	248	0.97
Fruit: rib (rib-shaped protrusion) in the peduncular zone	Absent	224	0.88
	Present	31	0.12
Fruit: depression in the peduncular zone	Absent	0	-
	Present	255	100
Fruit: pistillate scar shape	Form 1	167	0.66
	Form 2	5	0.02
	Form 3	83	0.32
	Form 4	0	-
Fruit: pistillate tip shape	Reentrant	78	0.31
	Pointed	8	0.03
	Flat	169	0.66
Fruit: green shoulder (before ripening)	Absent	255	100
	Present	0	-
Fruit: intensity of green color before ripening	Weak	236	0.92
	Average	19	0.08
	Strong	0	-
Fruit: external coloration at maturation	Cream, Yellow, Orange, Rosy, Brown	0	-
	Red	255	100
Fruit: intensity of red color at maturation	Weak	56	0.22
	Average	22	0.09
	Strong	177	0.69
Fruit: internal color (pulp) at maturation	Cream, Yellow, Orange, Rosy, Brown	0	-
	Red	255	100
Fruit: intensity of the red color of the Pulp at maturation	Weak	54	0.21
	Average	23	0.09
	Strong	178	0.70

Table 3. Quantitative descriptors, the division into groups, amplitude, and the number of low-growing tomato accessions. Goiânia – GO, 2019.

Descriptor	Groups	Amplitude	Number of accessions
Stem: internode length (cm)	G1	2.25-4.50	81
	G2	4.51-6.76	129
	G3	6.77-9.00	18
Leaf: length (cm)	G1	22.00-28.66	112
	G2	28.67-35.32	116
	G3	35.33-42.00	23
Leaf: width (cm)	G1	14.00-21.00	126
	G2	21.01-28.00	78
	G3	28.01-35.00	25
Peduncle: length (cm)	G1	0.00-0.43	58
	G2	0.44-0.87	133
	G3	0.88-1.30	27
Fruit: length/diameter ratio	G1	0.74-1.97	254
	G2	1.98-3.21	0
	G3	3.22-4.43	1
Fruit: shape in longitudinal section	G1	0.00-1.00	0
	G2	1.01-2.00	0
	G3	2.01-3.00	37
	G4	3.01-4.00	14
	G5	4.01-5.00	78
	G6	5.01-6.00	102
	G7	6.01-7.00	2
	G8	7.01-8.00	11
	G9	8.01-9.00	9
	G10	9.01-10.00	1
	G11	10.01-10.50	1
Fruit: diameter of the peduncular scar (mm)	G1	1.65-3.99	247
	G2	4.00-6.33	6
	G3	6.34-7.04	2
Fruit: diameter of the placental zone (mm)	G1	2.78-8.50	57
	G2	8.51-14.22	172
	G3	14.23-19.95	26
Fruit: pericarp thickness (mm)	G1	4.39-7.25	117
	G2	7.26-10.11	134
	G3	10.12-12.96	4
Fruit: predominant number of locules	G1	2.00-2.50	132
	G2	2.51-3.00	37
	G3	3.01-3.50	12
	G4	3.51-4.00	4
Fruit: firmness (newton)	G1	1.22-2.27	32
	G2	2.28-3.32	168
	G3	3.33-4.38	49
Cycle up to flowering: first open flower (days)	G1	21.00-23.00	25
	G2	23.01-26.00	121
	G3	26.01-27.00	109
Cycle up to maturity (days)	G1	100.00-104.33	110
	G2	104.34-108.66	25
	G3	108.67-113.00	120
Yield (t ha^{-1})	G1	39.12-80.40	41
	G2	80.41-121.68	167
	G3	121.69-162.97	41
Average number of fruits per plant	G1	35.50-111.33	114
	G2	111.34-187.16	131
	G3	187.17-263.00	10
Soluble solids (°Brix)	G1	1.20-2.83	29
	G2	2.84-4.47	125
	G3	4.48-6.10	101

The CV is a precision expression of an experiment. Each variable has a specific CV scale that refers to its intrinsic variability (Zimmermann, 2004). Silva et al. (2011), evaluating the experimental variation coefficient for pepper fruit traits, obtained a CV of 11.53 for the peduncle length variable, a value considered low according to the CV classification criteria proposed by Garcia (1989). Table 5 shows the estimates of Pearson correlation coefficients, with their respective significance, among the 18 variables. Among the variables of quantitative descriptors evaluated, those that expressed a strong, significant, and positive correlation were CICLOF x CICLOM with a value of 0.95** and FL x FR with a value of 0.90**. There was a negative correlation between FDZ x FFIRME with a value of -0.29** and FEP x NFRUTO with a value of -0.24**, values considered a moderate or a weak correlation according to Dancey & Reidy (2006).

The value zero demonstrates that the two variables do not depend linearly on each other, as happened with FFIRME x SS, FNL; HNO x NFRUTO, FEP; and FNL x FDZ. All correlations with the variable FDP were non-significant, except for FDP x FT, FDP x FL, and FDP x FOLHAC, which had a value of zero, in the same way as the variables that correlated with FT, except for FT x FOLHAC, which had a value zero.

Table 6 shows the estimates of the eigenvalues associated with the canonical variables and their total and accumulated variances obtained from eighteen quantitative descriptors evaluated in the 85 low-growing tomato accessions studied. The objective of this analysis is to demonstrate the existing variability among the 85 accessions analyzed.

The first two principal components (PC) absorbed 27.76% of the entire variation, 38.57% in the first three PCs, and 48.70% in the first four PCs. The first six principal components were needed to reach 60% of all existing variation. The variance distribution depends on the nature and amount of traits used in the analysis, concentrated in the first principal components, only when few descriptors are used (Pereira et al., 1992).

The traits selected based on the Jolliffe procedure (1972) are shown in Table 7. Eight traits were recommended based on the method of estimating eigenvalues associated with the analysis of the procedure proposed by Jolliffe (1972). Thus, the following descriptors were part of the final disposal: stem- internode length (HNO), fruit- number of locules (FNL), leaf – length (FOLHAC), fruit – transverse length (FT), leaf – width (FOLHAL), fruit – longitudinal length (FL), fruit – pericarp thickness (FEP) and cycle up to flowering (CICLOF).

Table 4. Descriptive statistics informing the maximum, minimum, and average values and the coefficients of phenotypic variation (CV) obtained in the 18 quantitative descriptors of 85 low-growing tomato accessions. Goiânia-GO, 2019.

Variables	Minimum	Maximum	Average	Standard	CV (%)
HNO	2.25	9.00	4.96	1.24	24.95
FOLHAC	22.00	42.00	29.80	4.22	14.17
FOLHAL	24.00	35.00	21.66	4.53	20.89
PENDC	0.00	1.30	0.51	0.29	55.78
FL	43.81	246.82	61.44	14.05	22.86
FT	39.28	152.46	48.48	9.67	19.95
FR	0.74	4.43	1.29	0.26	20.52
FF	3.00	10.50	5.38	1.45	26.91
FDP	1.65	7.04	2.34	0.62	26.23
FDZ	2.78	19.95	10.42	2.73	26.21
FEP	4.39	12.96	7.29	1.26	17.28
FNL	2.00	4.00	2.48	0.52	21.12
FFIRME	1.22	4.38	2.90	0.59	20.27
FRTY	39.12	162.97	101.96	21.42	21.01
CICLOF	21.00	27.00	24.99	1.94	7.77
CICLOM	100.00	113.00	110.95	2.06	1.85
NFRUTO	35.50	263.00	118.11	6.62	31.00
SS	1.20	6.10	4.05	0.97	23.83

HNO - Stem: internode length; FOLHAC - Leaf: length; SHEET - Sheet: width; PENDC – Peduncle: length; FL – Fruit: longitudinal length; FT – Fruit: transverse length; FR – Fruit: reason; FF – Fruit: format; FDP – Fruit: diameter of the peduncular scar; FDZ – fruit: diameter of the placental zone; FEP – Fruit: pericarp thickness; FNL – Fruit: number of locules; FFIRME – Fruit: firmness; FRTY – Fruit yield; CYCLE – Cycle up to flowering; CYCLOM – Cycle up to maturation; FRUIT – Average number of fruits per plant and SS – soluble solids; CV - Coefficient of variation.

Table 5. Estimates of Pearson's correlation coefficients, with their respective significance, among the 18 variables, in the municipality of Abadia de Goiás - GO, 2019.

	SS	NFRUTO	CICLOM	PROD	FFIRME	FNL	FEP	FDZ	FDP	FF	FR	FT	FL	PENDC	FOLHAL	FOLHAC	HNO
NFRUTO	0,09^{ns}																
CICLOM	-0,09^{ns}	-0,01^{ns}															
PROD	0,09^{ns}	0,04ns	0,15*														
FFIRME	0,00^{ns}	0,22**	0,03^{ns}	-0,04^{ns}													
FNL	-0,07^{ns}	-0,11^{ns}	-0,09^{ns}	-0,03^{ns}	0,00^{ns}												
FEP	-0,04^{ns}	-0,24**	-0,04^{ns}	-0,08^{ns}	0,05^{ns}	0,03^{ns}											
FDZ	0,04^{ns}	-0,04^{ns}	0,16**	0,15*	-0,29**	0,00^{ns}	-0,17**										
FDP	0,03^{ns}	-0,05^{ns}	0,02^{ns}	0,15*	-0,06^{ns}	0,02^{ns}	-0,02^{ns}	0,09^{ns}									
FF	0,05^{ns}	-0,07^{ns}	-0,02^{ns}	-0,04^{ns}	-0,02^{ns}	-0,04^{ns}	0,09^{ns}	0,13*	0,01^{ns}								
FR	0,06^{ns}	0,05^{ns}	0,03^{ns}	0,03^{ns}	-0,04^{ns}	-0,01^{ns}	0,01^{ns}	-0,08^{ns}	-0,01^{ns}	-0,01^{ns}							
FT	0,02^{ns}	-0,09^{ns}	0,05^{ns}	0,05^{ns}	-0,17**	0,01^{ns}	0,16*	0,22**	0,00^{ns}	0,24^{ns}	-0,17**						
FL	0,07^{ns}	-0,06^{ns}	0,02^{ns}	0,02^{ns}	-0,12^{ns}	-0,01^{ns}	0,19**	0,05^{ns}	0,00^{ns}	0,07^{ns}	0,90**	0,08^{ns}					
PENDC	0,05^{ns}	0,06^{ns}	-0,06^{ns}	0,08^{ns}	-0,13*	-0,10^{ns}	-0,03^{ns}	0,13*	-0,05^{ns}	0,05^{ns}	-0,08^{ns}	-0,02^{ns}	-0,04^{ns}				
FOLHAL	0,09^{ns}	0,08^{ns}	-0,06^{ns}	0,09^{ns}	0,03^{ns}	-0,5^{ns}	-0,11^{ns}	0,9^{ns}	-0,05^{ns}	0,15*	-0,03^{ns}	-0,08^{ns}	-0,04^{ns}	0,06^{ns}			
FOLHAC	0,07^{ns}	0,05^{ns}	-0,02^{ns}	0,11^{ns}	-0,01^{ns}	0,02^{ns}	-0,06^{ns}	0,12*	0,00^{ns}	0,04^{ns}	-0,1^{ns}	0,00^{ns}	-0,08^{ns}	0,14**	0,03**		
HNO	0,10^{ns}	0,00^{ns}	0,01^{ns}	0,04^{ns}	-0,19**	-0,02^{ns}	0,00^{ns}	0,22**	-0,09^{ns}	0,05^{ns}	0,07^{ns}	0,08^{ns}	0,10^{ns}	0,20**	0,05^{ns}	0,03^{ns}	
CICLOF	-0,09^{ns}	-0,05^{ns}	0,95**	0,13*	0,02^{ns}	-0,04^{ns}	-0,05^{ns}	0,19**	0,02^{ns}	-0,01^{ns}	0,02^{ns}	0,06^{ns}	0,03^{ns}	-0,06^{ns}	-0,07^{ns}	-0,03^{ns}	0,14^{ns}

Table 6. Estimates of the eigenvalues associated with the Canonical Variables and their total and accumulated variances obtained from the eighteen quantitative descriptors evaluated in 85 low-growing tomato accessions. Goiânia– GO, 2019

Principal component	Root	Root (%)	Accumulated (%)
1	2.62766538	14.5980769	14.5980769
2	2.3708871	13.171595	27.7696719
3	1.9451366	10.8063143	38.5759861
4	1.8236976	10.1316531	48.7076392
5	1.400666	7.7814778	56.489117
6	1.2955675	7.1975973	63.6867143
7	1.1782689	6.5459386	70.2326529
8	0.9118899	5.066055	75.2987079
9	0.8253939	4.5855215	79.8842295
10	0.7796821	4.331567	84.2157964
11	0.6555044	3.6416912	87.8574876
12	0.6177853	3.4321403	91.9601233
13	0.4806892	2.6704954	93.9601233
14	0.4058128	2.2545156	96.2146389
15	0.3349436	1.8607979	98.0754368
16	0.2797724	1.5542914	99.6297281
17	0.0472197	0.2623316	99.8920597
18	0.0194293	0.1079403	100

Table 7. Traits of 85 low-growing tomato accessions selected based on the Jolliffe procedure (1972). Goiânia – GO, 2019.

Variables	Eigenvalue	Importance	Recommendation
FDZ	2.63	14.60	Selected
CICLOM	2.37	13.17	Selected
FFIRME	1.94	10.81	Selected
FR	1.82	10.13	Selected
FDP	1.40	7.78	Selected
FF	1.29	7.20	Selected
NFRUTO	1.18	6.55	Selected
SS	0.91	5.07	Selected
FRTY	0.82	4.59	Selected
PENDC	0.78	4.33	Selected
HNO	0.65	3.64	Discard
FNL	0.62	3.42	Discard
FOLHAC	0.48	2.67	Discard
FT	0.40	2.25	Discard
FOLHAL	0.33	1.86	Discard
FL	0.28	1.55	Discard
FEP	0.05	0.26	Discard
CICLOF	0.02	0.11	Discard

FDZ – fruit: diameter of the placental zone; CICLOM – Cycle up to maturation; FFIRME – Fruit: firmness; FR – Fruit: reason; FDP – Fruit: diameter of the peduncular scar; FF – Fruit: format; NFRUTO – Average number of fruits per plant; SS – Soluble solids; FRTY – Fruit yield; PENDC – Peduncle: length; HNO - Stem: internode length; FNL – Fruit: number of locules; FOLHAC - Leaf: length; FT – Fruit: transverse length; FOLHAL - Leaf: width; FL – Fruit: longitudinal length; FEP – Fruit: pericarp thickness and CICLOF – Cycle up to flowering.

Regarding the descriptors selected in the analysis by Jolliffe (1972), we have: fruit – diam, cycle up to maturation (CICLOM), fruit – firmness (FFIRME), fruit – ratio (FR), fruit – peduncular scar diameter (FDP), fruit – shape (FF), the average number of fruits per plant (NFRUTO), soluble solids (SS), fruit yield (FRTY), and peduncle – length (PENDC). The selected descriptors are important in the characterization of low-growing tomato germplasm. They provide essential information for the genetic improvement of the studied accessions and the species. The disposal of unselected descriptors will reduce the labor, time, and cost of the evaluation and characterization activities of the low-growing tomato.

4. Conclusions

There is low genetic variability in the morphoagronomic traits evaluated in the 85 low-growing tomato accessions. Of the selected morphoagronomic descriptors, about 56.4% are essential in this characterization study because they presented significant contributions to the discrimination of genetic divergence between low-growing tomato accessions. Discarding 43.6% of the descriptors does not cause a loss of information in this study. It reduces costs and streamlines the management of the classification of the Horta-UFG collection.

Authors' Contribution

Mariana Vieira Nascimento: experiment setup, data collection, writing and translation of the article; Mylla Crysthyan Ribeiro Ávila: data collection; Ana Paula Oliveira Nogueira: statistical analysis and data interpretation; Abadia dos Reis Nascimento: orientation and review

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