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Prediction of genetic potential of ornamental pepper parents

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Abstract

Parental choice is key step in breeding programs. Better results are obtained when, in the base population a large genetic variability is combined with high traits means. The objective of this work was to estimate means, heritability and genetic diversity among eight *Capsicum annuum* ornamental lines to predict the potential of these accessions as genitors. Data were subjected to analysis of variance and means were grouped by Scott- Knott criteria at 5% of probability. Estimates of heritability; coefficient of genetic variance (CVg), and coefficient of environmental variance (CVe) were obtained. Mahalanobis Distance, Tocher's and canonical variables analysis were used to evaluate genetic divergence. The importance of variables to the genetic variability was determined by the Singh's method and canonical analysis. CVg/CVe ratio indicated greater importance of genetic variation in relation to environmental variation. Heritabilities ranged from 70% to 99.87%. Based on means and on Tocher's and canonical variables methods, the crossings UFSJ 7 x UFSJ 4, UFSJ 7 X UFSJ 5, UFSJ 7 X UFSJ 6, UFSJ 6 X UFSJ 4 and UFSJ 6 X UFSJ 5 are recommended. Dry matter fruit content and days to flowering contributed least to genetic divergence and should be suppressed in future works. Leaf length and width contributed most to this estimate.

Keywords: *Capsicum annuum,* genetic diversity, heritability, germplasm, selection

Introduction

In Brazil, potted peppers stand out among ornamental plants with economic potential due to the variability of fruit colors and forms, easy cultivation and great durability (Neitzke et al., 2010; Rêgo et al., 2012; Neitzke et al., 2016; Marcelino & Albuquerque, 2019; Fortunato et al., 2019). These plants are an excellent income alternative to small farmers due to their high commercial value (Bosland, 1993; Rêgo et al. 2015). Despite their growing acceptance by the consumers (Rêgo et al., 2009), there are few commercial cultivars available in the country (Nascimento et al., 2015).

The choice of parents is key step in breeding programs. Better results are obtained when genetic variability is combined better performance in the base population (Pimentel et al., 2013).

Ideotype is a conceptual model of a plant whose morphological, biochemical, physiological or agronomic characteristics are appropriate for a particular use (Martuscello et al., 2015). For Marcelino and Albuquerque (2019) the ornamental pepper ideotype is higher means in canopy and stem diameters, leaf length and width and number of fruits per plant and lower means in plant height, days to flowering and days to fruiting, fruit length, fruit diameter, fruit weight and fruit dry matter content. Barbosa (2002) and Barroso et al. (2012) also take into account the harmony of the plant in the pot.

The amount of genetic variability in a segregant population depends on the genetic divergence of their parents (Falconer, 1981), which can be estimated by predictive biometrical techniques. The variability can generate superior lineages in ornamental pepper breeding programs based on hybridization (Pessoa et al., 2018). The objective of this work was to estimate means, heritability and genetic diversity among ornamental pepper accessions to predict the genetic potential

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of these accessions as parents in a genetic breeding program.

Material and Methods

Eight ornamental pepper (*Capsicum annuum)* lines belonging to the germplasm bank of CSL-UFSJ (Campus Sete Lagoas, Universidade Federal de São João del Rei, Sete Lagoas, MG, Brazil) were sown in a 200-cell styrofoam tray. Seedlings were transplanted at the six-leaf stage into 900 ml plastic pots filled with commercial substrate (Bioplant, Brazil) and arranged in enterely randomized design, with three replicates and two plants per plot. Pots were kept under a mesh structure at 30% shading.

The eight treatments were evaluated according to 13 characteristics related to fruits and plants: canopy diameter (CD), plant height (PH), first bifurcation height (FBH), stem diameter (SD), days to flowering from transplanting date (DTF), days to fruiting from transplanting date (DTFr), leaf length (LL), leaf width (LW), fruit number per plant (FN), fruit mass (FM), fruit dry matter content (DMC), fruit length (FL) and fruit diameter (FD). All characteristics were evaluated based on the list of descriptors suggested by the International Plant Genetic Resources Institute (1995). The fruit traits were taken from 10 mature units randomly harvested on each plot.

Data were submitted to analysis of variance and means were grouped by the Scott- Knott criteria at 5% probability. Estimates of heritability and genetic and environmental variances were also calculated. Tocher's method based on the generalized Mahalanobis distance and analysis of canonical variables with graphical dispersion of genotypes were used to analyze genetic divergence. The relative importance of variables was determined by method described by Singh (1981). All statistical analyses were performed using the Genes computer software (Cruz, 2006).

Results and Discussion

Differences among accessions were significants for all evaluated traits (Table 1), except for first bifurcation height (data not shown).

Table 1. Analysis of variance summary for 12 traits of ornamental pepper accessions.

SV	MS					
Treatments	CD	PH	SD	DTF	DTFr	LL
	4082.46**	1664.84*	16.15**	309.12*	496.48**	1009.70**
h^2 (%)	94.84	74.70	88.56	70.00	84.29	99.87
CVg/CVe	2.47	0.99	1.61	0.88	1.34	15.76
CVe (%)	9.91	16.92	18.68	9.74	7.76	2.94
SV	MS					
	LW	FN	FM	DMC	FL	FD
Treatments	262.38**	138.4**	2.72**	0.11**	373.76**	53.73**
h^2 (%)	99.73	87.78	99.00	97.33	98.73	96.69
CVg/CVe	11.03	1.55	5.71	3.48	5.08	3.12
CVe (%)	4.00	22.85	6.65	10.94	9.18	10.10

^{sv} sources of variation, ^{ms} mean square, ^{h2} broad sense heritability, ^{cvg} coefficient of genetic variance, cv coefficient of experimental variance, cd canopy diameter (mm), ph plant height (mm), sd stem diameter, dtf days to flowering counted from transplanting date, ^{dtfr} days to fruiting counted from transplanting date, ^{ll} leaf length (mm), ^{lw} leaf width (mm), ^{fn} fruit number per plant, ^{fm} fruit mass (g), ^{dmc} fruit dry matter content (g), ^{fl} fruit length (mm) and ^{fd} fruit diameter (mm). **/* significant at 1% and at 5% probability by F-test.

Coefficient of experimental variance (CVe %) ranged from 2.94% for LL to 22.85% for FN. The highest CVe value (%) was obtained for fruit number per plant (FN), which is a trait related to production, controlled by a large number of genes and highly affected by environment. Silva et al. (2011) in work with *Capsicum* ssp. found that CVe values vary with traits, accessions and species. CVg/ CVe ratios were close to or greater than the unit except for plant height and days to flowering (Table 1). This fact indicates a major importance of genetic variance in relation to environmental variance for the evaluated traits.

Heritability coefficients were equal to or above 70% for all evaluated traits. The lowest coefficient was for DTF (70.00 %) and the highest coefficient was for LL (99.87 %) (Table 1). According to Singh (2007), these heritability values were moderately high to very high. High heritability estimates have been also reported for *Capsicum spp*. by Rosmaina et al. (2016) in plant height (94.15%), stem diameter (54.35%), leaf length (83.58%), leaf width (95.49%), plant canopy width (86.50%), fruit length (99.63%), fruit diameter (93.33%), days to flowering (95.31%), days to first harvest (98.51%), fruit weight (98.77%) and number of fruits per plant (81.21%). High heritability coefficients indicate relative small contribution of environment to phenotype and easy selection due to the high additive effects in the control of traits (Bello et al., 2014). Marcelino and Albuquerque (2019), working on this same population, found predominance of additive effects for all these characteristics, except for fruit mass (FM).

According to ornamental pepper ideotype UFSJ

8 was discarded because it was the latest (higher means for DTF and DTFr) and in ornamental peppers earliness is fundamental (Silva et al., 2015). Still in accordance to ornamental pepper ideotype discussed by Marcelino and Albuquerque (2019), the most prominent genotype was UFSJ 7 regarding the mean values of variables CD, SD, DTF, DTFr, LL, LW, FN, DMC, FL and FD. Then, genotypes UFSJ 4, UFSJ 5 and UFSJ 6 stood out in six traits. UFSJ 4 stood out for CD, DTF, DTFr, LL, FM and DMC, UFSJ 5 for PH, DTF, DTFr, LW, FM and DMC and UFSJ 6 for CD, DTF, DTFr, FM, DMC and FL (Table2). These selections are justified on account of smaller pepper plants are desirable for ornamental purposes (Carvalho et al., 2006; Rêgo et al., 2015; Silva et al., 2015), smaller fruit dimensions are recommended for maintaining plant architecture equilibrium (Fortunato et al., 2019), larger canopy diameter and larger leaf dimensions are more attractive (Silva et al., 2017), precocious plants reduce production costs and promptly supply the market (Silva et al., 2015), plants with very thin stems tend for lodging and lose its commercial value (Silva Neto et al., 2014), and there is direct relationship between reduce fruit dry matter content and lower abscission of ornamental pepper leaves due to ethylene deleterious effects (Nascimento et al., 2015).

Table 2. Means of 12 traits in eight accessions of ornamental pepper.

Accessions	Characters											
	CD	PH	SD	DTF	DTFr	LL	LW	FN	FM	DMC	FL	FD
UFSJ 1	115.67 c	132.73 a	7.37 b	97.33 b	110.67 b	13.77 h	8.10 h	14.00 c	4.22 a	0.67 a	12.38 d	8.88 c
UFSJ 2	129.50 c	111.50 b	4.67 b	100.67 b	113.67 b	38.78 d	20.93 d	12,00 c	2.16 d	0.70 a	48.39 a	18.14 a
UFSJ 3	106.33 c	85.83 b	5.55 b	93.67 b	108.33 b	31.63 f	13.97 g	10.33 c	3.53 b	0.75 a	24,31 b	12.88 b
UFSJ 4	157.50 b	133.50 a	7.23 b	96.00 b	107.33 b	47.20 c	18.70 e	19,67 c	1.94 e	0.37 c	24.24 b	14.87 b
UFSJ 5	116.18 c	94.30 b	5.60 b	85.67 b	102.00 b	35.00 e	25.23 c	15.00 c	1.31 f	0.31 c	26.61 b	19.37 a
UFSJ 6	158.08 b	119.67 a	6.33 b	97.67 b	112.33 b	21.90 g	16.57 f	19,00 c	1.88 e	0.32 c	20.22 c	14.09 b
UFSJ 7	173.87 b	135.33 a	10.28 a	99.00 b	112.00 b	62.03 b	27.27 b	22.67 b	2.71 c	0.44 b	20.23 c	8.22 c
UFSJ 8	215.42 a	157.67 a	11.17 a	121.33 a	144.33 a	66.60 a	38.73 a	31,33 a	2.23 d	0.34 c	13.65 d	9.23 c

^{cd} canopy diameter (mm), ^{ph} plant height (mm), ^{sd} stem diameter, ^{dtf} days to flowering from transplanting date, ^{dtfr} days to fruiting from transplanting date, ^{ll} leaf length (mm), ^{lw} leaf width (mm), ^{fn} fruit number per plant, ^{fm} fruit mass (g), ^{dmc} fruit dry matter content (g), ^{fl} fruit length (mm) and ^{fd} fruit diameter (mm). Equal letters in column represent same grouping by Scott-Knott criterion at 5% probability

The accessions were divided into 4 groups: four accessions were classified in the first cluster followed by two accessions categorized in the second cluster. The remaining two clusters had one genotype each (Table 3). Since the Tocher's optimization criterion minimizes the average intra-cluster distance and maximizes the average inter-cluster distance (Rao, 1952), greater heterotic effects should be recovered on progenies obtained from crosses between accessions of different groups. Considering the most promising accessions (UFSJ 4, UFSJ 5, UFSJ 6 and UFSJ 7), already selected based on means in evaluated characteristics, crosses between UFSJ 7 (group II) and UFSJ 4, UFSJ 5 and UFSJ 6 (group I) should be carried out. Despite being in the same group there is considerable variability between UFSJ 6 and UFSJ 4 and between UFSJ 6 and UFSJ 5 (Table 3 and Figure 1) which makes recommended too these crosses.

The first three canonical variables accounted for about 98.99% (Table 4) of the total variability among accessions and in dispersion graph the grouping was compatible with those grouped by the Tocher's method (Figure 1)

Table 3. Clustering of eight accessions based on 12 quantitative traits of ornamental pepper by the Tocher method. Sete Lagoas, 2018.

Groups	Accessions
I	UFSJ 3, UFSJ 6, UFSJ 4 and UFSJ 5
II	UFSJ 7 and UFSJ 8
III	UFSJ 2
IV	UFSJ 1

Table 4. Variance estimates (Eigenvalues) for canonical variables and relative importance (Eigenvectors) for 12 traits evaluated in ornamental peppers.

Canonical variable	Root (Eigenvalue)	Root (%)	Acumulated (%)	Relative importance					
				CD	PH	SD	DTF	DTFr	LL
1	2338.982	76.98	76.98	0.147089	-1.578848	0.774472	-0.438061	-1.787165	-1.925030
2	579.871	19.09	96.07	-1.589842	1.509519	-3.237253	-0.307412	0.044874	-.179771
3	88.793	2.92	98.99	0.181784	0.718515	-1.187685	0.982164	-0.521262	-1.001670
4	25.285	0.83	99.82	-0.945033	1.066787	-0.330537	-1.735840	2.197875	-.292189
5	3.432	0.11	99.94	1.159269	-0.216953	-0.131763	0.915398	-.0015055	-0.063019
6	1.299	0.04	99.98	-0.144073	0.634571	-0.288993	0.369111	0.106257	0.114244
7	0.661	0.02	100.0	0.453434	-1.117689	0.261524	0.285388	-0.042250	0.001402
8	0	0	100.0	-0.623943	0.096806	-0.319670	-0.381767	0.324156	0.011337
9	0	0	100.0	0.330917	0.049274	0.1255067	-0.948978	0.263862	-0.018033
10	0	0	100.0	0.085154	-0.419660	1.017050	-0.137624	0.091932	-0.028003
11		0	100.0	-0.346635	0.066690	0.469128	-3.323637	3.055119	0.056114
12	0	0	100.0	-0.315014	0.486641	-0.026985	0.548886	-0.469492	-0.009910
Canonical variable	Root (Eigenvalue)	Root (%)	Acumulated (%)	Relative importance					
				LW	FN	FM	DMC	FL	FD
1	2338.982	76.98	76.98	-1.806665	1.300159	0.278901	-0.732862	-0.930759	-0.727746
2	579.871	19.09	96.07	.251224	0.477503	-2.024513	1.404688	2.180283	0.605297
3	88.793	2.92	98.99	1.335514	-0.126948	-0.695801	-0.068984	-0.566585	-0.677670
4	25.285	0.83	99.82	0.715147	0.056874	0.811194	0.292094	0.429877	0.033810
5	3.432	0.11	99.94	-0.164124	-0.423111	-0.437826	0.475691	0.038381	-0.371488
6	1.299	0.04	99.98	-0.159778	0.881507	-0.215628	0.803750	-0.603666	0.991924
7	0.661	0.02	100.0	-0.062865	-0.351572	-0.595986	0.805863	-0.372953	-0.215941
8	0	0	100.0	-0.048789	1.068699	-0.271197	0.258504	0.008265	-0.364304
9	0		100.0	0.005632	0.173561	0.0138571	0.207150	-0.033727	0.178934
10	0	0	100.0	-0.063194	0.262007	-0.053893	0.192233	0.017888	0.310277
11	0	0	100.0	-0.194054	-0.094536	-0.049188	-0.288626	0.263056	-0.242899
12	0	0	100.0	0.011431	-0.079377	-0.612879	0.734631	-0.292780	-0.345986

[cd] canopy diameter (mm), [ph] plant height (mm), [sd] stem diameter, [dtf] days to flowering from transplanting date, [dtfr] days to fruiting from transplanting date, [ll] leaf length (mm), [lw] leaf width (mm), [fn] fruit number per plant, [fm] fruit mass (g), [dmc] fruit dry matter content (g), [fl] fruit length (mm) and [fd] fruit diameter (mm)

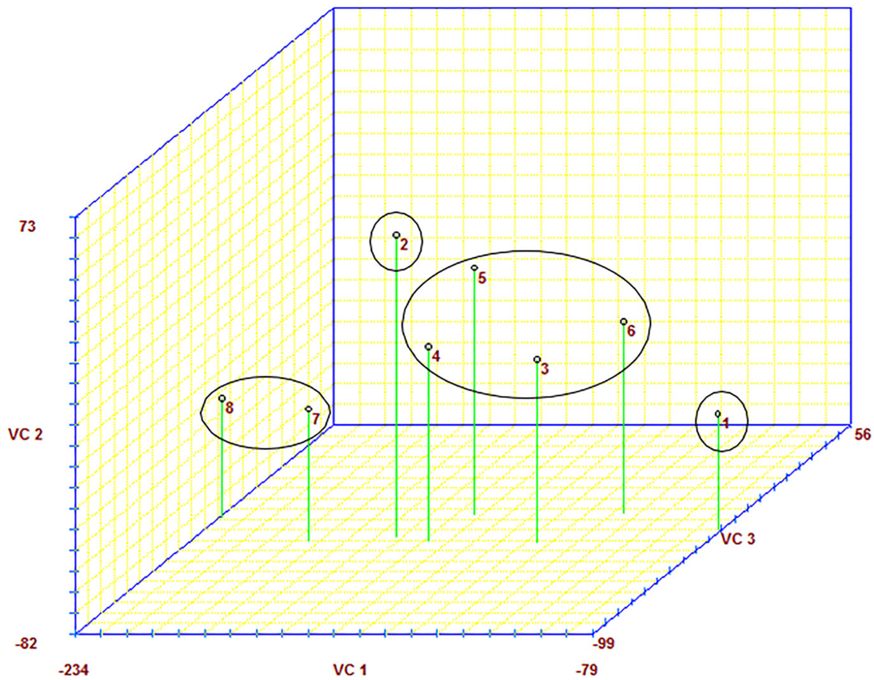

Figure 1. Graphical dispersion of accessions based on the scores in relation to the representative axes of canonical variables (VC1, VC2 and VC3) for 12 traits of ornamental pepper. Accessions: 1 = UFSJ 1, 2 = UFSJ 2, 3 = UFSJ 3, 4 = UFSJ 4, 5 = UFSJ 5, 6 = UFSJ 6, 7 = UFSJ 7 and 8 = UFSJ 8.

Variances (eigenvalues) associated with canonical variables and their respective eigenvectors are presented in Table 4 and show that variables fruit dry matter content and days for flowering presented the highest values in eigenvectors corresponding to at least three canonical variables whose variances were zero, indicating that these variables must be discarded in future analyzes that aim to estimate genetic divergence, for saving financial resources, time and labor in future experiments with ornamental peppers (Rêgo et al., 2003; Yamaki et al., 2009; Galate et al., 2012; Oliveira et al. 2019). According Singh method (1981) leaf length and leaf width were the traits that contributed most to genetic divergence estimation (Table 5).

Table 5. Relative importance of 12 characters of ornamental peppers for phenotypic divergence by the Singh method (1981).

Characters	Relative importance (%)
Canopy diameter	1.0979
Plant height	0.3753
Stem diameter	2.0583
Days to flowering	0.4906
Days to fruiting	2.4451
Leaf length	44.4704
Leaf width	29.0332
Fruit number per plant	2.5492
Fruit mass	6.7203
Fruit dry matter content	0.9039
Fruit length	8.8632
Fruit diameter	0.9926

Conclusions

Crossings between UFSJ 7 X UFSJ 4, UFSJ 7 X UFSJ 5, UFSJ 7 X UFSJ 6, UFSJ 6 X UFSJ 4 and UFSJ 6 x UFSJ 5 could result in high heterotic effect in future segregant generations.

Leaf length and width were the traits that contributed most to genetic divergence estimation.

Fruit dry matter content and days for flowering were the traits that contributed least to the estimation of genetic divergence and should be suppressed in future works.

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