Comunicata Scientiae
Horticultural Journal

ORIGINAL ARTICLE
published: 14 October 2021
https://doi.org/10.14295/CS.v12.3577

Selection of pepper genotypes for ornamentation

Maria Eduarda da Silva Guimarães*, Ana Izabella Freire, Ana Carolina Ribeiro de Oliveira, Ariana Mota Pereira, Paula Cristina Carvalho Lima, Fernando Luiz Finger

Federal University of Viçosa, Viçosa, Brazil
*Corresponding author, e-mail: maria.eduarda.ufv@gmail.com

Abstract

Capsicum annuum is one of the most the most suitable species for use in ornamentation. Despite the existing great variability, few commercial varieties are used for ornamentation in Brazil. Obtaining a variety that has high performance characteristics is the main focus of a breeding program. It is of interest to the breeder an ideotype plant that contains all the characteristics of interest for commercialization. The objective of this study was to evaluate the potential of genotypes of *C. annuum* for ornamentation and to select those with desirable ornamentation characteristics. 29 genotypes of *C. annuum* were evaluated in relation to eleven morphological characteristics. In order to study genetic variability, genetic parameters were estimated for the characteristics evaluated. The factor analysis was used to reduce the number of characteristics evaluated and to calculate the selection index. For the selection of genotypes, the multiple characteristics index based on factor analysis and ideotype-design (FAI-BLUP) was calculated. The cultivar Calypso was chosen as an ideotype because it has characters that are highly desirable in the ornamentation market. Predicted genetic gains were calculated for the genotypes selected by the FAI-BLUP index. Genetic variability was observed for all traits. The factor analysis was efficient in reducing the 11 characteristics in three factors. Based on the FAI-BLUP index, nine genotypes were selected for presenting means close to those of the ideotype, for all the characteristics evaluated. The selected genotypes shown gains by selection for most characteristics evaluated and were those with the greatest ornamental potential.

Keywords: *Capsicum annuum*, factor analysis, fai-blup index, ideotype, selection gains

Introduction

Pepper trees stand out for their diversified use. They are widely used in the food industry as a raw material in the manufacture of dyes, flavorings, oleoresins, condiments, sauces and seasonings. They are also highly valued in cooking, pharmacology, dentistry and medicine. The fruits of such tree are a source of vitamin compounds and natural antioxidants such as vitamin C, vitamin E, B vitamins and carotenoids. In addition to their importance in food, peppers have great potential for ornamentation due to a set of characters of high aesthetic value, such as plant architecture; reduced size; shape, color, position and quantity of fruits produced; ease of cultivation; fruit durability and the ability to grow in containers as a perennial plant (Neitzke et al., 2010).

Capsicum annuum is one of the most used species in pot planting for ornamental purposes, due to the large number of small cultivars and the great variability of shapes and colors of the fruits (Finger et al., 2015). Despite the great variability of the *Capsicum* genus (Neitzke et al., 2010) the market of ornamental plants lacks novelties and new products that add competitiveness to the sector and a considerably raise in the profit margin (Costa et al., 2019). The morpho-agronomic characterization enables the assessment of the presence of variability in the population, which is the basic premise for obtaining gains from selection.

The study of the morphological characters can be carried out individually or simultaneously. Through simultaneous analysis, it is possible to better interpret the relationship between variables. Studies that allow the conclusion for more than one characteristic can be performed using multivariate statistical techniques. One of these techniques is factor analysis as it makes it possible to group correlated variables into unobservable factors (latent variables), defined through the correlation

Received: 26 August 2020
Accepted: 30 March 2021

between variables. After identifying and interpreting the factors, the latent variables can be predicted and their values used in further analyses (Silva et al., 2014).

Obtaining high-performance genotypes based on simultaneous character selection is not always an easy task. In the genetic improvement of plants, it is sought an ideotype that has favorable phenotypes for all characteristics of agronomic interest aimed by both producers and consumers (Rocha et al., 2018). Selection indexes, established by the linear combination of several characters, allow simultaneous selection to be carried out more efficiently. However, multicollinearity conditions compromise the adequate interpretation of the results. The multiple characteristics index based on factor analysis and ideotype-design (FAI-BLUP), proposed by Rocha et al. (2018), is based on factor analysis and is not influenced by multicollinearity, allowing the selection of genotypes in a more appropriate way than traditional indices.

In light of the aforementioned, this study proposes was to evaluate the potential of pepper genotypes of *Capsicum annuum* and select those with desirable ornamentation characteristics.

Material and Methods

The experiment was conducted in a greenhouse, in the Department of Plant Science of the Federal University of Viçosa, using 29 genotypes of *C. annuum*, selected for their potential for ornamentation (Table 1). A completely randomized design was used, with 29 treatments (genotypes) and five replications, where the experimental unit consisted of one plant per pot. Sowing was carried out in 120-cell polystyrene trays containing commercial substrate. Seedlings with four pairs of permanent leaves were transplanted in 800-ml pots and thinning was performed one week later. Cultural treatments such as irrigation, fertilization, weed control were carried out whenever it was necessary.

For the morphological characterization of the genotypes, the ornamental potential associated with characters of interest for consumption was taken into account, considering that pepper plants can have dual purposes. The descriptors established by the International Plant Genetic Resources Institute for the genus *Capsicum* were taken as a base (IPGRI, 1995). 11 characteristics of plant, flower and fruit were evaluated: PH-plant height (cm); SL-stem length (cm); SD-stem diameter (mm); CAD-canopy diameter (cm); CORD-diameter of the corolla (mm); FW-fruit weight (grams); FL-fruit length (mm); FD-fruit diameter (mm); TP-thickness of the pericarp (mm); FM-fruit fresh matter (grams); DM – fruit dry matter (grams).

Table 1. List of the 29 evaluated genotypes of *Capsicum annuum*.

number of genotypes	common name
1	NuMex Big Jim 1
2	NuMex Big Jim 2
3	NuMex Conquistador 1
4	NuMex Conquistador 2
5	NuMex Espanola Improved 1
6	NuMex Espanola Improved 2
7	NuMex Joe E Parker 1
8	NuMex Joe E Parker 2
9	NuMex Mirasol 1
10	NuMex Mirasol 2
11	NuMex New México 6-4 1
12	NuMex New México 6-4 2
13	NuMex Sandia 1
14	NuMex Sandia 2
15	NuMex Sweet 1
16	BGH 1039
17	BGH 7073
18	MG 302
19	Calypso
20	Cayenne
21	*Guaraci Cumari do Pará*
22	Jamaica Red
23	Jamaica Yellow
24	Peter
25	*Pimenta Doce Italiana*
26	*Pimenta Doce Comprida*
27	*Pimenta Amarela Comprida*
28	*Picante para Vaso*
29	*Vulcão*

Estimates of genetic parameters

The statistical analyses were processed using the SELEGEN-REM/BLUP software (Resende, 2007). The mixed model for a completely randomized design was used (model 83):

$$Y=Xu+Zg+e$$

Where: Y = data vector; u = scalar referring to the overall mean (assumed as fixed); g = vector of genotypic effects (assumed as random); e = vector of residue (random). The uppercase letters X and Z, represent the incidence matrices for these effects.

Factor analysis

The orthogonal factorial model was used (Johnson & Wichern, 2007):

$$Y_i-\mu_i=\gamma_{i1}F_1+\gamma_{i2}F_2+\dots+\gamma_{im}F_m+\varepsilon_i$$

Where: Y_i - represents the observable variables with mean μ_i, i=1,2,...,p e $m \leq p$, and m ≤ p, in which p is the number of observable variables; The elements γ_{ij} - refer to the factor loads associated with the ith variable Y_i and the jth common factor; F_j, j = 1,2, ... m. Fj -corresponds to common unobservable latent factors; ε_i are the random errors associated with the ith variable Y_i.

Multitrait index based on factor analysis and genotype-ideotype distance (FAI-BLUP index)

This method combines factor analysis and proposition of ideotypes in order to explore the covariance between the characteristics. The ideotype is defined based on the combination of desirable factors in the selection (Rocha, et al. 2018). With the objective of designing the specific ideotype for ornamentation, the standard values were for the means of the Calypso variety (genotype 19 - see Table 1), which is a very popular among ornamental peppers, grown in Brazil and other countries (Finger et al., 2015).

Calypso is indicated as a potential ornamental pepper ideotype, as it presents characteristics of interest such as vigorous seedling, small size, large flowers, small fruits and large pedicels, which are important characteristics as large pedicels highlights the flowers and fruits among the leaves (Melo et al., 2014). In addition to having edible fruits, with an upright position, contrasting with the foliage and with different colors before, during and after ripening; harmonic plant architecture (balance between plant height, stem diameter and canopy diameter) and good adaptability in pot.

After ideotypes were determined, the distances from each genotype according to ideotypes (genotype-ideotype distance) were estimated and converted into spatial probability, enabling the genotype ranking. The following algorithm was used:

$$P_{ij}=\frac{\frac{1}{d_{ij}}}{\sum_{i=1;j=1}^{i=n;j=m}\frac{1}{d_{ij}}}$$

In which: P_{ij} - Probability of the ith genotype (i = 1, 2,. . ., n) to be similar to the j^{th} ideotype (j = 1, 2,. . ., m); dij - Genotypeideotype distance from the ith genotype to the jth ideotype - based on standardized mean Euclidean distance.

The R software (R Development Core Team, 2015) was used for the estimates of genetic parameters, factor analysis and genotype-ideotype distances (spatial probability).

Predicted genetic gain related to the mean of the genotypes

The gain considering the mean of the selected individuals, using the FAI-BLUP index, in relation to the mean of all genotypes. For the calculation, the following formula was used:

$$GS_{Gen}\%=\frac{\overline{X}_S-\overline{X}_{Gen}}{\overline{X}_{Gen}}\times 100$$

In which: $GS_{Gen}\%$ - predicted genetic gain, in relation to the mean of the genotypes, in percentage terms; $\overline{X}_S$ - the mean of the selected individuals, using the FAI-BLUP index, considering selection intensity of 30%; $\overline{X}_{Gen}$ - the mean of the genotypes.

Predicted genetic gain related to the mean of the calypso variety (ideotype)

The gain considering the mean of the selected individuals, using the FAI-BLUP index, in relation to the mean of Calypso variety. The following formula was used:

$$GS_{Calypso}\%=\frac{\overline{X}_S-\overline{X}_{Calypso}}{\overline{X}_{Calypso}}\times 100$$

In which: $GS_{Calypso}\%$ - predicted genetic gain, in relation to the mean of the Calypso variety, in percentage terms; $\overline{X}_S$ - the mean of the selected individuals, using the FAI-BLUP index, considering selection intensity of 30%; $\overline{X}_{Calypso}$ - the mean of Calypso variety.

Results and Discussion

Significant genotypes effect (P < 0.05) was detected by the joint deviance analysis in the for all morpho-agronomic characteristics (Table 2). These results indicate high genetic variability among the 29 C. annuum genotypes, allowing the exploitation of this variability in pepper breeding programs. Knowledge about population variability allows the selection of superior genotypes and, consequently, an increase in the favorable allelic frequency (Gonçalves et al., 2008).

Heritability values ranged from 52% to 90% (Table 2). For the characters FW, FL, FD, FM and DM, the heritability values were very high (> 80%). High heritability values indicate that most of the observed phenotypic diversity is of genetic origin (Fortunato et al., 2015). Similar results were obtained by Rosmaina et al. (2016), when evaluating morpho-agronomic traits in 16 pepper genotypes, they obtained estimates of heritability in a broad sense ranging from 54.35% for stem diameter to 99.63% for fruit length. The authors observed very high values of heritability (> 80%) for plant height, stem length, canopy width, length, diameter and weight of the fruit. On the other hand, Silva Neto et al. (2014) observed high heritability values for plant and flower characteristics: plant height (92,87%), canopy diameter (96,14%), stem length (94,05%), stem diameter (99,49%) and length of the corolla (85,61%), when analyzing 10 morpho-agronomic characters of a base population of ornamental pepper trees (*Capsicum annuum* L.).

Table 2. Estimates of V_g: genotypic variance, V_e: residual variance, V_f: individual phenotypic variance, $h^2_g = h^2$: heritability of individual plots in the broad sense, that is, of the total genotypic effects, CV_g%: coefficient of genotypic variation, CV_e%: coefficient of residual variation, $CV_r\% = CV_g/CV_e$: coefficient of relative variation. For plant, flower and fruit characters of the 29 genotypes of *C. annuum* evaluated.

genetic components	PH	SL	SD	CAD	CORD	FW	FL	FD	PT	FM	DM
V_g	117.78*	64.22*	0.37*	37.32*	22.31*	164.01*	1471.86*	86.71*	0.46*	153.43*	2.38*
V_e	98.71	38.79	0.22	33.84	8.40	26.86	224.02	9.11	0.21	23.82	0.56
V_f	216.49	103.01	0.59	71.16	30.71	190.87	1695.88	95.82	0.67	177.25	2.94
h^2_g	0.54	0.62	0.63	0.52	0.73	0.86	0.87	0.90	0.69	0.87	0.81
accuracy	0.74	0.79	0.79	0.72	0.85	0.93	0.93	0.95	0.83	0.93	0.89
CV_{gi}%	19.51	28.19	10.32	15.87	21.64	83.79	53.55	41.87	36.90	85.41	75.58
CV_e%	17.87	21.92	7.96	15.11	13.28	33.91	20.89	13.57	24.78	33.65	36.70
CVr%	1.09	1.30	1.29	1.05	1.30	2.47	2.56	3.08	1.49	2.54	2.06
overall mean	55.61	28.42	5.91	38.49	21.826	15.28	71.64	22.24	1.83	14.50	2.04

PH-plant height (cm); SL-stem length (cm); SD-stem diameter (mm); CAD-canopy diameter (cm); CORD-diameter of the corolla (mm); FW-fruit weight (grams); FL-fruit length (mm); FD-fruit diameter (mm); TP-thickness of the pericarp (mm); FM- fruit fresh matter (grams); DM – fruit dry matter (grams).

Selective accuracy reflects the quality of information and procedures used to predict genetic values. The higher the value of the accuracy of the genotype, the greater the confidence in the evaluation and in the predicted genetic value of the individual (Pimentel et al., 2014). The results of corolla diameter (CORD), fruit weight (FW), fruit length (FL), fruit diameter (FD), thickness of the pericarp (TP), dry matter (DM) and fresh matter (FM) stand out with expressive values of accuracy and heritability. These high values of selective accuracy and heritability indicate high precision of selection and therefore great possibilities for success and gains with selection.

The coefficients of genetic variation (CVg) ranged from 10.32% to 85.41%. In particular, FW (83,79%) and FM (85,41%) showed high CVg values. This coefficient quantifies the magnitude of the genetic variation available in the selection, where high values are desirable. Variability is a precondition in the establishment of any genetic improvement program; however, the efficiency of the selection of superior genotypes will depend on genetic and environmental parameters related to the characters of interest (Blind et al., 2018).

The CVr values obtained in the experiment were greater than 1 in most characters, which indicates that the genetic variation between the genotypes is greater than the environmental variation (Pimentel et al., 2014). The same results can be observed in some studies with genus *Capsicum*. Nascimento et al. (2012) when evaluating 11 quantitative morpho-agronomic characteristics of 55 C. annuum genotypes, observed CVe values between 3.30% (canopy width) and 86.81% (leaf length), CVg between 8.35% (corolla length) and 28.65% (stem diameter), and CVr values, mostly, greater than 1. Rêgo et al. (2011) in a study with Capsicum baccatum found CVg/CVe values greater than 1 for all evaluated characteristics. High coefficients of genetic variation and heritability are the main requirements for genetic gain and greater response to the selection of individuals (Falconer & Mackay, 1996). As showed on this work, the evaluated genotypes have a great potencial for selection for ornamentation and possible gains with the selection.

The eigenvalues and the accumulated variance of the 11 principal components were obtained from the genetic correlation matrix (Table 3). Only the first three components are associated with eigenvalues that are greater than one. Thus, according to Kaiser's criteria (Kaiser, 1958), the data can be condensed into three factors. The accumulated variance of the first three components was greater than 80%, indicating that these three factors are sufficient because they represent 85.15% of all variability.

Table 3. Eigenvalue estimates by principal components analysis and the variance proportion explained by them.

eigenvalues	eigenvalue (%)	accumulated variance (%)
6.36	57.89	57.89
1.79	16.27	74.16
1.20	10.98	85.15
0.52	4.78	89.93
0.44	4.00	93.93
0.26	2.39	96.33
0.16	1.48	97.81
0.14	1.30	99.11
0.05	0.50	99.62
0.04	0.37	99.99
0.00	0.002	100.00

After varimax rotation (Table 4), high genetic correlation for the first factor was observed among the traits, fruit weight, fruit length, fruit diameter, thickness of the pericarp, fresh matter, dry matter, diameter of the corolla, and this factor was named “fruit quality”. For the second factor, high genetic correlation was observed among plant height and stem length, and it was named "plant size". The third factor was named by "plant architecture", and canopy diameter and stem diameter are strongly correlated. Genetic correlations among traits within a factor can be given in the same and/or opposite direction.

Table 4. Factorial loadings after varimax rotation and communalities.

	fruit quality	plant size	plant architecture	commonality
FW	-0.9574	-0.0573	-0.1458	0.9412
FL	-0.9219	0.0741	-0.1572	0.8802
FD	-0.9144	-0.0831	-0.0953	0.8521
TP	-0.8793	-0.0434	-0.1087	0.7868
FM	-0.9554	-0.0582	-0.1502	0.9388
DM	-0.945	0.033	-0.2166	0.9411
CORD	-0.7629	0.189	-0.148	0.6396
PH	0.1932	-0.8752	0.163	0.8299
SL	-0.1505	-0.9095	-0.096	0.8592
SD	-0.4469	-0.2713	-0.7419	0.8238
CAD	0.0541	-0.2138	0.9167	0.8891

FW-fruit weight (grams); FL-fruit length (mm); FD-fruit diameter (mm); TP-thickness of the pericarp (mm); FM- fresh matter (grams); DM – Dry matter (grams); CORD-diameter of the corolla (mm); PH-Plant Height (cm); SL-stem length (cm); SD-stem diameter (mm); CAD-Canopy diameter (cm).

By using the values referring to the means of the characteristics of the cultivar Calypso, chosen in the present study as an ideotype for ornamentation, and the scores of the factor analysis, the FAI-BLUP index was calculated allowing the classification of the genotypes. Based on the genotype-ideotype distance, nine genotypes (2, 5, 14, 15, 16, 17, 27, 28 e 29 - see Table 1) were selected for showing means closer to those of the Calypso ideotype, for all evaluated characteristics.

According to Donald (1968), the ideotype can be defined as a model plant with a set of characteristics that can lead to high performance. Therefore, the creation of an ideotype focuses on several characteristics simultaneously. The genetic improvement of plants seeks an ideotype that contains all the characteristics of agronomic interest and allows the achievement of a final target for selection, replacing the trial and error method of gradually increasing the performance of the plant as a consequence (Rocha et al., 2018).

In order to develop new cultivars for the ornamental pepper tree market, Silva et al. (2017) selected hybrids based on an estimated ideotype. Such ideotype consisted of small plants (up to 30 cm), precocious in relation to the days until flowering and fruiting and a high number of fruits per plant. On the other hand, Hapshoh et al. (2016) when studying the qualitative inheritance of characters associated with shortening of internodes, fruit orientation and anthocyanin content, using six populations of ornamental pepper, determined an ideotype with shortened internodes that form a bouquet of flowers, with upright fruits with anthocyanins for a more attractive appearance.

Considering the nine individuals selected through the FAI-BLUP index, predicted gains were calculated in relation to the average of all evaluated genotypes and in relation to the average of the Calypso ideotype. As for the average of the genotypes, a negative genetic gain was observed for all traits. As a consequence, the selection for these characteristics results in their reduction. Regarding the ideotype, the gains were positive for most of the characters, except SD, CAD, FD and TP (Table 5).

Table 5. Selection gains obtained for 11 characteristics of *C. annuum* pepper plants where X_s - Means of individuals selected using the FAI-BLUP index, considering selection intensity of 30%; X_{id} – Means of the ideotype; X_{pop} - Population means; $GS_{id}\%$ - Gains by selection, in percentage terms, of the individuals selected in relation to the ideotype; $GS_{pop}\%$ - Gain by selection, in percentage terms, of the individuals selected in relation to the population.

	PH	SL	SD	CAD	CORD	FW	FL	FD	TP	FM	DM
X_s	46.52	21.78	5.66	36.87	20.81	9.27	55.01	17.75	1.64	8.77	1.35
X_{id}	30.89	12.66	6.01	37.23	17.84	3.64	26.04	19.26	2.09	3.30	0.49
X_{Gen}	55.61	28.42	5.91	38.49	21.83	15.28	71.64	22.24	1.83	14.50	2.04
$GS_{id}\%$	50.58	72.11	-5.82	-0.96	16.64	154.65	111.28	-7.83	-21.48	165.66	178.85
$GS_{Gen}\%$	-16.35	-23.37	-4.32	-4.20	-4.66	-39.34	-23.21	-20.16	-10.37	-39.56	-33.74

PH-Plant height (cm); SL-stem length (cm); SD-stem diameter (cm); CAD-canopy diameter (cm); CORD-corolla diameter (cm), FW-fruit weight (grams); FL-fruit length (cm); FD-fruit diameter (cm); TP-thickness of the pericarp (cm); FM- fruit fresh matter (grams); DM – fruit dry matter (grams).

Stem length and plant height are characters of great importance in the ornamental market, since small size genotypes allow cultivation in smaller containers without compromising the growth and development of the plant. Medium to high size genotypes can be used for landscaping, cultivation in gardens such as medicinal, aromatic and condiment gardens (Neitzke et al., 2010). In the selected individuals, there was a reduction of 8.2 cm for plant height and 6.42 cm for stem length, when compared to the average of the genotypes. Regarding the ideotype, the gain was 50.58% for plant height and 72.11% for stem length. Selection based on the ideotype would imply in higher plants, which is not interesting for ornamentation. This was because no selected genotype is shorter than the ideotype. The average of the selected is 46.52 cm while the Calypso ideotype is 30.89 cm.

The commercial success of ornamental plants grown in pots is mainly associated with the proportion, in volume, of the plant with the container used. According to Barbosa et al. (2002) the relationship between canopy width, plant height and pot size are important for plant harmony. The canopy (CAD) and stem (SD) diameters are relevant characteristics in the plant architecture. The SD should be sufficient to bear the weight of the plant and the fruits, since plants with very thin stems tend to lodging and lose their commercial value (Silva Neto et al., 2014). There was no gain in the SD due to the reduction in the diameter value, both in relation to the population (-4.32%) and in relation to the ideotype (-5.82%). Considering a more compact and harmonic plant for ornamentation, the ideal would be a reduction of the diameter of the canopy as observed in relation to the population and the ideotype.

The mean value of the corolla diameter was reduced from 21.83 mm to 20.87 mm (gain of -4.6%) regarding the mean of the genotypes. In relation to the mean of the ideotype, the gain was positive (16.64%), which would result in an increase in the CAD. According to Nascimento et al. (2015), larger flowers are preferable because they provide beauty to the plant, standing out among the foliage, looking more attractive and pleasant to the consumer. Santos et al. (2013) reported that the selection of plants with large flowers has potential for use in ornamental pepper breeding programs.

As for the weight, length and diameter of the fruit, the gains were -39.97%, -21.30% and -20.16% respectively, in relation to the population mean. In relation to the mean of the ideotype, the gains were positive for weight and length (154.65% for FW and 111.28% for FL) and negative for diameter (-7.83%). According to Bento et al. (2007), regarding the market of ornamental plants, the preference for plants with shorter length and diameter of the fruit was observed. The diameter associated with the length is important in harmonizing the fruits with the plant size. Lighter-weight and shorter- length fruits are ideal for ornamental purposes due to the small size of the plants. In addition, they indicate a greater possibility of obtaining erect fruits, more prominent in the foliage (Silva et al., 2015). Broad and long fruits are generally more attractive to the fresh pepper market (Cardoso, 2018). Thus, selection to reduce these characters is more appropriate.

Ornamental pepper fruits are of great value mainly for their dual purpose. Besides, they can be used for consumption in addition to granting beauty to them. This characteristic has added value to pepper plants, configuring itself as another way to increase the financial return for the producer (Rêgo & Rêgo, 2016). In view of this, the study of fruit characters such as pericarp thickness, fresh matter and dry matter, becomes interesting.

For the characteristic thickness of pericarp, the gain was -10.37% in relation to the population and -21.48% in relation to the ideotype, therefore selection for this character results in its reduction. Thinner fruits are more suitable for industry, as they can be used in processing due to the higher content of soluble solids, in addition to requiring less energy inputs in dehydration for the production of paprika. Fruits with thick pericarp are more suitable for fresh consumption, as they are more resistant to physical damage during handling and have a fresher appearance (Lannes et al., 2007).

According to Lannes et al. (2007), there is a positive linear correlation between the thickness of the pericarp and the fresh matter content of the fruit, which is important for the selection of varieties more appropriate for the consumption of fresh fruits. Fruits with a higher dry matter content have a higher content of soluble solids, a characteristic of interest mainly for fruits consumed in their fresh form (Conti et al., 2002). The gains for the contents of fresh matter (-39.56%) and dry matter (-33.74%) were negative in relation to the population and positive in relation to the ideotype (165.66% for FM and 178.85% for DM). Selection based on the ideotype to increase these characters is preferable, as fruits with higher dry matter and fresh matter content are more attractive for fresh consumption.

In view of the gains for most characters, the selected genotypes are the most recommended for crossing both with the evaluated genotypes and with the ideotype. Hybridization, an improvement method, is widely used in peppers in the development of new cultivars (Nascimento et al., 2015). Crossing with the ideotype is the best recommendation as it allows improving and adding new characteristics and increasing variability while maintaining the existing ideal characters (Rocha et al., 2018).

Conclusions

Variability and possibility of gains by means of selection were predicted in the desirable direction in all the measured traits.

Based on the FAI-BLUP index, nine genotypes with greater performance in terms of ornamental use were selected.

The selected genotypes showed gains for most characters evaluated.

References

Barbosa, R.I., Luz, F.J.F., Nascimento-Filho, H.R., Maduro, C.B. 2002. Capsicum peppers cultivated in Roraima, Brazilian Amazonia. I. Domestic species. *Acta Amazônica* 32: 177-132.

Bento, C.S., Sudré, C.P., Rodrigues, R., Riva, E.M., Pereira, M.G. 2007. Descritores qualitativos e multicategóricos na estimativa da variabilidade fenotípica entre acessos de pimentas. *Scientia Agraria* 8: 147-154.

Blind, A.D., Valente, M.S.F., Lopes, M.T.G., Resende, M.D.V. 2018. Estimativa de parâmetros genéticos, análise de trilha e seleção em bucha vegetal para caracteres agronômicos. *Revista Brasileira de Ciências Agrárias* 13: 1-8.

Cardoso, R., Ruas, C.F., Giacomin, R.M., Ruas, P.M., Ruas, E.A., Barbieri, R.L., Rodrigues, R., Goncalves, L.S.A. 2018. *Genetic variability in Brazilian Capsicum baccatum germplasm collection assessed by morphological fruit traits and AFLP markers*. *PloS one* 13: 1-15.

Conti, J.H., Minami, K., Tavares, F.C.A. 2002. Produção e qualidade de frutos de morango em ensaios conduzidos em Atibaia e Piracicaba. *Horticultura Brasileira* 20: 10-17.

Costa, G., Nascimento, D., Silva, B., Lopes, Â.C.D.A., Carvalho, L.C.B., Gomes, R.L.F. 2019. Selection of pepper accessions with ornamental potential. *Revista Caatinga* 32: 566-574.

Donald, C.M. 1968. The breeding of crop ideotypes. *Euphytica* 17: 385-403.

Falconer, D.S., Mackay, T.F.C. 1996. *Introduction to quantitative genetics*. Longman Group Limited, Edinburgh, UK. 365 p.

Finger, F.L., Silva, T.P., Segatto, F.B., Barbosa, J.G. 2015. Inhibition of ethylene response by 1-methylcyclopropene in potted ornamental pepper. *Ciência Rural* 45: 964-969.

Fortunato, F.L.G., Rêgo, E.R., Rêgo, M.M., Pereira dos Santos, C.A., Carvalho, M.G. 2015. Heritability and Genetic Parameters for Size-Related Traits in Ornamental Pepper (*Capsicum annuum* L.). *Acta Horticulturae* 1087: 201-206.

Gonçalves, L.S.A., Rodrigues, R., Amaral Júnior, A.T., Karasawa, M., Sudré, C.P. 2008. Comparison of multivariate statistical algorithms to cluster tomato heirloom accessions. *Genetics Molecular Research* 7: 1289-1297.

Hapshoh, S., Syukur, M., Wahyu Y. 2016. Pewarisan Karakter Kualitatif Cabai Hias Hasil Persilangan Cabai Besar dan Cabai Rawit. *Indonesian Journal of Agronomy* 44: 286-291.

IPGRI. 1995. *Descriptores para Capsicum (Capsicum spp)*. IPGRI, Roma, Italy. 110 p.

Johnson, R.A., Wichern, D.W. 2007. *Applied Multivariate Statistical Analysis*. Prentice Hall, New Jersey, USA. 773 p.

Kaiser, H.F. 1958. The varimax criterion for analytic rotation in factor analysis. *Psychometrika* 23: 187-200.

Lannes, S.D., Finger, F.L., Schuelter, A.R., Casali, V.W.D. 2007. Growth and quality of Brazilian accessions of *Capsicum chinense* fruits. *Scientia Horticulturae* 112: 266-270.

Melo, L.F., Gomes, R.L.F., Silva, V.B., Monteiro, E.R., Lopes, A.C.A., Peron, A.P. 2014. Potencial ornamental de acessos de pimenta. *Ciência Rural* 44: 2010-2015.

Nascimento, N.F.F., Rêgo, E.R., Nascimento, M.F., Finger, F.L., Bruckner, C.H., Neto, J.J.S., Rêgo, M.M. 2012. Heritability and Variability of Morphological Traits in a Segregating Generation of Ornamental Pepper. *Acta Horticulturae* 953: 299-304.

Nascimento, M.F., Nascimento, N.F.F., Rêgo, E.R., Bruckner, C.H., Finger, F.L., Rêgo, M.M. 2015. Genetic Diversity in a Structured Family of Six Generations of Ornamental Chili Peppers (*Capsicum annuum*). *Acta Horticulturae* 1087: 395-402.

Neitzke, R.S.; Barbieri, R.L.; Rodrigues, W.F.; Correa, I.V.; Carvalho, F.I.F. 2010. Dissimilaridade genética entre acessos de pimenta com potencial ornamental. *Horticultura Brasileira* 28: 47-53.

Pimentel, A.J.B., Guimarães, J.F.R., Souza, M.A., Resende, M.D.V., Moura, L.M., Ribeiro, G. 2014. Estimação de parâmetros genéticos e predição de valor genético aditivo de trigo utilizando modelos mistos. *Pesquisa Agropecuária Brasileira* 49: 882-890.

R Development Core Team. R: A Language and Environment for Statistical Computing. 2015. https://www.r-project.org/<Access in 26 Ago. 2020>

Rêgo, E.R., Rêgo, M.M., Cruz, C.D., Finger, F.L., Casali, V.W.D. 2011. Phenotypic diversity, correlation and importance of variables for fruit quality and yield traits in Brazilian peppers (*Capsicum baccatum*). *Genetic Resources and Crop Evolution* 58: 909-918.

Rêgo, E.R., Rêgo, M.M. 2016. Genetics and breeding of chili pepper *Capsicum* spp. In: Rêgo, E.R., Rêgo, M.M., Finger, F.L. (ed). *Production and Breeding of Chilli Peppers (Capsicum spp.)*. Springer International Publishing, Gewerbestrasse, Switzerland. p. 1-129.

Resende, M.D.V. 2007. *Selegen-REML/BLUP: Sistema estatístico e seleção genética computadorizada via modelos lineares mistos.* Embrapa Florestas, Colombo, Brazil. 359 p.

Rocha, J.R.A.S.C., Machado, J.C., Carneiro, P.C.S. 2018. Multitrait index based on factor analysis and ideotype-design: proposal and application on elephant grass breeding for bioenergy. *Global Change Biology Bioenergy* 10: 52-60.

Rosmaina, H., Syafrudin, F., Hasrol, T.H., Yanti, F., Juliyanti, K.H., Zulfahmi, K.F. 2016. Estimation of variability, heritability and genetic advance among local chili pepper genotypes cultivated in peat lands. Bulgarian Journal of Agricultural Science 22: 431-436.

Santos, R.M.C., Nascimento, N.F.F., Borém, A., Finger, F.L., Carvalho, G.C., Nascimento, M.F., Lemos, R.C., Rêgo, E.R., Rêgo, M.M. 2013. Ornamental pepper breeding: could a chili be a flower ornamental plant? *Acta Horticulturae* 1000: 451-456.

Silva Neto, J.J.D., Rêgo, E.R., Nascimento, M.F., Silva Filho, V.A.L., Almeida Neto, J.X., Rêgo, M.M. 2014. Variabilidade em população base de pimenteiras ornamentais (*Capsicum annuum* L.). *Revista Ceres* 61: 84-89.

Silva, C.Q., Jasmim, J.M., Santos, J.O., Bento, C.S., Sudré, C.P., Rodrigues, R. 2015. Phenotyping and selecting parents for ornamental purposes in chili pepper accessions. *Horticultura Brasileira* 33, n.1, p.66-73.

Silva, C.Q., Rodrigues, R., Bento, C.S., Pimenta, S. 2017. Heterosis and combining ability for ornamental chili pepper. *Horticultura Brasileira* 35: 349-357.

Silva, N.C.N., Ferreira, W.L., Cirillo, M.A., Scalon J.D. 2014. O uso da análise fatorial na descrição e identificação dos perfis característicos de municípios de Minas Gerais. *Revista Brasileira de Biometria* 32: 201-215.

Conflict of Interest Statement: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.