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TESTING ORNAMENTAL CHILI PEPPER PRE-CULTIVARS

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Abstract: There is a wide new frontier for science and innovation in agriculture, including new cultivars development. Ornamental plants in Brazil represent an open market that should be targeted by breeders, since it has become a profitable alternative for agribusiness, thus demanding the development of new genotypes to attend both growers and consumers. Twelve chili peppers genotypes were characterized in relation to morphoagronomic characteristics, as well as to acceptance and preference of consumers. Plants were grown in a greenhouse using randomized block design. Sixteen qualitative and thirteen quantitative descriptors related to ornamental purposes were considered. At the beginning of fruit maturation, three plants of each genotype were exposed to consumers' evaluation to assess their acceptance and preferences. Structured queries were applied individually to 89 people in order to determine their perceptions regarding the ornamental peppers. All genotypes have met the established standards for ornamental peppers: compact and erect plants, erect and intense colored fruits. Nevertheless, consumers sensorial perception was highly variable. The highest preference scores were attributed to HPO 03 (hybrid) and to PIMOR 05 (pure line). These two genotypes have some traits in common, such as short internodes, bright and intense fruit color and larger canopy diameter. All evaluated genotypes are promising for potting and have potential to be registered and protected. HPO 03 and PIMOR 05 were the most preferred by consumers. HPO 12 has great flowering potential to explore differing from most cultivars available in the market. HPO 04 can be indicated for cultivation in gardens and hanging gardens.

Keywords: *Capsicum annuum* L., ornamental plant breeding, phenotyping.

Introduction

Capsicum plants have conquered the ornamental market, representing an alternative for fruit and foliage use, especially for small farmers. Nowadays, cultivation of potted chili peppers is very popular, with increasing and continuous acceptance in the consumer market, parallel to the expanding performance of the flower and ornamental plants sector, especially of the bottled plants (Junqueira and Peetz, 2014). In Brazil, this market grossed approximately R$ 7.2 billion in 2017, accumulating an average annual growth of 9%. Rio de Janeiro state, one of the main national producers, accounts for about 11% of the sector annual revenues (IBRAFLOR, 2017).

The sales of flowers and ornamental plants through self-service retail (supermarkets and garden centers), among other factors, have contributed to the popularization and growth of the flower trade throughout Brazil, with good prospects for the next few years. This expansion is accompanied by an increase in the number of producers, growth of the area under cultivation, diversification of cultivated species, and specialization of the labor force (SEBRAE, 2015). Ornamental plants are a profitable alternative for micro and small farmers which generates new employments, income and incorporates the rural women (Stommel and Bosland, 2007; Junqueira and Peetz, 2014).

Ornamental peppers success is due to the compact architecture of the plants, the presence of intense colored fruits in contrast with the foliage (Carvalho et al., 2006), and the ease of cultivation and durability (Stommel and Bosland, 2007). In this scenario, breeding programs have been required to meet the demand for new products. Horticulturists have required varieties more suited to regional tastes and cultures (SEBRAE, 2015), and more adapted to Brazilian conditions, since most of the cultivars available in the market come from breeding programs conducted outside the country (Neitzke et al., 2010; Luz et al., 2018).

Brazil is considered to be one of the main diversity centers of the genus *Capsicum*, being wild and domesticated species being a valuable part of national biodiversity, with many varieties of types, sizes, colors and pungency (Barboza et al., 2011). This diversity offers countless possibilities to be explored in breeding programs, with opportunities to develop cultivars with unique characteristics (Stommel et al., 2018).

An important challenge is to implement cultivars that meet consumer preferences. In this sense, the acceptance study is a fundamental step in the development and improvement process; and breeders ought to use this tool to investigate the new product potential (Schimmenti et al., 2013). Based on the results of this analysis, it is possible to measure, evaluate and interpret the sensory perception regarding the analyzed products, thus increasing the chances of success in the development and releasing of a cultivar. However, in Brazil, few studies have evaluated the consumer market perception of ornamental plants (Neitzke et al., 2016).

Herein, we report the evaluation of 12 chili pepper ornamental pre-cultivars developed from *Capsicum* breeding program, taking the morphoagronomic performance and the Brazilian consumer preferences into account.

Material and methods

Genotypes

The study was carried out with twelve genotypes of *C. annuum* from the *Capsicum* Breeding Program (Figure 1), with six parents (PIMOR 01, PIMOR 02, PIMOR 03, PIMOR 04, PIMOR 05 and PIMOR 06) and six hybrids (HPO 02, HPO 03, HPO 04, HPO 07, HPO 08 and HPO 12). These genotypes were selected based on preliminary studies performed by Silva et al. (2017) for presenting small plants with erect flowers and fruits; and whose fruits have a red coloration, in the last ripening stage, among other characteristics (Table 1). The cultivars 'Pirâmide ornamental' and 'Espaguetinho ornamental', from *ISLA Sementes Ltda*, were used as control.

Experimental conditions

The experiment was carried out in a greenhouse, by using a randomized block design with 14 treatments (six parents, six hybrids and two commercial cultivars) and four replications, being one plant per pot. The genotypes were seeded in polystyrene trays with 128 cells containing commercial substrate and transplanted when the seedlings reached six true leaves on average.

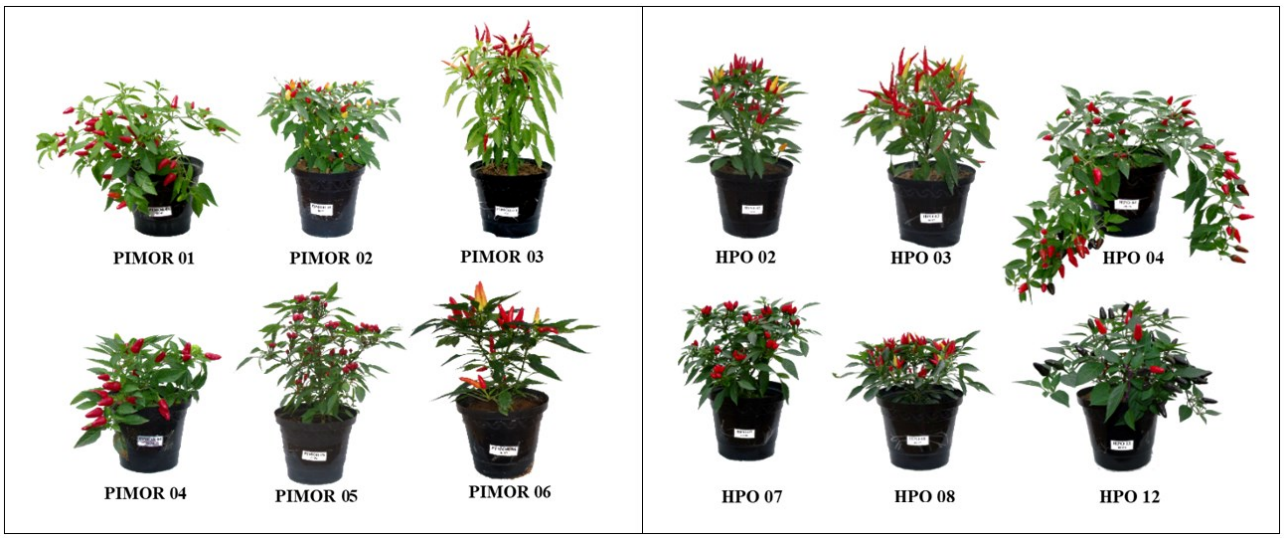

Figure 1. A) Parents and B) Hybrids of ornamental pepper breeding program.

Table 1. Characteristics of parents (PIMOR) and hybrids (HPO) of *Capsicum annuum* L. with ornamental potential.

Genotypes	Days to flowering	Plant height (cm)	Fruit length (cm)	Fruit width (cm)
PIMOR 01	50	43.3	2.91	1.41
PIMOR 02	51	53.3	2.11	1.05
PIMOR 03	51	51.5	3.91	0.98
PIMOR 04	48	32.6	2.96	1.81
PIMOR 05*	47	37.9	1.13	0.79
PIMOR 06	44	35.0	3.43	1.47
HPO 02	52	23.0	3.01	1.01
HPO 03	49	24.7	5.03	1.06
HPO 04	47	26.9	2.62	1.26
HPO 07	49	21.1	1.69	0.94
HPO 08	50	22.0	2.65	0.91
HPO 12	49	22.3	2.90	1.29

**Capsicum annuum* var. glabriusculum. *Source: Silva et al. (2017).*

The seedlings were transferred to 2 L plastic pots, containing a mixture of soil, washed sand and bovine manure in a ratio of 1: 1: 1. Soil fertility correction was carried out according to previously performed soil analysis and the recommendation of chemical fertilization for the crop, according to the fertilization manual for the state of Rio de Janeiro (Freire, 2013). Irrigation was performed once a day with water replenishment according to water demand. Each plot was constituted by six plants, totaling 336 plants evaluated. The planting and management conditions adopted were similar to those recommended for the production of ornamental plants for potting, according to *Cooperativa Veiling Holambra* (2020).

Morphoagronomic characterization

Taking into account the ornamental potential, the fourteen genotypes were characterized by means of qualitative and quantitative descriptors. These were proposed by the International Plant Genetic Resources Institute for *Capsicum* (IPGRI, 1995), as well as the ones established for cultivar protection policies in Brazil - *Serviço Nacional de Proteção de Cultivares* (Brasil, 2006).

Sixteen qualitative and thirteen quantitative descriptors were considered: plant height - PHG (cm); stem length - SLG (cm); stem diameter - SDT (mm); canopy diameter - CDT (cm); leaf length - LLG (mm); leaf width - LWD (mm); fruit length - FLG (cm); fruit width - FWD (cm); fruit

mass - FWG (g); number of locules – NLC; pedicel length - PLG (cm); total number of fruits – NTF; and 1000-seed mass - SWD (g) (Table 2).

All experimental plot plants were characterized. For the qualitative descriptors, the data were obtained from the modes of observation of five leaves and five fruits in each plant. In case any of these presented polymorphism, they were submitted to divergence analysis. The genetic distance matrix was obtained by the Simple Coincidence method; whereas the Ward method was employed for grouping.

As for the quantitative traits, the mean values of the experimental plot for each descriptor were considered, each plant comprising five leaves and five fruits. The obtained means were submitted to analysis of variance and grouped according to Scott-Knott algorithm (1974). The graphical visualization of the genetic divergence derived from the dispersion of the first two principal components. The analyses were performed using the R (http://www.r-project.org) and Genes (Cruz, 2013) softwares.

Table 2. Qualitative descriptors used in the characterization of ornamental peppers genotypes of the breeding program.

Descriptors	Classes
Plant growth habit	3-prostrate; 5-intermediate; 7-erect; 9-other
Stem colour	1-green; 2-green with purple stripes; 3-purple;
Short internodes (at the top)[1]	1-absent; 2-present
Anthocyanin pigmentation at node[1]	1-absent/very weak; 3-weak; 5-medium; 9-very strong
Leaf colour	1-yellow; 2-light green; 3-green; 4-dark green; 5-light purple; 6-purple; 7-variegated; 8-other
Leaf shape	1-deltoid; 2-ovate; 3-lanceolate
Leaf variegation	1-absent; 2-present
Leaf pubescence	1-absent; 3-esparse; 5-intermediate; 7-dense
Leaf roughness[1]	1-absent; 3-weak; 5-medium; 7-strong
Corolla colour	1-white; 2-light yellow; 3-yellow; 4-yellow-green; 5-purple with white base; 6- white with purple base; 7-white with purple margin; 8-purple; 9-other
Anther colour	1-white; 2-yellow; 3-pale blue; 4-blue; 5-purple
N° of maturation stages[1]	1-one; 2-two; (…); 7-seven; 8-eight or more
Fruit shape	1-elongate; 2-almost round; 3-triangular; 4-campanulate; 5-blocky; 6-other
Fruit surface	1-smooth; 2-semiwrinkled; 3-wrinkled
Fruit brightness[1]	1-weak; 2-medium; 3-strong
Fruit colour intensity[1]	1-light; 2-medium; 3-dark

[1] Characteristics evaluated according to Brasil (2006). All others were evaluated according to IPGRI (1995).

Consumer acceptance and preference evaluation

At the beginning of the fruiting season, which corresponds to the stage considered suitable for commercialization (*Cooperativa Veiling Holambra*, 2020), a plant of each one of the fourteen genotypes was selected to be displayed to the interviewees whose consuming preferences were to be assessed. The plants were placed in areas of easy visualization, on a bench, in spaces of expressive circulation of people, and coded from A to N so as to avoid confusion.

The passers-by who showed interest in the plants displayed, were invited to participate in the research. Through a structured questionnaire the gender and age of the interviewees were recorded; then they were asked whether they had already bought or would consider buying ornamental peppers. The interviewees were asked to indicate in order of preference and rejection two ornamental peppers plants, among those presented, combined with their preference regarding the fruit color and shape. The interviews were carefully transcribed for exploratory analysis and inferences.

Results and discussion

Qualitative characteristics

Considering the demand of the ornamental sector for the development of new cultivars, the present study evaluated *C. annuum* genotypes which are promising for pot cultivation by means of the most relevant morphoagronomic descriptors for the characterization of peppers with ornamental purpose. Out of the sixteen (16) qualitative descriptors assessed, only pubescence, roughness and variegation in leaves were monomorphic. These three descriptors were absent in all genotypes.

As for the growth habit, four genotypes, including the two commercial cultivars, were classified as intermediate (PIMOR 06, HPO 08, 'Espaguetinho ornamental' and 'Pirâmide ornamental'); the others depicted erect growth habit. These two classes are desirable for the ornamental market. Intermediate growth plants tend to be shorter and therefore more adapted to potting, whereas erect growing plants are more showy, resulting in greater harmony with the canopy diameter and the pot (Silva et al., 2015).

Most genotypes showed green stem color. The exception included the 'Pirâmide ornamental' and all hybrids in which the parent was PIMOR 05 (HPO 04, HPO 07 and HPO 12), which exhibited the green stem with purple stripes. Variation was shown in anthocyanin pigmentation at the nodes. The classes ranged from absent (PIMOR 04); weak (PIMOR 01 and HPO 08); medium (PIMOR 02, PIMOR 03, PIMOR 06, HPO 02, HPO 03, HPO 04, HPO 07 and HPO 12); and very strong (PIMOR 05 and PIMOR 07). The presence of stripes and purple pigmentations on the plant stems are characteristics that differentiate the genotypes and increase aesthetic value (Neitzke et al., 2010; Silva et al., 2015).

Leaf coloration also contributes to the attractiveness of the genotypes, as it directly affects their contrast to the fruits. It was observed the occurrence of plants with all shades of green, from light to dark. Lanceolate-shaped leaves were characteristic of most plants, except for PIMOR 05 and HPO 07 which presented oval leaves.

As a feature of *C. annuum* species, all genotypes exhibited white corolla flowers. The PIMOR 05, an unique evaluated genotype of *C. annuum* var. *glabriusculum* showed purple corolla and anther. HPO 04, HPO 07 and HPO 12 hybrids wich had PIMOR 05 as parent, exhibited white corolla with purple margins and purple anthers. These traits make such genotypes unique and very promising for the market, once the flowers become an ornamental component along with the fruits, the period of maintenance of its ornamental aspect is extended, from the beginning of the anthesis to the end of the fruiting. The other genotypes as well as commercial cultivars had white and pale blue anthers, except for PIMOR 6, which depicted green anthers.

The fruit shape was predominantly triangular and elongated. Seven genotypes exhibited triangular shape (PIMOR 01, PIMOR 02, PIMOR 04, HPO 04, HPO 07, HPO 12 and 'Pirâmide ornamental'); six exhibited elongated shape (PIMOR 3, PIMOR 6, HPO 02, HPO 03, HPO 08 and 'Espaguetinho ornamental'); and only the parental PIMOR 05 presented oval-shape fruits. The predominance of triangular and elongated fruits was also observed by Melo et al. (2014), who evaluated the ornamental potential of peppers from the collection of the Universidade Federal do Piauí (Brazil). It is worth highlighting the presence of short internodes, observed in seven genotypes (PIMOR 02, PIMOR 03, PIMOR 05, PIMOR 06, HPO 02, HPO 03, HPO 07) (Figure 1) and the 'Espaguetinho ornamental'. This characteristic gives the impression of plants having more than one fruit per node, simulating a bouquet, leaving, then, the fruits in prominence in the floral arrangement.

According to Neitzke et al. (2016), the facts that fruits go through several colors during maturation process and the simultaneous occurrence of fruits at different stages of development, with different colors in the same plant, increase the aesthetic value of the genotypes, which should be considered as new cultivars are developed. All evaluated genotypes showed at least three maturation stages (Figure 2), i.e. they changed fruit color at least three times. The HPO 04, HPO 07 and HPO 12 hybrids and the PIMOR 05 parental showed the highest number of fruit colors with five stages, followed by the parental PIMOR 04 and the 'Pirâmide ornamental' with four maturation stages. The other genotypes showed fruits with three maturation stages. The dried fruit has ornamental value, as the color of the last stage remains until the fruit dries completely, only increasing the color intensity.

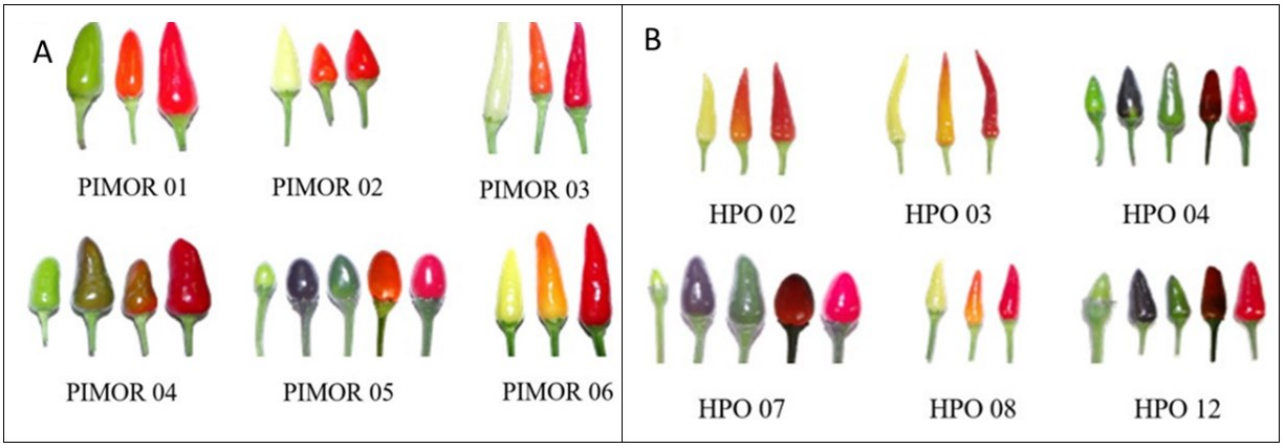

Figure 2. Number of stages of fruit maturation, observed from the initial staining of the fruit until the beginning of the senescence process. A) Parentals and B) Hybrids of ornamental pepper.

As regards fruit appearance in relation to surface texture, brightness and color intensity, hybrids HPO 04, HPO 07, HPO 12, parental PIMOR 05, and the 'Pirâmide ornamental' control had a smooth texture; whereas the others showed slightly wrinkled texture. Fruits with intense brightness and color were observed in HPO 03, HPO 04, HPO 07, HPO 12, PIMOR 03, PIMOR 04 and PIMOR 05 genotypes. The others showed fruits with medium brightness and color intensity. Thus, most hybrids exhibited smooth, bright and dark colored fruit, making them more interesting for the ornamental market.

Multivariate analysis revealed two phenotypic groups (Figure 3). The first one formed by the PIMOR 05 parental and the hybrids resulting from their crosses (HPO 04, HPO 07 and HPO 12), characterized by purple pigmentation on stems, flowers, and immature fruits, as well as fruits with intense brightness and coloring, all of them with five maturation stages, predominantly smooth and triangular. The second group assembled the other genotypes, with prevalence of the following characteristics: lanceolate leaves; flowers with white border and pale blue anthers; fruits with medium brightness and intensity of coloration; wrinkled; and with three or four stages of maturation. The genotypes PIMOR 03 and HPO 02 did not differ in relation to any qualitative descriptor studied.

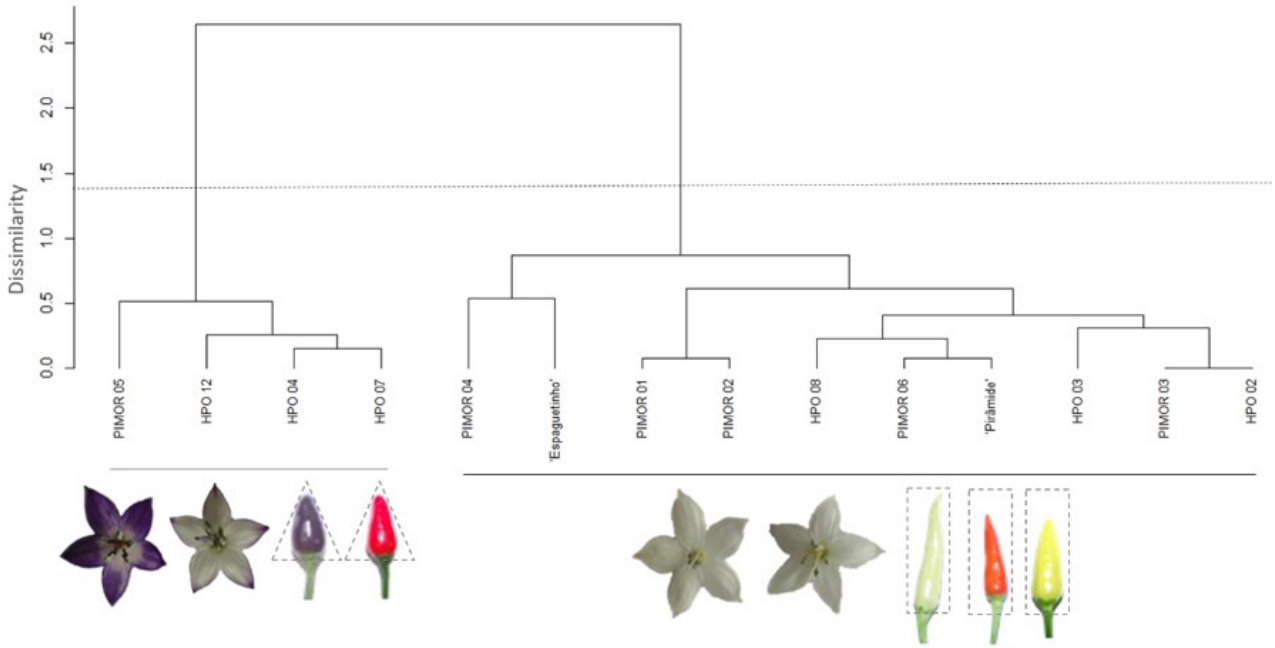

Figure 3. Dendrogram based on the dissimilarity matrix of qualitative characters of ornamental pepper genotypes of the breeding program and two commercial cultivars ('Espaguetinho ornamental' and 'Pirâmide ornamental') by the Ward method.

Quantitative characteristics

The analysis of variance showed a significant difference between the genotypes for all the quantitative traits studied; and 12 out of the 13 descriptors evaluated presented a highly significant difference ($p \leq 0.01$). The coefficient of variation (CV) values ranged from 4.41 (mean fruit width) to 18.51 (mean fruit mass) (Table 3).

Table 3. Mean values of ornamental pepper genotypes of the breeding program and two commercial cultivars regarding to twelve quantitative descriptors.

GENOTYPES	PHG (cm)	SLG (cm)	SDT (mm)	CDT (cm)	LLG (mm)	LWD (mm)
PIMOR 01	30.21c	23.45a	6.26c	34.33b	61.14a	26.31a
PIMOR 02	36.66a	22.83a	7.15a	35.83a	51.77b	22.54a
PIMOR 03	39.66a	23.29a	7.30a	29.21b	60.26a	25.21a
PIMOR 04	22.79e	20.20a	6.52b	39.00a	56.54a	23.45a
PIMOR 05	34.04b	21.41a	7.05a	33.62b	53.51b	23.04a
PIMOR 06	26.33d	17.25b	7.11a	29.87b	54.65b	23.05a
HPO 02	33.57b	21.53a	6.60b	33.33b	57.99a	23.94a
HPO 03	30.46c	21.91a	6.98a	31.58b	60.44a	24.49a
HPO 04	26.96d	25.07a	6.70b	44.08a	53.62b	23.17a
HPO 07	29.33c	19.75a	7.31a	33.01b	53.53b	23.50a
HPO 08	19.62e	14.21b	5.92c	26.49b	51.71b	20.05a
HPO 12	22.25e	22.45a	6.52b	39.25a	53.57b	24.45a
'Espaguetinho'	21.79e	15.96b	6.76b	32.75b	51.89b	21.99a
'Pirâmide'	24.33d	19.33a	6.89a	36.33a	53.30b	22.31a
CV (%)	9.34	12.21	7.93	5.71	7.93	13.37

GENOTYPES	FLG (mm)	FWD (mm)	FWG (g)	PLG (mm)	NTF	SWD (g)
PIMOR 01	32.75c	13.06b	2.85b	23.07b	169d	4.79c
PIMOR 02	23.53e	9.64d	1.25e	22.85b	328c	4.49c
PIMOR 03	41.56b	9.27d	2.07c	25.74a	295c	5.03b
PIMOR 04	33.94c	16.23a	3.42a	21.63b	150d	6.53a
PIMOR 05	12.29g	8.81e	0.65f	22.83b	625a	2.90e
PIMOR 06	35.60c	9.18d	1.52d	25.75a	297c	3.43d
HPO 02	32.85c	8.69e	1.30e	23.31b	333c	3.85d
HPO 03	50.80a	8.38e	1.72d	26.40a	312c	4.22c
HPO 04	25.58d	11.14c	1.80d	20.72b	327c	4.57c
HPO 07	16.48f	8.41e	0.75f	20.88b	398b	2.86e
HPO 08	23.58e	7.42a	1.17e	25.24a	390b	3.15e
HPO 12	27.32d	11.23c	2.07c	22.12b	307c	5.26b
'Espaguetinho'	41.80b	6.46f	1.32e	24.29a	397b	2.96e
'Pirâmide'	21.05e	16.29a	2.37c	18.73b	272c	5.41b
CV (%)	6.27	4.37	10.24	15.06	18.51	6.89

Means followed by the same letter, in each column, do not statistically differentiate among themselves, by the Scott-Knott test at the 1% level of significance. PHG: Plant height; SLG: stem length; SDT: stem diameter; CDT: canopy diameter; LLG: leaf length; LWD: leaf width; FLG: fruit length; FWD: fruit width; FWG: fruit mass; PLG: pedicel length; NTF: total number of fruits; and SWD: 1000-seed mass.

According to the Scott-Knott test ($p \leq 0.01$) (Table 3), the variables that showed greater variability were mean fruit length and width, thus forming seven groups; followed by average fruit mass, with six groups; and plant height combined with 1000-seed mass, composing five groups. The characteristics with lower variability were: total number of fruits, with four groups; stem diameter, with three groups; and canopy diameter, stem, leaf and pedicel lengths, with two groups. Silva et al. (2017), having evaluated the same genotypes, also observed a wide diversity for most of the characteristics considered for ornamental purposes, as well as a greater

diversity for characteristics related to the fruit, as noted by Neitzke et al. (2010). However, in a phenotypic characterization study of *C. annuum* F_2 segregating generation, Silva Neto et al. (2014), found wide variability for both stem and canopy diameter, with formation of thirteen and eight groups respectively.

Plant height is a determining characteristic when using peppers with ornamental purposes, for only small genotypes adapt to potting with limited amount of substrate (Neitzke et al., 2010). Thus, this characteristic was previously selected by Silva et al. (2017) for the genotypes studied here. As expected, all hybrids and five out of the six parents met the required standards observed in ornamental cultivars. The genotypes showed average values varying from 19.62 to 39.66 cm. Hybrids reached lower averages in relation to the parents, being the lowest average observed in the hybrid HPO 08 (19.62 cm) and the highest in HPO 02 (33.57 cm) (Figure 4).

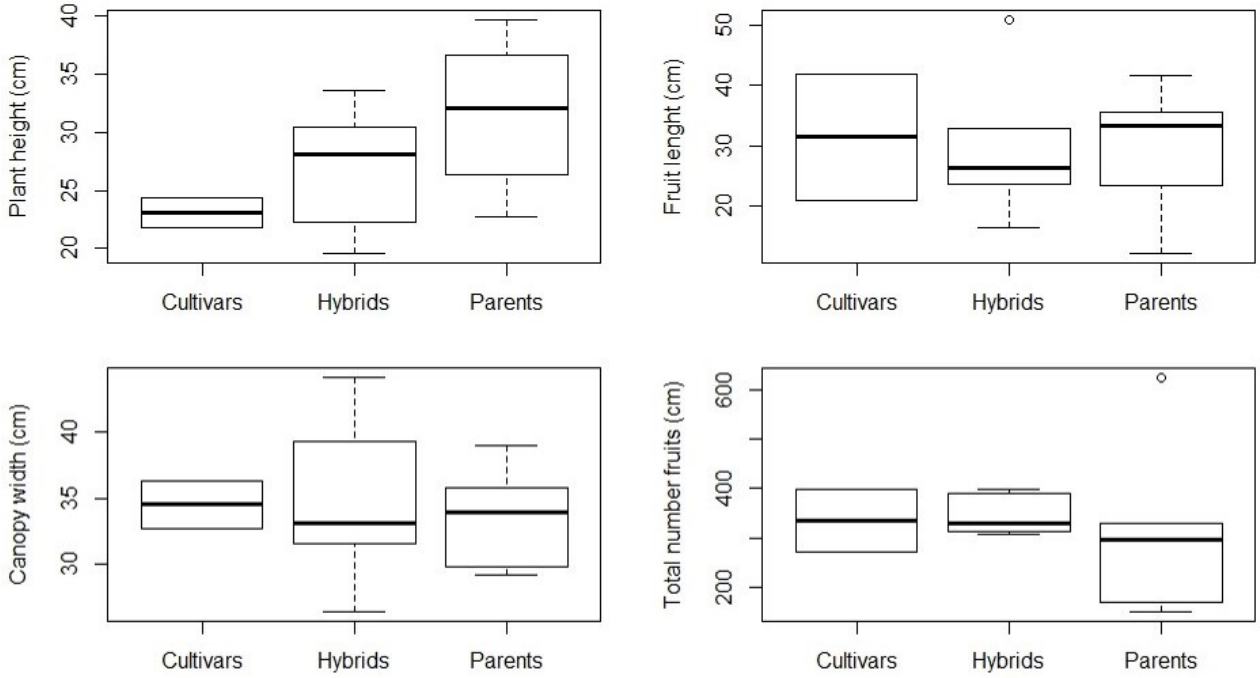

Figure 4. Characterization based on quantitative descriptors of cultivars, hybrids (H) and parentals (P) of ornamental peppers.

According to the quality standards of the *Cooperativa Veiling Holambra* (2020), the minimum and maximum plant height are 12 and 38.5 cm respectively. Only the parent PIMOR 03 exceeded this highest value. However, some authors considered ornamental *Capsicum* height taller than those aforementioned.

Neitzke et al. (2010), having evaluated the ornamental potential of peppers from *Embrapa Clima Temperado* germplasm bank, selected six accessions of *C. annuum*, whose heights varying from 15.03 to 52.20 cm. Melo et al. (2014) considered the genotypes of *Capsicum* spp. which presented plant height ranging from 19.75 to 61.28 cm, promising for cultivation.

Stem length values, close to plant height values, provide good coverage of the pot and formation of a circular canopy, making the relation between plant and pot more harmonious. In the present study, the values observed for this descriptor ranged from 14.21 to 25.07 cm, grouping the genotypes into two groups. The first group comprised most of the hybrids (HPO 02, HPO 03, HPO 04, HPO 07), parental (PIMOR 01, PIMOR 02, PIMOR 03, PIMOR 04, PIMOR 05) and the commercial 'Pirâmide ornamental' ranging from 19.33 to 25.07 cm. The second group included the hybrid HPO 08, the 'Espaguetinho ornamental' and the PIMOR 06 wich exhibited lower means, less than 17.25 cm. The averages for stem diameter ranged from 5.92 (HPO 08) to 7.31 mm (HPO 07), being the same magnitude observed by Silva Neto et al. (2014) (4.2 to 8.9 mm). According to these authors, such characteristic is of interest in breeding, since

plants with a very thin stem tend to lose their commercial value.

For canopy diameter, the highest value was 44.08 cm in the HPO 04 hybrid, which is not statistically different from the values obtained in HPO 12, PIMOR 04 and 'Pirâmide ornamental' genotypes. The other genotypes and the cultivar 'Espaguetinho ornamental' showed the lowest values, ranging from 26.49 to 34.33 cm (Table 3, Figure 4). For the ornamental market, plants that have larger canopy diameter, i.e. larger leaf volume, are desirable because they are more attractive. Silva Neto et al. (2014) and Neitzke et al. (2010) found in *C. annuum* values ranging from 16 to 31 cm and 19.07 to 68.40 cm respectively. The work herein emphasizes that the HPO 04 hybrid showed the highest value for canopy diameter (44.08 cm), thus showing hanging stems, with fruits arranged throughout the plant (Figure 1). This peculiarity makes it suitable for growing in hanging pots or high places, reaching another niche market, such as hanging and/or vertical gardens.

The average leaf length varied between 51.71 and 61.14 mm; whereas its width went from 20.05 to 26.31 mm. Only the HPO 03 and HPO 04 hybrids and the parental PIMOR 01, PIMOR 03 and PIMOR 04 had average leaf length higher than the two commercial controls. The length/width ratio ranged from 2.19 to 2.58, characterizing lanceolate leaves (Melo et al., 2014). For leaf length, the values observed by Silva Neto et al. (2014) were lower (30 to 52.70 mm) than those found in the present study.

The fruit length, width and weight featured greater variability among the studied genotypes. In these cases, seven groups were formed for the first two variables; whereas six groups came from the fruit mass values based on the Scott-Knott cluster test. The mean values for fruit length varied from 12.29 (PIMOR 05) to 50.8 mm (HPO 03), and most of the genotypes presented intermediate values against the commercial controls (Figure 4). The average width ranged from 6.46 mm ('Espaguetinho ornamental') to 16.29 mm ('Pirâmide ornamental'). Both fruit length and width were close to the means previously found for these genotypes (Silva et al., 2017). Other authors have obtained similar values: Melo et al. (2014) found values for fruit length between 9,65 and 26,90 mm; and Fortunato et al. (2019) observed mean diameter between 6.66 and 20.00 mm. Negative correlation between length and total fruit yield was observed by some authors (Rêgo et al., 2010; Silva et al., 2015). The mean fruit mass values ranged from 0.65 (PIMOR 05) to 3.42 g (PIMOR 04).

Regarding the length of the pedicel, higher values are interesting for pot-cultivation and floral arrangements, so as to provide better visibility by highlighting the fruits among the foliage. In the present work, the hybrids and parental studied had lengths ranging from 20.72 (HPO 04) to 26.40 mm (HPO 03); whereas the 'Pirâmide ornamental' and 'Espaguetinho Ornamental' had values equal to 18.73 and 24.29 mm, respectively. Accessions of *C. annuum* with ornamental potential selected by Neitzke et al. (2010) and Melo et al. (2014) exhibited values varying from 15 to 25 mm and from 18 to 29.3 mm, respectively.

Considering the total fruit production, the PIMOR 04 and PIMOR 05 parentals were the least and most productive genotypes, with a mean of 150 and 625 fruits, respectively. The hybrids HPO 07 and HPO 08 had averages of production statistical equal to the commercial cultivars 'Espaguetinho Ornamental' that produced 397 fruits. The others (HPO 02, HPO 03, HPO 04, and HPO 12) had statistical equal averages to the 'Pirâmide ornamental', with 272 fruits (Figure 4). This is a characteristic of extreme importance for the ornamental market, since the bigger the quantity of fruits more attractive are the ornamental peppers.

For 1000-seed mass, the genotypes were grouped into five groups, ranging from 2.86 (HPO 07) to 6.53 g (PIMOR 04). This characteristic is of great importance because it is linked to seed commercialization. According to the information contained in the *Isla sementes Ltda* marketing seed envelope, for the two commercial cultivars 'Pirâmide ornamental' and 'Espaguetinho ornamental', about 1000 seeds would correspond to a weight of 5 grams. The HPO 12 hybrid showed a statistical equal mean to the 'Pirâmide ornamental' control with 5.2 g. Hybrids HPO 07 and HPO 08 had 1000-seed mass mean values statistical equal to the 'Espaguetinho ornamental', with 2.86 and 3.15g.

respectively. The other hybrids weighed between 3.8 and 4.57g. The ornamental pepper seed market is another interesting niche. Five hundred seeds from 'Pirâmide ornamental' and 'Espaguetinho ornamental' cultivars are being marketed for $ 80.30 (www.isla.com.br on 03/31//2020).

Preference evaluation

Although the ideotype for ornamental peppers is extensively described in the literature, consumer acceptance and preference ratings related to these plants have been poorly explored (Neitzkel et al., 2016). To evaluate the sensorial perception of the consumers in relation to the studied genotypes, a group of 89 people was interviewed, being 43 women and 45 men. Participants' ages ranged from 17 to 47 years old and consisted of consumers or potential consumers of ornamental peppers, according to 72% who said they would buy or had already bought peppers for such purpose.

Even though all the genotypes have met the established standards for ornamental peppers - which are compact, erect and intense color fruits, among others, acceptance levels were very variable. The highest preference scores were attributed to HPO 03 (60.6 points) and to the PIMOR 05 (47.10 points) (Figure 5). Among these genotypes we can see differences in leaf and fruit shape, number of maturation stages, flower and stem color, among others.

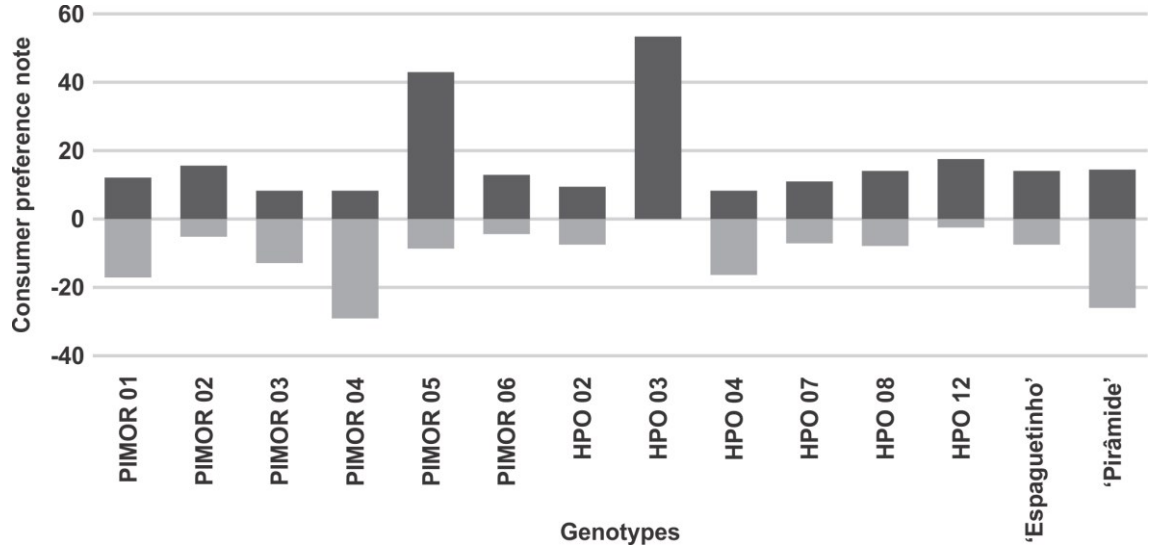

Figure 5. Consumer preference note: acceptance of ornamental pre-cultivars of *Capsicum annuum* L. and two commercial cultivars.

The hybrid HPO 03 presented leaves with lanceolate format, flowers with white corolla and anther pale blue and elongated fruits. Considering the quantitative descriptors, it was observed the highest averages for fruit and pedicel length, and canopy diameter. The parental PIMOR 05 showed purple corolla and anthers, green stem with purple striae, leaves and oval-shape fruits, besides presenting the highest averages for fruit production and canopy diameter. The characteristics common to both genotypes were: erect growth habit, bright and intense colored fruits, and the presence of short internodes.

These results suggest that the leaf and fruit form, as well as the leaf color, from both the flower and the immature fruit were not decisive in the acceptance evaluation of the ornamental peppers studied. Neitzel et al. (2016), having evaluated the preference of the consumers in relation to the 18 accessions of *C. annuum* of the Germplasm Bank of *Embrapa Clima Temperado*, also observed low relevance of both leaf color characteristics and fruit shape in the consuming preference evaluation.

On the other hand, in the present study, the presence of short internodes, fruits with bright and intense color, as well as greater canopy diameter were strongly considered. These characteristics result, individually and mainly together, in the fruit enhancement, that is, in the

contrast of these to the foliage, a pattern that is associated with the greater acceptance and preference of consumers (Rêgo et al., 2010; Neitzel et al., 2016). Additionally, it is assumed that the preference for PIMOR 05 is associated with its peculiar characteristics. Because it is the only genotype of *C. annuum* var. *glabriusculum*, and the only one to present strong purple pigmentation in the stems, flowers and fruits, besides fruits and oval leaves.

The PIMOR 04 genotypes and the commercial 'Pirâmide ornamental' received the highest rejection scores, equal to 32.5 and 29.2, respectively (Figure 5). These genotypes presented, in common, lanceolate leaves, white corolla, pale blue anthers, and triangular shaped fruits. They both were characterized by low average values for canopy diameter, plant height, pedicel length and highest average for fruit width. Although the PIMOR 04 parental presented fruits with intense brightness and coloring, the absence of short internodes and the low production of total fruits certainly made this genotype less attractive, as well as the cultivar 'Pirâmide ornamental' that exhibited fruits with medium brightness and color .

In view of the importance of the fruit characteristics for the aesthetic quality of the chili peppers, the interviewees were also questioned about individual aspects of this part of the plant. More than half of the participants (53%) said they preferred elongated fruits, followed by triangular (32.55%) and then oval (13.50%). Regarding the color of the fruit, the following rankings were found: red (68.6%), followed by orange (21.35%), purple (9%) and yellow (1.12%).

The fruit shape preference is contrary to the evaluation performed regarding the general plants appearance, since the genotype that exhibited oval fruit had greater acceptance in relation to the plants with triangular fruits. These results reveal that despite the preference for certain characteristics of leaves, flowers and fruits, the harmony and the overall appearance of the plant are more important in the final choice. Neitzkel et al. (2016) observed that the general aspect of the plant is the second factor that most influences the acceptance of ornamental peppers, only behind the fruit color.

Conclusions

In addition to presenting the characteristics referenced in the literature as more related to ornamental purposes, the present work sought to validate hybrids and parental elites of the breeding program in relation to consumers' preferences. It was observed that the presence of short internodes, fruits with intense brightness and color, greater canopy diameter, and pedicel length were decisive in the acceptance evaluation of the peppers studied. However, the presence of short internodes and fruit brightness is not explored in the development of new cultivars. Although these descriptors are not on the list proposed by IPGRI (1995), it is recommended to include them in evaluations of pepper improvement programs for this purpose.

Even though all evaluated genotypes are promising for potting, HPO 03 and PIMOR 05 are recommended for cultivar registration and protection. This is because they have achieved the best results in terms of consumer preference, which is on account of being a hybrid and a lineage, hence enabling future cultivars to serve small and medium farmers. In addition, both genotypes may continue the ornamental *Capsicum* breeding program, and new crosses may be carried out in the search for new genotypes.

Furthermore, two hybrids are also considered promising to other niche markets. HPO 12 has great potential regarding the flowering stage, having exhibited flowers with white corolla and purple margins, different from most of the cultivars. Hybrid HPO 04, which has not been well evaluated for potting, can be indicated for cultivation in gardens and hanging gardens, an market trend.

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References

BARBOZA, GE; AGRA, MF.; ROMERO, MV.; SCALDAFERRO, MA.; MOSCONE, EA. 2011. New endemic species of *Capsicum* (Solanaceae) from the Brazilian Caatinga: comparison with the re-circumscribed *C. parvifolium*. **Systematic Botany**, 36:768-781.

BRASIL 2006. Ato no. 2 de 22 de março de 2006. Instruções para execução dos ensaios de distinguibilidade, homogeneidade e estabilidade de cultivares de pimentão e pimenta (*Capsicum* spp.). Brasília: Diário oficial [da República Federativa do Brasil], p. 7.

CARVALHO, SIC.; BIANCHETTI, LDB.; RIBEIRO, CDC.; LOPES, CA. 2006. Pimentas do gênero *Capsicum* no Brasil. **Embrapa Hortaliças-Documentos**.

COOPERATIVA VEILING HOLAMBRA. 2020. Padrão de Qualidade para Pimenta ornamental de vaso. Padrão de qualidade. Available from URL. http://www.veiling.com.br/padrao-qualidade. [Accessed 15/02/2020].

CRUZ, C.D. 2013. GENES: a software package for analysis in experimental statistics and quantitative genetics. **Acta Scientiarum.Agronomy**, 35(3):271-276.

FORTUNATO, FLG.; DO RÊGO, ER.; DE CARVALHO, MG.; DOS SANTOS, CAP.; DO RÊGO, MM. 2019. Genetic diversity in ornamental pepper plants. **Comunicata Scientiae** , 10 (3): 364-375.

FREIRE, LR. 2013. Manual de calagem e adubação do Estado do Rio de Janeiro. **Embrapa Solos-Livro técnico**.

IBRAFLOR. 2017. Available from URL. http://www.ibraflor.com/site/2017/11/04/mercado-de-flores-vera-longuini/. [Accessed 15/02/2020].

IPGRI. 1995. Descriptores para *Capsicum* (*Capsicum* spp.). 51p.

JUNQUEIRA, AH; PEETZ, MDS. 2014. O setor produtivo de flores e plantas ornamentais do Brasil, no período de 2008 a 2013: atualizações, balanços e perspectivas. **Revista Brasileira de Horticultura Ornamental**, 20:115-120.

LUZ, PBD.; SANTOS, AABD.; AMBROSIO, VC; NEVES, LG.; TAVARES, AR. 2018. Selection of indexes to evaluate the genetic variability aiming ornamental use of peppers accessions. **Ornamental Horticulture**, 24:7-11.

MELO, LF; GOMES, RLF; SILVA, VB; MONTEIRO, ER; LOPES, ÂCA; PERON, AP. 2014. Potencial ornamental de acessos de pimenta. **Ciência Rural**, 44(11):2010-2015.

NEITZKE, RS; BARBIERI, RL; RODRIGUES, WF; CORRÊA, IV; DE CARVALHO, FI. 2010. Genetic dissimilarity among pepper accessions with potential for ornamental use. **Horticultura Brasileira**, 28:47-53.

NEITZKE, RS; FISCHER, SZ; BARBIERI, R; TREPTOW, R. 2016. Pimentas ornamentais: aceitação e preferências do público consumidor. Embrapa Clima Temperado-Artigo em periódico indexado (ALICE).

RÊGO, ER; DA SILVA, DF; DO RÊGO, MM; DOS SANTOS, RMC; SAPUCAY, MJDLC; DA SILVA, DR. 2010. Diversidade entre linhagens e importância de caracteres relacionados à longevidade em vaso de linhagens de pimenteiras ornamentais. **Ornamental Horticulture,** 16(2).

SEBRAE. 2015. Flores e plantas ornamentais do Brasil. Available from URL. https://bibliotecas.sebrae.com.br/chronus/ARQUIVOS_CHRONUS/bds/bds.nsf/4c7a617954ca9be59d73ae831d8acac6/$File/5516.pdf. [Accessed 15/03/2020].

SCHIMMENTI, E; GALATI, A; BORSELLINO, V; IEVOLI, C; LUPI, C; TINERVIA, S. 2013. Behaviour of consumers of conventional and organic flowers and ornamental plants in Italy. **Horticultural Science**, 40(4):162-171.

SCOTT, AJ; KNOTT, M. 1974. A cluster analysis method for grouping means in the analysis of variance. **Biometrics**, 507-512.

SILVA, CQ; RODRIGUES, R; BENTO, CS; PIMENTA, S. 2017. Heterosis and combining ability for ornamental chili pepper. **Horticultura Brasileira**, 35:349-357.

SILVA, CQ; JASMIM, JM; SANTOS, JO; BENTO, CS; SUDRÉ, CP; RODRIGUES, R. 2015. Phenotyping and selecting parents for ornamental purposes in chili pepper accessions. **Horticultura Brasileira**, 33:66-73.

SILVA NETO, JJD.; RÊGO, ERD.; NASCIMENTO, MF; SILVA FILHO, VAL; ALMEIDA NETO, JXD; RÊGO, MMD. 2014. Variability in a base population of pepper (*Capsicum annuum* L.). **Revista Ceres**, 61:84-89.

STOMMEL, JR; BOSLAND, PW. 2007. **Ornamental pepper**. *In*: Flower Breeding and Genetics. Springer, 561-599.

STOMMEL, JR; KOZLOV, M; GRIESBACH, RJ. 2018. Ornamental pepper (*Capsicum annuum* L.) cultivars comprising the christmas lights cultivar ceries. **HortScience**, 53:391-394.