Original Research Article

General and specific combining ability of flower characters in *Capsicum annuum* L.

ABSTRACT

The study was carried out with the objective of estimating the combinatorial capacity of ornamental pepper (*C. annuum* L.) genotypes for flower traits, aiming to identify the best hybrid combinations and the best parents for the synthesis of new populations. The experiment was conducted in a greenhouse in the Laboratório de Biotecnologia Vegetal of Centro de Ciências Agrárias, Universidade Federal da Paraíba, State of Paraíba, Brazil. Seven accessions of *Capsicum annuum* were hand-crossed. Seven flower traits were evaluated: days for flowering, flower diameter, petal length, number of petals, number of stamens, anther length and filament length. Data were submitted to diallel analysis using the Griffing method I. The GCA (ĝi) values obtained for the characteristic for flowering, showed 001, 004 and 099 as the best parental options. Para as características da flor (dias para floração, comprimento do filamento e comprimento da antera) que apresentaram estimativas de efeitos recíprocos significativos, indica a existência de uma diferença entre os híbridos e seus recíprocos. The additive effects of the genes have been predominant for most of the flower characteristics and the non-additive effects were higher only for the days for flowering character. Genotypes 001, 004 and 099 are indicated for crosses when the scope of the program is to increase flower characteristics. The best hybrids for obtaining large flowers in ornamental pepper are: 134 x 004, 137 x 001, 390 x 004, 77.3 x 099, 001 x 390, 001 x 77.3 and 099 x 77.3.

Keywords: Breeding; diallel; genetic effects; ornamental pepper

1. INTRODUCTION

Capsicum annuum L. species belong to the Solanaceae family, which has numerous members admired for their ornamental value [1].

The use of ornamental pepper should be easy to propagate and grow, with short vegetative phases and high aesthetic value [2, 3, 4]. Aesthetic value is associated with a great variety of fruit shapes and coloring, by the variation of foliage color [5, 4], plant architecture, fruit and leaf quantity [6, 7,8].

In addition to the characteristics of plant, leaves and fruits, the characterization of pepper flowers is an interesting aspect for ornamentation since, despite their small size; they have attractive colors and upright position, which allows greater visualization [9, 10].

The study on flower characters is important for the ornamental aspect, with the selection of accessions that have large flowers [9] and can also facilitate other phases of a breeding program, such as crossing, and consequently, the obtaining of hybrid or genetic seeds and the advancement of segregating generations [2].

In breeding programs, hybridization is a strategy used to gather favorable alleles from different parents [11]. Among the methodologies, diallel analysis provides estimates of useful parameters in the selection of parents for hybridization [12, 13].

The Griffing diallelic method [14] makes it possible to estimate the general combining ability obtained from hybrid populations, indicating how much it differs from the general average of the diallel population's parents [15] (SCA), which is the result of the concentration of non-additive genes [16]. This work was carried out with the objective of determining the general and specific combining abilities, by means of diallel crossing, of flower characters in ornamental peppers.

2. MATERIAL AND METHODS

The treatments were the accessions 001, 004, 77.3, 099, 134, 137 and 390 and their hybrids. The accessions were selected based on genetic diversity [8].

Manual crosses were performed in pre-anthesis floral buds. The floral buds were emasculated in the morning, immediately pollinated by placing the pollen from a donor plant on the stigma of an acceptor flower from another plant, labeled and covered with aluminum foil to avoid contamination [17]. Fruits were collected when ripe, and seeds were removed.

Seeds from the 49 treatments, seven parents and 42 hybrids, were sown in polystyrene trays with 128 cells, which were filled with commercial substrate (Plantmax®). Seedlings, thirty days old, were transferred to plastic pots containing 900 mL of the same substrate.

The experimental was developed at Laboratório de Biotecnologia Vegetal, Centro de Ciências Agrárias, Universidade Federal da Paraíba (CCA-UFPB).

The flower characteristics evaluated were: Days for Flowering (DFL), Flower Diameter (FD), Petal Length (PL), Number of Petals (NP), Number of Stamens (NS), Anther Length (AL) and Filament Length (FL) [18]. To obtain data on the dimensions, a digital caliper was used (Leetools® digital caliper) and the quantity values were taken by counting.

The 49 treatments were displayed in a completely randomized block design with eight replicates. Each repetition consisted of a vase with a plant. The data were subjected to Griffing Diallel.

General combining ability (GCA) and specific combining ability (SCA) were estimated using the Griffing's [13] method I (fixed model). The statistical model was $X_{ijk} = \mu + g_i + g_j + s_{ij} + r_{ij} + b_k + e_{ijk}$, where: X_{ijk} = observation value for a cross between the *i*th and *j*th parents in the *k*th replication; μ = population mean; g_i and g_j = GCA effect for the *i*th and *j*th parents, respectively; s_{ij} = SCA effect for the hybrid between the *i*th and *j*th parents; r_{ij} = reciprocal effect for the hybrid; b_k = repetition effect and e_{ijk} = experimental error. Significant differences between GCA, SCA and reciprocal effects were tested using the F test.

3. RESULTS

The mean squares of general combining ability (GCA) were significant (p <0.01) for all characteristics: days for flowering, flower diameter, petal length, number of petals, number of stamens and filament length. The anther length also showed significance (p <0.05) (Table 1).

For specific combining ability (SCA), the traits days for flowering, number of petals, and filament length traits were significant (p <0.01), as well as the number of stamens (p <0.05). The traits, flower diameter, petal length and anther length were displayed non-significant SCA (Table 1).

Estimates of reciprocal effects were non-significant for flower diameter, petal length, number of petals and number of stamens traits. Only the characters days for flowering (p <0.01), filament length (p <0.01) and anther length (p <0.05) presented significance (Table 1).

GCA effects were higher than SCA effects for flower diameter, petal length, number of petals, and number of stamens, as well as the and days for flowering traits (Table 1).

Table 1. Summary of the analysis of variance and quadratic components associated with general combining ability (ϕ_g^2), specific combining ability (ϕ_s^2) and reciprocal effects ($\phi_r^2 e$) for ornamental pepper flower traits (*Capsicum annuum* L.).

Variation factor	GL	Trait

		DFL	FD	PL	NP
Treatments	48	86.250**	0.149**	0.020**	0.480**
GCA	6	222.296**	0.989**	0.114**	2.529**
SCA	21	75.790**	0.040^{ns}	0.007^{ns}	0.225**
Reciprocal effect	21	57.839**	0.017^{ns}	0.007^{ns}	0.150^{ns}
Residual	343	8.400	0.047	0.008	0.116

Variation factor	GL	Trait		
		NS	AL	FL
Treatments	48	0.456**	0.003*	0.010**
GCA	6	2.448**	0.006*	0.043 **
SCA	21	0.189*	0.002^{ns}	0.007**
Reciprocal effect	21	0.155^{ns}	0.004*	0.003**
Residual	343	0.107	0.002	0.003

^{ns} Not significant, **and* Significant according to the F test, at p ≤ 0.01 and p ≤ 0.05, respectively. Days for Flowering (DFL), Flower Diameter (FD), Petal Length (PL), Number of Petals (NP), Number of Stamens (NS), Anther Length (AL) and filament length (FL).

The GCA (ĝi) values obtained for the characteristic days for flowering, showed 001, 004 and 099 as the best parental options. These accessions presented negative values which influenced in the crossings decreasing the number of days to the beginning of the flowering, while accessions 77.3 and 390 contributed to increase the number of days for flowering in pepper (Table 2).

For flower diameter, petal length, number of petals and number of stamens traits, accessions 001, 004 and 099 recorded high and positive estimates of ĝi whereas accessions 77.3 and 390 presented high and negative values (Table 2).

In relation to filament length trait, the accessions 004, 099 and 77.3 influenced in the crossings reducing this characteristic, with negative values of ĝi, whereas the accessions 134 and 137 contributed to the increase of this character (Table 2).

Table 2. Estimates of the effects of general combining ability (ĝi) on seven quantitative characteristics of ornamental pepper flowers (*Capsicum annuum* L.).

Accessions	Traits			
	DFL	FD	PL	NP
001	-1.284**	0.077**	0.023*	0.177**
004	-1.195**	0.060**	0.033**	0.073*
77.3	2.099**	-0.174**	-0.046**	-0.162**
099	-1.338**	0.096**	0.025**	0.171**
134	-0.025^{ns}	0.010^{ns}	0.004^{ns}	0.019^{ns}
137	0.126^{ns}	-0.008^{ns}	0.001^{ns}	-0.096**
390	1.617**	-0.062**	-0.041**	-0.183**

Accessions	Traits		
	NS	AL	FL
001	0.166**	0.004^{ns}	-0.007^{ns}
004	0.085*	0.006^{ns}	-0.019**
77.3	-0.147**	-0.002^{ns}	-0.012*
099	0.166**	0.004^{ns}	-0.018**
134	0.017^{ns}	0.007^{ns}	0.027**
137	-0.090**	-0.006^{ns}	0.025**
390	-0.197**	-0.012*	0.003^{ns}

^{ns} Not significant **and* Significant according to the Student's t-test, at p ≤ 0.01 and p ≤ 0.05, respectively. Days for Flowering (DFL), Flower Diameter (FD), Petal Length (PL), Number of Petals (NP), Number of Stamens (NS), Anther Length (AL) and Filament Length (FL).

When it comes to SCA, the hybrid combination 77.3 x 099 (-4.912) recorded the highest significant negative estimate for the character days for flowering (Table 3) and only the hybrid 134 x 001 (0.045) presented significant and positive value for petal length trait (Table 3).

The hybrid 134 x 77.3 showed the highest significant positive value of S_{ij} for number of petals and number of stamens traits. For anther length trait, only 390 x 77.3 and 77.3 x 004 hybrids revealed positive and significant values. In the other hand, the reciprocal 004 x 77.3 (-0.051) had a greater significant negative effect for anther length trait. The hybrid combination 77.3 x 001 (0.027) presented the highest positive and significant estimates for filament length trait, whereas, the hybrid 390 x 77.3 showed the highest negative value (-0.031) (Table 3).

Table 3. Estimates of the effects of specific combining capacity (S_{ij}) for seven characteristics of flowers in ornamental pepper (*C. annuum* L.).

Hybrid/Reciprocal	Traits							
	DFL		FD		PL		NP	
001x004 (004x001)	-0.483^{ns}	1.187^{ns}	0.079^{ns}	-0.005^{ns}	0.002^{ns}	-0.020^{ns}	0.147*	0.021^{ns}
001x099 (099 x 001)	-0.215^{ns}	-0.937^{ns}	0.020^{ns}	-0.091^{ns}	-0.000^{ns}	0.012^{ns}	0.153*	0.022^{ns}
004x099 (099 x 004)	0.570^{ns}	0.688^{ns}	-0.079^{ns}	0.016^{ns}	-0.026^{ns}	0.035^{ns}	0.028^{ns}	-0.021^{ns}
77.3x001 (001x77.3)	2.159**	-2.750**	0.013^{ns}	0.002^{ns}	-0.006^{ns}	0.002^{ns}	-0.076^{ns}	-0.062^{ns}
77.3x004 (004x77.3)	-0.242^{ns}	0.687^{ns}	-0.044^{ns}	-0.021^{ns}	0.006^{ns}	-0.012^{ns}	-0.222**	-0.021^{ns}
77.3x099 (099x77.3)	-4.912**	-1.625**	-0.011^{ns}	0.003^{ns}	-0.007^{ns}	0.015^{ns}	-0.008^{ns}	-0.250**
134x137 (137x134)	0.561^{ns}	1.188^{ns}	0.041^{ns}	-0.040^{ns}	0.003^{ns}	-0.019^{ns}	0.079^{ns}	0.055^{ns}
134x390 (390x134)	-1.492*	2.500**	-0.001^{ns}	-0.019^{ns}	-0.018^{ns}	0.030^{ns}	-0.085^{ns}	-0.083^{ns}
134x77.3 (77.3x134)	0.275^{ns}	-0.125^{ns}	0.074^{ns}	-0.022^{ns}	-0.014^{ns}	-0.016^{ns}	0.165*	0.062^{ns}
134x001 (001x134)	-0.466^{ns}	2.625**	-0.060^{ns}	-0.018^{ns}	0.045*	0.022^{ns}	0.034^{ns}	-0.021^{ns}
134 x004 (004x134)	-1.492*	3.437**	0.013^{ns}	0.028^{ns}	0.009^{ns}	0.019^{ns}	-0.028^{ns}	0.062^{ns}
134x099 (099x134)	0.338^{ns}	0.625^{ns}	0.023^{ns}	-0.016^{ns}	-0.014^{ns}	-0.022^{ns}	0.040^{ns}	-0.021^{ns}
137x390 (390x137)	-0.769^{ns}	-2.000**	0.077^{ns}	-0.049^{ns}	0.021^{ns}	-0.016^{ns}	0.093^{ns}	-0.062^{ns}
137x77.3 (77.3x390)	-0.564^{ns}	-0.312^{ns}	0.047^{ns}	0.048^{ns}	0.030^{ns}	-0.031^{ns}	0.114^{ns}	-0.021^{ns}
137x001(001x137)	-1.492*	2.500**	-0.044^{ns}	0.037^{ns}	-0.022^{ns}	0.039*	-0.058^{ns}	-0.229**
137x004 (004x137)	-0.332^{ns}	2.250**	-0.035^{ns}	-0.041^{ns}	-0.021^{ns}	0.002^{ns}	-0.016^{ns}	-0.083^{ns}
137x099 (099x137)	2.124**	3.687**	-0.035^{ns}	0.026^{ns}	0.029^{ns}	-0.024^{ns}	-0.240**	-0.125^{ns}
390x77.3 (77.3x390)	-2.742**	-1.000^{ns}	-0.046^{ns}	0.016^{ns}	0.011^{ns}	-0.025^{ns}	0.076^{ns}	-0.021^{ns}
390x001 (001x390)	0.954^{ns}	-1.312**	-0.029^{ns}	-0.006^{ns}	-0.009^{ns}	0.001^{ns}	-0.180*	0.104^{ns}
390x004 (004x390)	-1.760**	1.312**	0.002^{ns}	0.031^{ns}	-0.002^{ns}	0.018^{ns}	0.070^{ns}	-0.042^{ns}
390x099 (099x390)	0.195^{ns}	1.500**	0.022^{ns}	0.008^{ns}	0.013^{ns}	-0.009^{ns}	-0.008^{ns}	0.146^{ns}

Table 3 (Continued)

Hybrid/Reciprocal	Traits					
	NS		AL		FL	
001x004 (004x001)	0.135*	-0.032^{ns}	0.001^{ns}	-0.016^{ns}	0.004^{ns}	-0.004^{ns}
001x099 (099x001)	0.117^{ns}	-0.062^{ns}	0.006^{ns}	-0.002^{ns}	-0.008^{ns}	-0.002^{ns}
004x099 (099 x 004)	0.031^{ns}	-0.021^{ns}	0.016^{ns}	-0.008^{ns}	-0.014^{ns}	0.007^{ns}
77.3x001 (001x77.3)	-0.070^{ns}	-0.062^{ns}	-0.011^{ns}	0.007^{ns}	0.027*	0.014^{ns}
77.3x004 (004x77.3)	-0.136*	0.083^{ns}	0.021*	-0.051**	0.005^{ns}	-0.019^{ns}
77.3x099 (099x77.3)	-0.008^{ns}	-0.250**	0.001^{ns}	-0.026*	0.003^{ns}	-0.001^{ns}
134x137 (137x134)	0.084^{ns}	-0.023^{ns}	0.000^{ns}	-0.010^{ns}	0.009^{ns}	-0.008^{ns}
134x390 (390x134)	-0.079^{ns}	-0.104^{ns}	0.003^{ns}	0.002^{ns}	-0.002^{ns}	-0.003^{ns}
134x77.3 (77.3x134)	0.166*	0.062^{ns}	-0.016^{ns}	-0.007^{ns}	0.022*	-0.004^{ns}
134x001 (001x134)	0.037^{ns}	-0.042^{ns}	0.015^{ns}	0.002^{ns}	0.005^{ns}	0.022^{ns}
134 x004 (004x134)	-0.029^{ns}	0.062^{ns}	-0.004^{ns}	0.002^{ns}	0.001^{ns}	0.023^{ns}
134x099 (099x134)	0.057^{ns}	-0.021^{ns}	-0.006^{ns}	-0.001^{ns}	0.021*	0.001^{ns}
137x390 (390x137)	0.111^{ns}	-0.062^{ns}	0.003^{ns}	-0.000^{ns}	0.010^{ns}	0.008^{ns}
137x77.3 (77.3x390)	0.081^{ns}	-0.023^{ns}	0.014^{ns}	-0.023*	0.017^{ns}	-0.004^{ns}
137x001(001x137)	-0.044^{ns}	-0.229**	-0.006^{ns}	0.007^{ns}	0.001^{ns}	0.036**
137x004 (004x137)	-0.026^{ns}	-0.083^{ns}	-0.014^{ns}	0.004^{ns}	-0.026*	-0.009^{ns}
137x099 (099x137)	-0.231**	-0.125^{ns}	0.002^{ns}	-0.008^{ns}	-0.023*	0.006^{ns}
390x77.3 (77.3x390)	0.042^{ns}	-0.021^{ns}	0.021*	-0.026*	-0.031**	-0.003^{ns}
390x001 (001x390)	-0.187**	0.062^{ns}	-0.003^{ns}	-0.002^{ns}	0.006^{ns}	0.006^{ns}
390x004 (004x390)	0.060^{ns}	-0.021^{ns}	-0.007^{ns}	0.004^{ns}	0.032**	0.018^{ns}
390x099 (099x390)	0.022^{ns}	0.146^{ns}	-0.014^{ns}	0.001^{ns}	0.017^{ns}	0.001^{ns}

^{ns} Not significant **and* Significant according to the Student's t-test, at p ≤ 0.01 and p ≤ 0.05. Days for Flowering (DFL), Flower Diameter (FD), Petal Length (PL), Number of Petals (NP), Number of Stamens (NS), Anther Length (AL) and Filament Length (FL).

4. DISCUSSION

The significance observed in the general combining ability (GCA) of flower traits is indicative that additive effects are involved in the genetic control of these traits. The significance of these characteristics reflects the high importance of the additive gene effects on the expression of the characters [6, 19].

The mean value of the GCA indicates that for a few of the evaluated characteristics (FDL, NP, FL and NS) the additive gene effects are involved in the control of these characteristics [20, 21], and that the hybrid combinations differ from the parents [22].

The additive effects of the genes have been predominant for most of the flower characteristics and the non-additive effects were higher only for the days for flowering character. In relation to this, Pessoa et al. [23] found that the additive effects influenced the performance of the hybrids for the characteristics of flowers in ornamental pepper. Santos et al. [24] in a study with *C. annuum* for ornamental pepper, found a similar result to that work, and identified the control of the additive effects for the characteristic corolla diameter.

For the flower characteristics (days for flowering, filament length and anther length) that presented estimates of significant reciprocal effects, it indicates the existence of a difference between the hybrids and their reciprocals. Accessions may be used as a male parent or as a female parent in a hybrid combination, according to their performance as donor or as pollen recipient [15].

For the traits (flower diameter, petal length, number of petals and number of stamens) that showed no significant reciprocal effect, it ensures that the direction in which the cross is made does not influence the results [25] and that there was no significant influence of the cytoplasmic genes [26].

The 001, 004 and 099 genitors parents are considered good parents because they presented high GCA for the flower characteristics and should be prioritized in hybrid combinations, favoring the selection of homozygous lines [27]. The GCA variability allows us to infer that the parents contributed differently at the crosses involved [25]. Medeiros et al.

[28] evaluating the genetic and heterosis effects in crosses of *C. baccatum*, selected the characteristics with greater general combining ability (ĝi) according to the characteristics of interest.

Thus, GCA values are good criteria for selection of genotypes in a breeding program, evidencing increments for petal length characteristics, number of petals and number of stamens showing positive and significant results, and reduction for days for flowering and filament length which presented significant and negative results. When the GCA effects are positive or negative for a given parent, it may be considered superior or inferior to the other parents included in the diallel [29, 30].

The estimates of the effects of specific combining ability (SCA) indicate that the effects of the hybrid combinations obtained between the parents and their interpretation are in accordance with their relationship with the GCA values of their parents [13].

For flower characteristics (flower diameter, petal length and anther length) that did not detect significant differences for SCA, Gomide et al. [29] reported that in this case non-additive effects are nonexistent or irrelevant to the characteristics evaluated. Therefore, when there is a magnitude of additive effects of the genes for certain traits of interest, it is suggested to make a selection after continuous self-fertilization until obtaining pure desirable lines [31].

The hybrid combinations indicated in obtaining early plants in flower production are: 134 x 004, 137 x 001, 390 x 004, 77.3 x 099, 001 x 390, 001 x 77.3 and 099 x 77.3 which presented predictable heterosis.

5. CONCLUSION

Genotypes 001, 004 and 099 are indicated for crosses when the scope of the program is to increase flower characteristics.

The best hybrids for obtaining large flowers in ornamental pepper are: 134 x 004, 137 x 001, 390 x 004, 77.3 x 099, 001 x 390, 001 x 77.3 and 099 x 77.3.

REFERENCES

1. Stummel JR, Bosland PW, Ornamental pepper, *Capsicum annuum* L. In: Anderson, N. Flower Breeding and Genetics: Issues, Challenges and Opportunities for the 21st Century. Netherlands: Springer. 561 - 599. 2007.

2. Rêgo ER, Santos RMC, Rêgo MM, Nascimento NFF, Nascimento MF, Bairral MA. Quantitative and Multicategoric Descriptors for Phenotypic Variability in a Segregating Generation of Ornamental Peppers. Acta Horticulturae. 937: 289- 296. 2012.

3. ER Dream, MM Dream, FL Finger. Production and Breeding of Chilli Peppers (*Capsicum spp*.). Springer International Publishing Switzerland. 1-129. 2016.

4. Rêgo ER, Rêgo MM. "Ornamental Pepper", in Ornamental Crops. Ed. Van Huylenbroeck, J. (Springer International Publishing Switzerland). 2018.

5. JR Stommel, Bosland P. Ornamental pepper. Capsicum annuum. In: Anderson NO. Flower breeding and genetics: issues, challenges, and opportunities for the 21st Century, ed. Dordrecht, Holanda: Springer. 561 – 599. 2006.

6. Nascimento NFF, Nascimento MF, Rego ER, Lima JAM, Rêgo MM, Finger FL, Bruckner CH. Intraspecific Cross-Compatibility in Ornamental Pepper. Acta Horticulturae. 1087: 339-344. 2015.

7. Neitzke RS, Fischer SZ, CS Vasconcelos, Barbieri RL, Treptow RO. Pimentas ornamentais: aceitação e preferências do público consumidor. Horticultura Brasileira. 34: 102–109. 2016.

8. Pessoa AMS, Rêgo ER, Carvalho MG, Santos CAP, Rêgo MM. Genetic diversity among accessions of Capsicum annum L. through morphoagronomic characters. Genetics and Molecular Research. 17: 1-15. 2018.

9. Santos RMC, Nascimento NFF, Borem A, Finger FL. Ornamental pepper breeding: Could a chili be a flower ornamental plant? Acta Horticulturae. 1000: 451-456. et al. 2013.

10. Melo LF, RLF Gomes, VB SILVA, MONTEIRO ER, ACA LOPES, PERON AP. Ornamental potencial of pimenta acessos. Ciência Rural. 44: 2010-2015. 2014.

11. Laurindo RDF, Laurindo BS, Delazari FT, Carneiro PCS, Silva DJH. Potencial de híbridos e populações segregantes de abóbora para teor de óleo nasementes e plantas com crescimento do tipo hala. Revista Ceres. 64: 582-591. 2017.

12. Cruz CD, Regazzi AJ, Carneiro PCS. Modelos Biométricos Aplicados ao Melhoramento Genético. Viçosa - MG: Ed. UFV. 2012.

13. Gonçalves JGR, Chiorato AF, Silva DA, Esteves JAF, Bosett F, Carbonell SAM. Análise da capacidade combinatória em feijoeiro comum submetido ao deficit hídrico. Bragantia. 74. 149- 55. 2015.

14. Griffing B. Concept of general and specific combining ability in relation to diallel crossing systems. Australian Journal of Biological Sciences. 9: 463 – 493. 1956.

15. Oliboni R, Faria MV, Neumann M, Resende JTV, GM Battistelli, Tegoni RG, Oliboni DF. Anilise dialelica na avaliação do potencial de híbridos de milho para a geração de populações-base para getção de linhagens. Semina: Ciências Agrárias. 34: 7-18. 2013.

16. Baldissera JNC, Valentini G, MM Cian, Almeida CB, Guidolin AF, Coimbra JLM. Combining ability and reciprocal effect on agronomical traits of bean. Semina: Ciências Agrárias. 33: 471-480. 2012.

17. Nascimento NFF, Rêgo ER, Rêgo MM, Nascimento MF, Alves LI. Compatibilidade em cruzamentos intra e interespecíficos em pimenteiras ornamentais. Revista Brasileira de Horticultura Ornamental. 18: 57-61. 2012.

18. IPGRI. International plant genetic resources institute. Descriptors for Capsicum. Rome, IBPGR. 49. 1995.

19. Melo AV, Tuabinger M, Santos V M, Cardoso DP, Vale JC. Capacidade combinatória de milho para produção de grãos sob níveis de fósforo. Revista de Agricultura Neotropical. 4: 15-25. 2017.

20. ER Dream, MM Dream, FL Finger, Cruz CD, Casali VWD. A diallel study of yield components and fruit quality in chilli pepper (*Capsicum baccatum* L.). Euphytica. 168: 275-287. 2009.

21. Nascimento NFF, Rêgo ER, Nascimento MF, Bruckner CH, Finger FL, Rêgo MM. Combining ability for yield and fruit quality in the pepper *Capsicum annuum* L. Genetics and Molecular Research. 13: 3237-3249. 2014.

22. Rocha F, Stinghen JC, MS Gemeli, Coimbra JLM, Guidolin AF. Análise dialélica como ferramenta na seleção de genitores em feijão. Revista Ciência Agronômica. 45: 74-81. 2014.

23. Pessoa AMS, Rêgo ER, Santos CAP, Carvalho MG, Mesquita JCP, Rêgo MM. Inheritance of flower traits in ornamental pepper. Revista Agropecuária Técnica. 39: 50-60. 2018.

24. Santos RMC, Rêgo ER, Borém A, Nascimento MF, Nascimento NFF, Finger FL, Rêgo MM. Epistasis and inheritance of plant habit and fruit quality in ornamental pepper (*Capsicum annuum* L.). Genetics and Molecular Research. 13: 8876 – 8887. 2014.

25. Vivas M, Silveira SF, Cardoso DL, Pereira MG, Vivas JMS, Ferreguett GA. Capacidade combinatória em mamoeiro para resistência a oídio. Bragantia 71:455-459. 2012.

26. Engelsing MJ, Rozzetto DS, Coimbra JLM, Zanin G, Guidolin AF. Capacidade of combinação em milho para resistência to Cercospora zeae-maydis. Revista Ciência Agronômica. 42: 232-241. 2011.

27. Miranda JEC, Costa CP, Cruz CD. Análise dialélica em pimentão I: capacidade combinatória. Revista Brasileira de Genética. 11: 431-440. 1998.

28. Medeiros AM, Rodrigues R, Gonçalves LSA, Sudré CP, Oliveira HS, Santos MH. Gene effect and heterosis in Capsicum baccatum var. pendulum. Ciência Rural. 44: 1031–1036. 2014.

29. Gomide ML, Maluf WR, Gomes LAA. Heterose e capacidade of combinatória of pimentão linhagens (*Capsicum annuum* L.). Ciência e Agrotecnologia. 27: 1007-1015. 2003.

30. Santos RL, Pavan MA, Silva N, Gioria R, Souza Neto IL. Estimativas et al. Estimativas de capacidades de combinação em cebola para resistência a raíz rosada and agrronomicos characters. Summa Phytopathologica. 41: 133-137. 2015.

31. Hei N, Hussein S, Laing ME. Heterosis and combining ability of slow rusting stem rust resistance and yield and related traits in bread wheat. Euphytica. 207: 501-514. 2016.