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Intraspecific Cross-Compatibility in Ornamental Pepper

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Abstract

The production of *Capsicum* for ornamental purposes in Brazil has increased in recent years. To support the activities of this promising market, it is essential to develop new cultivars by hybridization. The knowledge of cross compatibility is also important in plant evolution research as it provides new genetic combinations and promotes speciation. There are few records of intraspecific compatibility studies in *Capsicum*. The objective of this work was to evaluate and describe cross compatibilities in accessions of *Capsicum annuum*. This experiment was carried out in a greenhouse at Universidade Federal da Paraíba (UFPB). Nine lines of *Capsicum annuum* (UFPB 45, UFV 46, UFPB 132, UFPB 134, UFPB 390, UFPB 392, UFV443, UFV 448, and UFV 449), belonging to the Horticultural Germplasm Bank of UFPB and Universidade Federal de Viçosa (UFV), were chosen for the study based on their broad genetic background and phenotypic diversity. They were crossed according to a full diallel schedule. The manual crosses were made at pre-anthesis stage in emasculated flowers. The percentage of fruit set was estimated as the number of fruits formed divided by the total crosses made and varied from 20 to 100%. The intraspecific compatibility varied both with the direction of the crossings and the parents used in the crossing, showing intraspecific incompatibility exists and depends on the genotypes. Parthenocarpic fruits and fruits with very few seeds were observed. Some fruits showed apocarpic. Some crosses showed anthocyanin in the placenta tissues. The knowledge of the intraspecific compatibility as well as of the direction of crossing is extremely important for success in hybrid breeding programs.

INTRODUCTION

Brazil has a broad diversity of species of the genus *Capsicum*. This diversity can be used as basis for genetic breeding programs with ornamental purposes (Rêgo et al., 2003; Nascimento et al., 2012). Production of pepper plants for this specific purpose has increased in the last years in the country (Finger et al., 2012).

To be used as ornamental plants the pepper must have characteristics that give aesthetic value, such as variegated leaves, dwarf plants, erect growth habit, erect fruits and colorful flowers. Beside this, the resistance to ethylene is necessary (Carvalho et al., 2006; Segatto et al., 2013; Rêgo et al., 2011a).

The genus *Capsicum* has between 25 and 30 species, five of them are domesticated: *C. annuum*, *C. baccatum*, *C. frutescens*, *C. chinense*, and *C. pubescens* states that (Heiser, 1995). Among the species of this genus, *C. annuum* is the most widely cultivated and the most important economically (Heiser, 1976; Pickersgill, 1997). It is also considered as the most well-known domesticated species around the world (Eshbaugh, 1993). This species has two botanical forms that distinguish mainly for the color of their corolla: *C. annuum* var. *annuum*, (white corolla) and *C. annuum* var. *glabriusculum* (purple corolla) (Viñals et al., 1996). Their flowers are hermaphroditic and despite the predominance of natural self-pollination, commercial hybrids have been traditionally developed by hybridization in the last 15 years (Nascimento et al., 2013).

Hybridization is an important factor in the evolution of plants, as source of new

genetic combinations and as a mechanism of speciation; it is useful in the cultivation of plants as a way to insert a desirable attribute, resulting in new cultivars of agronomic interest (Cruz and Regazzi, 1994; Gonçalves et al., 2011).

For successful intra- and inter-specific hybridization, in genetic terms, it is necessary that meiosis is regular, so it will result in the formation of viable gametes (Martins et al., 2010), i.e., the parents must be closely related genetically and show some chromosomal homology, reducing incongruity problems, and thus make the hybrid possible (Prestes and Goulart, 1995).

Other factors contributing to the restriction of hybridization studies with *Capsicum* are due to the difficulty to handle small flowers to perform crossings and the scarce production of seeds per fruits, since they are usually too small and extremely pungent, which makes it difficult to extract the seeds (Rêgo et al., 2012).

However, in *Capsicum* breeding programs few intraspecific hybridization registers are available (Nascimento et al., 2012). The objective of the present study was to evaluate and describe the intraspecific compatibility in a selection of *C. annuum* genotypes.

MATERIALS AND METHODS

The experiment was conducted from January to November 2014, in a greenhouse at the Biotechnology Section of the Center for Agricultural Sciences of Universidade Federal da Paraíba (CCA-UFPB). The Areia city is located in the middle region of the Agreste of Paraíba State, at an altitude of 618 m showing humid tropical climate with dry summer, with the rainy season in the autumn-winter period to begin in January/February and end in September, and may be delayed to October. The average temperature is 23°C, the average relative humidity of 80% and the average annual precipitation is 1400 mm (Mascarenhas et al., 2005).

Seeds were sown in a 200-cell expanded polystyrene tray using a commercial substrate (Plantmax), with pH 5.7 with organic matter and 2.37 g/dm³, macro- and micro-nutrients such as Ca + Mg + Al, M, P, K at the concentrations required for growth and development of the plant. When plantlets displayed four pairs of definitive leaves, they were transplanted to 900-ml pots using the same substrate. The cultivation followed the recommendations made by Filgueira (2000).

Nine non-related and contrasting parents of *Capsicum annuum* (UFPB 45, UFV 46, UFPB 132, UFPB 134, UFPB 390, UFPB 392, UFV443, UFV 448 and UFV 449) from the Horticultural Germplasm Bank of Universidade Federal da Paraíba (UFPB) and Universidade Federal de Viçosa (UFV) were used. They were pre-selected based on morpho-agronomic and qualitative traits and also on resistance to ethylene (Table 1).

All crossings and their reciprocals were made in a diallel arrangement, generating 72 hybrid combinations. At least ten crossings were made for each hybrid combination. Crossings were made manually at pre-anthesis stage in emasculated flower buds. Immediately after emasculation, flowers were pollinated by moving the pollen from a plant to the stigma of the recipient flower, with 100% of pollen germination and viability. After pollination, the crossed flowers were covered with foil to prevent contamination (Nascimento et al., 2012, 2013; Rêgo et al., 2012).

The ripe fruit was collected on average one to two months after pollination, varying according to the genotype. The number of seeds per fruit was counted as well. The percentage of fruit set was calculated as the number of fruits formed divided by the total crosses made.

The Pearson correlation between the evaluated traits was calculated. The analysis was performed using the computer program Genes (Cruz, 2006).

RESULTS AND DISCUSSION

The percentage of fruit set varied from 20 to 100% (Table 2) and the average number of seeds per fruit varied from 12 to 75 (Table 3). These results demonstrate that the knowledge of the intraspecific compatibility as well as of the direction of crossing is extremely important to obtain high seed amounts of intraspecific hybrids in ornamental

pepper breeding programs.

The correlation between the fruit set of the crossings and the number of seeds per fruit was 63.58%. As expected, the correlation was high indicating that selection of plants with cross compatibility will also cause an increase in the number of seeds per fruit. Cross et al. (1988) state that, in breeding programs, correlation between traits should be taken into account, because changing one trait, by selecting, cause change in another trait related to it.

The combinations with highest percentage of fruit formation were 134×390 (100%), 443×448 (90%), 132×443 (90%) and combinations 448×132 (100%), 134×45 (91%), 443×392 (91%), 449×392 (91%) and 392×134 (90%). Low compatibility was observed for the combinations 45×448 (20%), 449×46 (29%), 132×448 (30%), 45×134 (36%) and combination 449×448 (36%) (Table 2).

Given the observed results, it can be stated that the intraspecific compatibility varied both with the direction of crosses and with the utilized lines. Similar results were obtained by Nascimento et al. (2012), who evaluated intraspecific compatibility also in other *C. annuum* accessions. Costa et al. (2009) stated that the fruit set in a cross depends on the background of the utilized accession of the *Capsicum* species.

Despite of low percentage of fruit set, reciprocal combinations 449×448 and 449×46 showed the highest number of seeds per fruit: 75 and 73, respectively. It is known that success in hybridization involves not only the compatibility but also pollen germination, growth of the pollen tube, fertilization, development of embryo and endosperm, and seed maturation (Debbrema et al., 2013). In this regard, in addition to the aforementioned combinations, 46×134 (73), 46×449 (64), 449×134 (63), 46×390 (62), 449×443 (61) also had a good seed number per fruit (Table 3).

The best female parents were 46, 134, 392, 443 and 448 with a cross success rate above 65%, while 45, 392 and 449 were the best pollen donors. (Table 2). Although the genotypes belong to the same species but genetic background is different which may explain the differences in genetic complementation between them. The definition of parents to be used in crossing is essential to determine the cross direction. According to Rêgo et al. (2009b) it influences the vigor of hybrids seeds.

When parents 46 and 449 were used as female parents, the number of formed seeds was higher than 50 (Table 3). When they were used as male parent the number of seeds per fruit was reduced to 30 seeds per fruit.

Hybridization among varieties of the same species in general produces a good number and quality of seeds (Rêgo et al., 2011b), but variations may occur depending on the genetic complementation of each cross. In the present study, parthenocarpic fruits were observed in the following crosses: 132×449 (12.5%), 448×132 (9%), 448×443 (23%) and 443×45 (27%). Finger et al. (2012) highlighted the use of ornamental pepper with a dual purpose: as a functional food (fruits can and should be consumed or used for making teas or spices) in addition to its use in the indoor decoration and gardens. Since the presence of seeds complicates the fruit handling in preparation of sauces and pasta, these hybrids can be selected (Shifriss and Eidelman, 1986; Tofanelli et al., 2003).

When parents 45, 132 and 392 were used as females, all hybrids showed anthocyanin pigmentation in the placenta. Ornamental pepper can also be consumed in natura (Finger et al., 2012). Beside this, there is an increasing demand for vegetables with high contents in health promoting compounds according to Bosland and Votava (2000).

CONCLUSIONS

Intraspecific hybrids are an important source of variability in breeding programs, and the knowledge of the intraspecific compatibility as well as of the direction of crossing is extremely important for success in hybrid breeding programs. Results obtained in this study are useful for further breeding in ornamental pepper.

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Tables

Table 1. Qualitative description of the *Capsicum* hybrids and lines used in this study.

Genotype	GH	LC	CC	RFC	FS	PPS	SE
45	Erect	Variegated	Purple	Dark red	Triangular	Persistent	Tall
46	Erect	Light green	White	Red	Triangular	Easy	Tall
132	Erect	Light green	Purple	Red	Elongate	Easy	Medium
134	Intermediate	Dark green	White	Orange	Triangular	Persistent	Short
390	Erect	Light green	White	Red	Rounded	Intermediate	Medium
392	Erect	Purple	Purple	Red	Rounded	Intermediate	Short
443	Intermediate	Dark green	White	Red	Triangular	Easy	Tall
448	Erect	Green	White	Orange	Triangular	Persistent	Tall
449	Erect	Dark green	White	Red	Elongate	Persistent	Tall

GH - growth habit; LC - leaf color; CC - corolla color; RFC - ripe fruit color; FS - fruit shape; PPS - persistence of peduncle with stalk; SE - susceptibility to ethylene.

Table 2. Percentage (%) of fruits formed in nine genotypes of *Capsicum annuum*.

♀/♂	45	46	132	134	390	392	443	448	449	Mean*
45	100	80	50	36	64	53	67	20	60	53.75
46	61	100	77	77	53	78	73	57	75	68.87
132	83	40	100	64	44	40	90	30	47	54.75
134	91	70	64	100	100	83	69	64	69	76.25
390	77	70	57	53	100	69	40	70	80	64.5
392	75	71	69	90	85	100	77	40	62	71.12
443	80	40	58	45	69	91	100	90	60	66.62
448	50	50	100	69	75	57	60	100	70	66.37
449	69	29	44	40	27	91	43	36	100	47.37
Mean*	73.2	56.2	64.8	59.2	64.6	70.2	64.8	50.8	65.3	

* Average of hybrid combinations.

Table 3. Number of seeds per fruit in each cross in nine genotypes of *Capsicum annuum*.

♀/♂	45	46	132	134	390	392	443	448	449	Mean*
45	20	44	32	16	36	25	35	21	20	28.62
46	47	50	53	73	62	57	56	45	64	57.12
132	21	18	29	23	22	20	22	14	22	20.25
134	42	26	40	49	30	31	38	40	31	34.75
390	19	19	27	32	28	28	19	21	23	23.5
392	16	23	23	20	23	23	20	12	20	19.62
443	25	47	29	37	37	37	46	29	40	35.12
448	18	34	29	21	28	29	26	38	28	26.62
449	43	73	43	63	58	38	61	75	42	56.75
Mean*	28.8	35.5	34.5	35.6	37	33.1	34.6	32.1	31	

* Average of hybrid combinations.