

## Selection of F<sub>3</sub> populations of *Capsicum annuum* for greenhouse production

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### Abstract

*Capsicum annuum* is one of the most important plant species in the world. México has the greatest diversity for this plant. However, its production is limited due to the scarcity of improved varieties for greenhouse production. Therefore, the development of high-yield varieties would be possible through the genetic recombination of native varieties (Creole populations) and superior cultivars. Therefore, the purpose of this research work was to assess and select outstanding F<sub>3</sub> populations for greenhouse production. The work was carried out in a greenhouse at Saltillo, Coahuila Mexico in 2018, involving 8 parents, in which 3 varieties were used as female (pollen-receptor plants), 5 varieties as males (pollen-donor plants) and 9 F<sub>3</sub> populations derived by selfing from 9 F<sub>2</sub> populations. The parents and F<sub>3</sub> populations composed 17 treatments that were established in a greenhouse under a randomized block design with three replications. The variables were total fruit yield, average fruit weight, total number of fruits per plant, ascorbic acid content, total capsinoids, days to flowering, days to harvest, final plant height, and basal stem diameter. Significant differences were found in all variables of F<sub>3</sub> populations. The highest RTF (total fruit weight) belonged to P<sub>1,4</sub> and P<sub>1,6</sub>, with 1647.0 and 1652.0 g/plant, respectively. In terms of CAA (ascorbic acid content), population P<sub>2,4</sub>, was significantly superior to the rest of the genotypes and exceeded the best parent by 19.8%. We concluded that populations P<sub>1,4</sub>, P<sub>1,6</sub> and P<sub>2,4</sub> may be used to develop cultivars with high yield and high quality for greenhouse production.

**Keywords:** *Capsicum annuum*, transgressive segregation, vitamin C, protected agriculture.

### Introduction

The *Capsicum annuum* species is one of the most important cultivated horticultural species in the world. Mexico is the second leading global producer with 173 thousand hectares. This crop is also a source of 12000 jobs for growers (SIAP, 2018) and provides more than 30 million salaries to day laborers in the agrochemical, transportation, storage and trade industries (Ramírez Meraz et al., 2019). Its great potential is due to its high global consumption, being one of the most widely used condiments in the world. Consumption rate for Asia and the Middle East is 3% to 4%. Globally, the rate of consumption is 2% to 3% per annum (Olatunji and Afolayan, 2018).

More than 2 billion individuals in the world are facing micronutrient deficiencies, such as zinc, iodine, and iron, followed by vitamins. However, hot pepper consumption worldwide can reduce the human micronutrient deficiency. Thus, sufficient amounts of micronutrients can be provided by incorporating the pepper fruit with a common diet that could

beneficially help to combat nutrient deficiency (Motukuri and Jaswanthi, 2020). Chili pepper is a source of vitamins (A, B<sub>6</sub>, C and E), antioxidants, minerals (K, P, Mg, Ca, Fe,) and fiber (Olatunji and Afolayan, 2018; USDA, 2016) for standard reference release 28 (revised May 2016). It is indispensable for human nutrition and it is raw material for the industrial sector. Despite being the center of origin, Mexico only produces 40% of the green chili peppers eaten in the country; 60% come from China (Seva Rivadulla, 2019). Currently, there is a drop in production, which is associated with limited cultivable lands, due to conversion of agricultural lands to urban, degradation and other soil and climatic factors (FAO, 2019). In Mexico, only 15.5% of the green chili peppers (Jalapeño, Serrano, Poblano, sweet pepper) come from protected agriculture, using bred varieties and sophisticated production technologies (Clausen et al., 2017). To encounter this problem, it is necessary to produce varieties of chili peppers for cultivation in greenhouse, as an alternative to improve productivity in this crop. A more

efficient use of inputs occurs with the use of improved seeds, considering greater production and fruit quality and cost-benefit ratio. Therefore, the development of improved varieties and the use of other technologies are alternatives to improve productivity. The high yield of *Capsicum annuum* will be guaranteed with the use of improved cultivars and efficient use of water and nutrition (Maraña Santacruz et al., 2018).

A hybridization or pedigree selection-breeding program must ensure proper trait combination and good trait selection to obtain high-quality products (Márquez, 1988). The purpose of this research work was to assess and select  $F_3$  outstanding populations for greenhouse production.

## Results and Discussion

### Yield and yield components

Parental and  $F_3$  population analysis presented significant differences ( $P < 0.01$ ) among RTF, NFP and PPF genotypes. Populations  $P_{1,4}$  and  $P_{1,6}$ , had the highest yield per plant, with 1647.0 and 1652.0 g/plant, respectively, significantly exceeding the parents ( $P < 0.01$ ), creole Mirador, UANs and the populations  $P_{2,4}$  and  $P_{2,5}$  (Table 2). The estimated yield in these populations was 68.6 and 68.8 t/ha, respectively, although they were significantly equal to the origin. The populations  $P_{1,4}$  and  $P_{1,6}$  were higher by 34.4 and 34.8% than their UANj parents and more than 18% than the paternal parents, with the advantage that the fruit of the populations  $P_{1,4}$  and  $P_{1,6}$  are of the UANj type, which are considered outstanding. Also  $P_{1,4}$  and  $P_{1,6}$  populations exceeded the Mexico's average production by 333%, which reached 20.6 t/ha in 2019 (SIAP, 2019). García et al. (2014) obtained 55 t/ha of jalapeño chili pepper yield, while García Sandoval et al. (2016) obtained only 38 t/ha. Populations  $P_{1,4}$  and  $P_{1,6}$ , exceeded 25% up to 80% the production obtained in previous research works. Maximum yield reported in Mexico for Jalapeño chili pepper Mita variety, grown under greenhouse conditions, was 65.2 t/ha (Duarte et al., 2012), which is lower than the yield obtained in this research work.

Creole Mirador (parent) showed the highest NFP (61.6), although it was equal ( $P \leq 0.05$ ) to maternal parents. However, PPF was 8.9 g. Therefore, it does not have significant influence on RTF. This coincides with the results reported by Cebula (1995), who mentioned that some hybrids with high NFP were smaller. These fruits reached smaller size (length and width), as they are the product of a highest fruit-set. Female parents were significantly different ( $P \leq 0.05$ ) from male parents in terms of NFP, obtaining an average of 10.14; although other research works obtained NFP of 7 to 11.8 (Moreno-Pérez et al., 2011).

UANcN genotype had the highest PPF, which was equal to UANrd and UANShw and higher than the PPF of  $F_3$  populations, which ranged between 21.8 and 55 g. The  $P_{1,4}$  and  $P_{1,5}$  populations were significantly superior than the female parents. In this research, the selection process focused on fruit development, with traits similar to UANj type. Therefore, the PPF of  $F_3$  is between twice the weight of the female parents and 50% the weight of male parents, enabling to take advantage of additive genetic variance (Suryakumari et al., 2010).

Maternal parents had a PPF of 15.4 g, matching the results reported by Ramírez Meraz et al. (2019) in Serrano hybrids

with a PPF between 9 and 14 g.  $F_3$  populations had 36.4 g, coinciding with the results of García Sandoval et al. (2016), who found that 68% of the Jalapeño chili pepper lines in their research work exceeded 30 g.  $P_{1,4}$  and  $P_{1,5}$  UANj populations had the highest PPF, 55 and 52.7g, respectively; which is attributed to the interaction and gene recombination of the parental populations and the preservation of such trait by phenotypic selection.

### Fruit quality









In CAA and CAPs variables, we found significant differences among parents and  $F_3$  populations ( $P \leq 0.01$ ). Table 3 shows that parents  $P_6$  and  $P_7$  had higher CAAs and were significantly higher than the rest of the male and female parents. The  $P_{1,5}$  and  $P_{1,7}$  populations of  $F_3$  were significantly equal to four male progenitors in CAA. However,  $P_{2,4}$  population was significantly superior among all the genotypes, with 224.9 mg/100g; and 19.8% more CAA than the best parent, showing a gene interaction that fosters the overexpression of this trait. CAA of  $P_{2,4}$  population was superior in terms of CAA than 30 collections of Guajillo chili pepper from Durango and Zacatecas, Mexico (Martínez-Damián et al., 2019).

On the other hand, Cares et al. (2015) reported a CAA in pepper ranging between 274.3 and 355.5 mg/100g, values which are significantly higher than those found in this research. It is known that CAA in *Capsicum* species is widely affected by environmental factors, such as high temperatures, salinity, biotic factors, or nutritional factors. Preciado-Rangel et al. (2019) indicated that an increase in K in the nutrient solution increases vitamin C content in Serrano chili pepper. Therefore, knowledge on the genotype-environment interaction can be used in breeding programs to obtain fruits with high CAA content, in order to improve nutrition. The CAA is an essential antioxidant, capable of neutralizing free radicals, regenerate vitamin E and act as a co-factor of  $\alpha$ -ketoglutarate-dependent dioxygenase enzymes (Villagrán et al., 2019). Daily recommended vitamin C intake requirements range from 75 to 90 mg/day (Valdez, 2006). This information is important for backcross breeding programs that can help increasing the values of this antioxidant and produce high-yielding crops with nutraceutical quality.

UANs chili pepper was significantly superior to the rest of the genotypes in terms of CAPs content, followed by UANj and Creole Mirador, which exceeded significantly the male parents and  $F_3$  populations. Male parents were significantly equal and had the least CAPs content, while a wide variability was showed in CAPs of  $F_3$  populations, with a range 6361.4 to 10264.9 SHU. The population  $P_{3,8}$  (10264.9 SHU) and  $P_{1,4}$  (9716.6 SHU) had the highest CAPs but were statistically equal. Maternal parents had an average of 13590.9 SHU, the fathers had 776.4 and  $F_3$  populations had 7183.7 SHU, outstanding  $P_{3,8}$  genotype with 10,264.9 SHU.

In *Capsicum* there are different levels of itching characteristic that is determined by genetic, environmental and genetic-environmental interaction factors. Therefore, the conditions of management of chili cultivation also affect the content of capsaicinoids (Garcés-Claver et al., 2007). On the other hand, Rostini et al. (2019) stated that Capsaicin is a polygenic inherited trait, controlled by four pairs of genes that affect

**Table 1.** Parents and F<sub>3</sub> populations used in this research work.

Genotypes	Description
Female parents	
UANj	 Spicy fruit, 6 to 8 cm in length and diameter of 2.5 to 3 cm
Creole mirador	 Spicy fruit, 4 to 6 cm in length and diameter of 1.8 to 2.3 cm
UANs	 Spicy fruit, 5.8 to 6 cm in length and diameter of 1.9 to 2.0 cm
Male parents	
UANOg	 Sweet pepper, 8.5 to 8.6 cm in length and diameter of 8.2 to 8.4 cm
UANRd	 Sweet pepper, 8.5 to 8.6 cm in length and diameter of 8.2 to 8.4 cm
UANShw	 Sweet pepper, 10 to 12 cm in length and diameter of 8.2 to 8.6 cm
UANYw	 Sweet pepper, 6.5 to 7.0 cm in length and diameter of 7.9 to 8.0 cm
UANCn	 Sweet pepper, 8.0 to 8.2 cm in length and diameter of 8.9 to 9.0 cm
F <sub>3</sub> populations	F <sub>3</sub> origin
P <sub>1,4</sub>	UANj x UANOg Crossing
P <sub>1,5</sub>	UANj x UANRd Crossing
P <sub>1,6</sub>	UANj x UANShw Crossing
P <sub>1,7</sub>	UANj x UANYw Crossing
P <sub>2,4</sub>	Creole Mirador x UANOg Crossing
P <sub>2,5</sub>	Creole Mirador x UANRd Crossing
P <sub>2,6</sub>	Creole Mirador x UANShw Crossing
P <sub>3,4</sub>	UANs x UANOg Crossing
P <sub>3,8</sub>	UANs x UANCn Crossing

**Table 2.** Mean yield values and yield components in *Capsicum annuum* parents and F<sub>3</sub> populations.

Genotypes	Total fruit yield g/plant	Fruit per plant	Average fruit weight g
P1.-UANj	1225.2 abc*	56.6 ab*	23.2 de*
P2.-Creole mirador	552.3 e	61.6 a	8.9 e
P3.-UANs	678.6 bcde	48.3 abc	14.1 de
P4.-UANOg	1395.0 ab	11.4 fg	123.0 b
P5.-UANRd	1240.5 abc	8.7 g	131.6 ab
P6.-UANShw	1329.6 ab	11.7 fg	127.8 ab
P7.-UANYw	1243.9 abc	10.4 g	123.8 b
P8.-UANCn	1247.1 abc	8.5 g	153.6 a
P1,4	1647.0 a	29.6 de	55.0 c
P1,5	1487.2 ab	29.3 de	52.7 c
P1,6	1652.0 a	43.2 bcde	35.6 cde
P1,7	1301.5 ab	34.5 cde	41.2 cd
P2,4	609.9 de	27.5 ef	22.3 de
P2,5	860.9 bcde	39.0 cde	21.8 de
P2,6	1239.8 abc	43.7 bcd	28.6 cde
P3,4	1205.8 abc	32.2 cde	32.9 cde
P3,8	1177.1 abcd	30.5 de	37.8 cd
DMS	584.15	16.16	28.25

DMS= minimum significant difference; \*values followed by the same letter are not statistically different.

**Table 3.** Mean values of quality in *Capsicum annuum* parents and F<sub>3</sub> populations.

Genotypes	Ascorbic acid content	Capsaicinoids
	mg/100g	SHU
P1.-UANj	88.7 ef*	12645.9 b*
P2.-Creole Mirador	90.6 ef	12936.4 b
P3.-UANs	113.9 de	15190.6 a
P4.-UANog	140.7 cd	965.7 i
P5.-UANRd	144.2 cd	849.4 i
P6.-UANShw	187.7 b	763.8 i
P7.-UANYw	157.6 bc	635.2 i
P8.-UANCn	136.3 cd	668.0 i
P1,4	77.8 fg	9716.6 cd
P1,5	124.4 cd	8083.7 ef
P1,6	67.7 fg	6361.4 g
P1,7	127.9 cd	7264.3 fg
P2,4	224.9 a	7966.6 ef
P2,5	50.6 g	4634.9 h
P2,6	62.4 fg	7774.7 ef
P3,4	46.4 g	8652.7 de
P3,8	60.5 fg	10264.9 c
DMS	33.46	1065.7

DMS= minimum significant difference; \*values followed by the same letter are not statistically different, SHU = Scoville units.

**Table 4.** Mean values of precocity in *Capsicum annuum* parents and F<sub>3</sub> populations.

Parents	Days to flowering	Days to harvest
	P1.-UANj	61.6 bc*
P2.-Creole Mirador	81.1 a	114.1 cd
P3.-UANs	54.0 bcd	129.5 abc
P4.-UANog	60.2 bc	141.0 ab
P5.-UANRd	59.0 bc	96.7 d
P6.-UANShw	61.9 b	128.1 abc
P7.-UANYw	51.6 cde	109.6 cd
P8.-UANCn	49.1 def	110.9 cd
P1,4	36.2 gh	110.0 cd
P1,5	31.2 h	105.0 cd
P1,6	31.7 h	119.8 bcd
P1,7	31.6 h	107.4 cd
P2,4	34.3 gh	104.9 cd
P2,5	39.0 fgh	109.5 cd
P2,6	30.4 h	106.3 cd
P3,4	42.1 efg	119.0 bcd
P3,8	37.0 gh	118.9 bcd
DMS	10.14	25.51

DMS= minimum significant difference; \*values followed by the same letter are not statistically different

**Table 5.** Mean values of agronomic variables in parents and F<sub>3</sub> populations of *Capsicum annuum*.

Genotype	ADP	DBT
	cm	mm
P1. UANj	53.4 g	11.5 def
P2. Creole Mirador	65.0 fg	8.3 f
P3. UANs	100.3 def	11.4 def
P4. UANog	82.8 efg	23.7 ab
P5. UANRd	53.3 g	18.5 bcd
P6. UANShw	70.7 efg	18.2 bcde
P7. UANYw	56.3 g	21.8 abc
P8. UANCn	50.7 g	20.4 bc
P1,4	155.5 abc	18.2 bcde
P1,5	124.9 cd	19.8 bcd
P1,6	167.5 ab	19.3 bcd
P1,7	110.3 de	20.7 abc
P2,4	77.5 efg	9.7 ef
P2,5	78.1 efg	14.2 cdef
P2,6	124.1 cd	19.6 bcd
P3,4	175.1 a	29.2 a
P3,8	136.1 bcd	23.7 ab
DMS	37.12	8.56
CV	12.2	15.3

ADP = The final plant height; DBT = basal stem diameter; DMS= minimum significant difference; CV = Variation coefficient; \*values followed by the same letter are not statistically different.

CAPs' synthesis pathways in a differential way, due to the expression levels of involved genes. This information is quite important to breed this plant species.

### Precocity

Precocity is important, because it enables earlier harvesting and thereby lower production costs, especially when capsicum is grown in greenhouse, which is very input demanding system. There were significant differences ( $P \leq 0.01$ ) in DAF and DAC among parents and  $F_3$  populations. In DAF, there was a range of 49.1 to 81d, with an average of 59.8 days, showing variability among the parents. The later was Mirador, while the most early was UANcn with significant difference. However, in  $F_3$  populations, the range of DAF was 30.4 ( $P_{2,6}$ ) to 42.1 ( $P_{3,4}$ ), with an average of 34.8 days. Population  $P_{2,6}$  had the highest precocity (30.4 DAF). This is important, because the DAF difference between parents and their offspring was 25 days (Table 4). Therefore, we can infer that DAF reduction in  $F_3$  populations is due to the transgressive segregation of this trait. The transgressive segregation is referred to genetic recombination in generations after  $F_1$ . Therefore, we can conclude that DAF is a polygenic trait and can be reduced by selection without reducing yield.

We found significant differences ( $P \leq 0.01$ ) among the genotypes in terms of DAC. UANj was the latest (149 DAC), although it was significantly equal to UANs. Female parents were later with an average of 130.8 days. Male parents UANog (141 DAC) and UANShw (128.1 DAC) were the latest and significantly equal, while different to UANRd ( $P \leq 0.01$ ) (96.7 DAC). This parent was significantly equal to  $F_3$  populations, with an average of 111.2 DAC.  $P_{2,4}$  and  $P_{1,5}$  populations were earlier similar to Jalapeño chili pepper commercial varieties, Don Benito, Don Pancho and Kohulich that were harvested 110 after transplanting (Ramírez Meraz et al., 2015). DAC variable showed transgressive heritage, since the average number of days required by populations  $P_{1,4}$  and  $P_{1,6}$  were lower than the DAC of the parents.

### Agronomic variables

Among parents and  $F_3$  populations, there were significant differences ( $P \leq 0.01$ ) in ADP and DBT. Table 5 shows that in  $F_3$  population,  $P_{3,4}$  had higher ADP (175.1) cm, although it was significantly equal to populations  $P_{1,6}$  (167.5cm) and  $P_{1,4}$  (155.5cm), while significantly exceeded ( $P \leq 0.01$ ) all other populations and parents. In greenhouse crops, the ADP variable is important to take advantage of the higher air-conditioned environmental volume inside the greenhouse prolonging the production cycle.  $F_3$  populations exhibited higher ADP with an average of 127.67 cm, while maternal parents 72.9 cm and paternal parents 62.7 cm.  $F_3$  populations exceeded the average maternal progenitors by 75.1% and by 103.6% female parents. This is important since the plant with continuous growth, maintains flower production for longer (Aguilar-Delgado et al., 2018) time increasing the production cycle.

The  $F_3$ ,  $P_{3,4}$  population had the highest DBT (29.2 mm) but was significantly equal to  $F_3$  populations ( $P_{3,8}$  and  $P_{1,7}$ ) and paternal parents ( $P_4$  and  $P_7$ ). Stem diameter is important, since along with the higher DBT, there is greater capacity to support the weight of branches, leaves, flowers and fruits. Therefore, the risk of rupture of the aerial part of the plant will be lower

(Elizondo-Cabalceta and Monge-Pérez, 2016). On the other hand, Cankaya et al. (2010) indicated that both ADP and DBT are significantly related to RTF per plant and that this variable should be used with the aim of increasing yield per plant in pepper populations. In sweet chilli, the diameter of the stem ranges from 14.0 to 27.3 mm (Moreno et al., 2011; Reséndiz-Melgar et al., 2010). Parent Mirador has a thin, low and fragile stem that limits high production in greenhouse. This genotype did not develop properly, even in controlled environment conditions with optimal irrigation and nutrition. However, some  $F_3$  populations derived from Mirador exhibited outstanding yield characteristics ( $P_{2,6}$ ) and fruit quality ( $P_{2,4}$ ).

## Materials and Methods

### Location

This research work took place at "Universidad Autónoma Agraria Antonio Narro" (UAAAN) in Saltillo, Coahuila, Mexico, located at 25°21'19" North latitude, 101°01'48" West longitude ("Servicio Meteorológico Nacional"-National Weather Service, 2018).

### Plant materials

Four types of *Capsicum annuum* were studied (Jalapeño, Mirador, Serrano and sweet pepper selected at UAAAN). The study included the original parents (3 females and 5 males) and 9  $F_3$  offspring populations from derived from parental crossings (Table 1).

To obtain the  $F_3$  populations, the following procedure was carried out in a greenhouse.

1- three varieties of hot chili (1- Jalapeño, 2- Mirador, 3- Serrano) were selected as females and five varieties of pepper (4- UANog, 5- UANRd, 6- UANShw, 7- UANYw, 8- UANcn) that were used as males.

2- By manually crossing the females with the males, only nine  $F_1$  hybrids were obtained (Table 1).

3- In each of the  $F_1$  populations, self-fertilization was allowed in a natural way and the best plants were selected, from which the seeds that showed higher characteristics over nine populations were obtained.

4- In the  $F_2$  populations, natural self-fertilization is again included and the best plants from each  $F_2$  populations were selected to form nine  $F_3$  populations.

### Establishment and management of parents and $F_3$ populations

Parental seeds and  $F_3$  populations were sown in 200-cavity polystyrene trays. The substrate was peat (Premier Sphagnum Peat Moss, Angeles Millwork & Lumber Co.) and mineral perlite (*Termolita* by Hortiperl) in a 70:30 ratio, respectively. Transplantation took place 50 days after planting, establishing 12 plants per plot in 25 cm-high x 1.60 m-wide beds, with white plastic mulching, subsurface drip irrigation, leaving 30 centimeters between plants, staggered at double row with double-stem pruning and with Dutch type tutored. Plants received drip irrigation at a rate of 0.5 L/plant/day until blooming, gradually increasing to 3 L/plant/day at full production. Nutrition (Steiner, 1984) was applied with the irrigation water according to the crop's developmental stage (15% seedling, 25% growth; 50% development, 75% flowering and 100% fruit filling and harvest).

The crop was established under a fully randomized experimental block design with three replicates. Irrigation was applied every third day, with preventive control every 15 days, using active ingredients such as Imidacloprid, abamectin, thiamethoxam and chlorpyrifos against *Bemisia tabaci*, *Bactericera cockerelli*, *Lirimyza* sp.

#### Yield and yield components

Total fruit weight (RTF) (g/plant) was estimated by weighing all the fruits from 6 plants per treatment in every harvest, using Ohaus Compass™ CX electronic scale. We added the weights before dividing them by the number of plants and the number of cuts. We divided RTF by the number of harvested fruits to estimate average fruit weight (PPF). The number of fruits per plant (NFP) was estimated by counting all the fruits that were harvested throughout the crop season divided by the six harvested plants.

#### Fruit quality measurements

Fruit quality was determined in three fresh fruits per treatment in every replicate of the fifth harvest. Ascorbic acid content (CAA) of the fruits was estimated using AOAC (2000) color-change titration methodology, with 100 g of fruit per treatment.

Capsaicinoids (CAPs) were quantified by Bennet & Kirby method (1968), using physiologically mature fruits and a Bio-145025 BIOMATE-5 spectrophotometer (Thermo Electron Corporation, Madison, USA) at 286 nm wavelength. In order to estimate CAPs, we built a calibration curve of this compound (Sigma, Co.), within 0 to 1.2 mg/ml range. CAPs content of every sample was triple-folded, expressed in Scoville units, (SHU).

#### Precocity measurements

Days to flowering (DAF) and days to harvest (DAC) were determined by counting the days from transplant until every plant had its first flower, and until harvesting the first fruit from every plant. We left ten days between harvests and there were nine harvests within 80 days.

#### Estimation of agronomic variables

The final plant height (ADP) was measured with a tape measure, from the base to the apex of the plant at the end of the production cycle (85 days after the first cut). The basal stem diameter (DBT) was measured at 3cm above the floor surface with an Autotec brand digital vernier.

#### Variance analysis

All the variables subjected to variance analysis and Tukey's mean comparison test ( $P \leq 0.01$ ) using SAS® V.9.0 (SAS Institute Inc., 2002) statistical program.

#### Conclusions

F<sub>3</sub> populations showed transgressive segregation resulting from the genetic recombination of previous generations. The selection can be efficiently used to breed high-yield chili pepper cultivars and quality for greenhouse production. Intercrossing enabled genetic recombination and the expression of high phenotypic variability in yield, yield components, fruit quality and precocity. Populations P<sub>1,4</sub> and

P<sub>1,6</sub>, were the most promising candidates to backcrossing breeding due to their precocity and high yields. Furthermore, population P<sub>2,4</sub>, showed higher ascorbic acid content.

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