

Second Generation (F₂) Hybrid Cultivars for Jalapeño Production

Paul W. Bosland

Department of Agronomy and Horticulture, New Mexico State University, Las Cruces, NM 88003

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Abstract. Chile pepper (*Capsicum* spp.) hybrids are normally produced by hand-emasculating the female parent and then pollinating the emasculated flower by hand. Increased yield has occurred with F₁ hybrid seed, but the seed is considered too expensive by growers to be direct-seeded, a common production practice in the southwestern U.S. chile pepper industry. In ornamental flowers, when F₂ hybrid seed is available, it is cheaper than F₁ hybrid seed. If F₂ hybrid chile pepper cultivars could manifest heterosis, and produce fruit quality acceptable to the chile pepper industry, then a less-costly alternative would be available to growers. A series of field trials with jalapeños was conducted to test F₁ hybrid cultivars to their F₂ progeny for yield and fruit quality. The results indicated that in some instances the F₂ progeny can yield as well as the F₁ hybrid parent. Therefore, F₂ hybrid cultivars can be used in a commercial production system. However, if a male-sterility system is used to produce the F₁ hybrid cultivar, the F₂ progeny will have significantly lower yield than the F₁ hybrid parent, as was the case in one accession in this trial. Nevertheless, F₂ hybrid cultivars are an additional way to supply high yielding hybrid cultivars to growers.

The introduction of F₁ hybrid cultivars has dramatically influenced crop production (Coors and Pandey, 1999). Heterosis or hybrid vigor produced by F₁ hybrid cultivars can significantly increase yield and crop uniformity for maturity and quality. In addition, F₁ hybrid cultivars allow the plant breeder to quickly combine dominantly inherited disease and pest resistance in a single generation. However, the cost of producing F₁ hybrid cultivars in some crops can restrict their use because the seed is too expensive. The high-priced seed of F₁ hybrid cultivars limits their use for some direct-seeded vegetable crops. For example, in chile peppers (*Capsicum annuum* L.) only 2% of the United States acreage is planted to F₁ hybrid cultivars (Janick, 1998).

The second-generation hybrid (F₂ hybrid cultivar) has not received as much attention as a means of providing cost-effective hybrid vegetable cultivars. This may be attributed to the fact that F₂ hybrid cultivars have a reputation of lower yield and unacceptable uniformity of fruit quality. Nevertheless, the cost of F₂ hybrid cultivar seed should be considerably less than that of an F₁ hybrid cultivar, because it can be produced by open-pollination without the precaution against selfing or sibbing that is required for producing F₁ hybrid cultivar seed. Several ornamental flower cultivars are sold as F₂ hybrids rather than F₁ hybrids to reduce seed cost. For example, 'Speckles Mixed' geranium (*Pelargonium* × *hortorum* L.H. Bailey), 'Padparadja' and 'Jolly Joker' pansy (*Viola wittrockiana* Gams.), 'Fuseedia' *Fuchsia hybrida* hort. Ex Sieb and Voss, and 'Kariba Mixed' portulaca (*Portulaca grandiflora* Hook.), are all sold as F₂ hybrid cultivars (Thompson and Morgan,

2004). The retail seed cost of these F₂ hybrid cultivars are about less than one-half the price of a comparative F₁ hybrid cultivar.

In vegetable crops, few F₂ hybrid cultivars are sold. There are reports that F₂ hybrid cultivar vegetable populations can yield as much or nearly as well as the F₁ hybrid population for some crops. Curtis (1941) observed that the F₂ generation of a *Cucurbita pepo* L. hybridization did not differ from the F₁ generation in early or total fruit yields. Both the F₁ and F₂ populations were significantly earlier than either parent. He proposed that F₂ generation seed could be used for commercial planting. In addition, Schuster et al. (1974) reported the hybrid vigor of *C. pepo* hybridizations diminished only slightly in the F₂ generation, but decreased significantly in the next generation (F₃). They suggested that F₁ hybrid seed produced by hand pollination could be multiplied by open pollination to produce F₂ hybrid seed for commercial sale.

Jalapeño chile pepper is an important crop in the southwestern U.S. and Mexico. In 2002 in New Mexico, jalapeños were worth \$3 million at farm-gate alone and with processing, more than \$20 million (NMDA, 2002). The current F₁ hybrid cultivars of jalapeño available to the growers are uniform and high yielding, but relatively expensive as compared to commercially available open-pollinated cultivars of jalapeño. Presently, popular F₁ hybrid cultivars of jalapeño are priced at 25 times the cost of open-pollinated jalapeño cultivar seed (personal observation). This is due in part to the hand labor costs in producing F₁ hybrid cultivars. Manual emasculating and hand-pollination of flowers adds considerable costs to producing F₁ hybrid cultivars of jalapeño.

Most jalapeño growers in the southwestern U.S. direct-seed the crop, therefore, the cost of F₁ hybrid cultivar seed has been prohibitive. Consequently, jalapeño production in the southwestern United States could benefit from

having inexpensive F₂ hybrid cultivar seed available that produces acceptable fruit quality and yield.

To test the feasibility of using F₂ hybrid cultivars to produce an acceptable jalapeño crop, four commercially available F₁ hybrid cultivars of jalapeño were self-pollinated to produce F₂ progeny. The original F₁ hybrid cultivar was then compared to its F₂ progeny for yield, and plant and fruit characteristics.

Materials and Methods

Seed of the F₁ hybrid jalapeño cultivars 'Grande', 'Mitla', 'Perfecto', and 'Tula' were acquired from a commercial seed source. The F₁ hybrid cultivars were grown under insect-proof net cages to produce the F₂ generation seed (Bosland, 1993). The comparison experiments were conducted for 2 years at the Leyendecker Plant Science Research Center (LPSRC), 2.5 km south of Las Cruces, N.M., and at the Fabian Garcia Science Center (FGSC), Las Cruces. The soil type at the LPSRC is a Brazito sandy loam (mixed thermic typic torripsamment) and a Glendale clay-loam (fine-silty, mixed (calcareous), thermic typic torrifluent) at the FGSC.

The original F₁ hybrid cultivar seed along with its F₂ progeny were planted in a randomized complete block design with five replications. Each replication had 36 plants. A single line of plants was spaced 25 cm apart within the row and 1 m between rows. The plants were grown using standard cultural practices for growing jalapeños in southern New Mexico (Bosland et al., 1994). Plots were furrow irrigated throughout the season to maintain optimal plant growth.

For the first year, the data collected included plant height, plant width, single fruit weight, fruit length, fruit width, wall thickness, pungency, and marketable yield (Tables 1 and 2). Two days before the first harvest, six randomly chosen plants in each replication were measured for plant height and plant width. The experiment was harvested three times throughout the season. From the middle of each replication, 10 randomly chosen plants were harvested and the fruit bulked. After harvesting, the fruit were sorted with any fruit deemed unacceptable for the market, i.e., red, diseased, deformed, small, etc., being discarded and only the marketable yield recorded. A random subsample of 10 fruit from each replication was taken from the first harvest and the fruit quality traits measured and recorded (Tables 1 and 2). In the second year, the plots were harvested in a similar manner with the exception that only marketable yield data were collected (Tables 1 and 2). As in the first year, the plots were harvested three times throughout the season. The data of the yield and fruit characteristics of the F₁ hybrid cultivars and the F₂ hybrid populations were compared using Student's *t* test with probability set at 5%.

Results

In both years, at the two research sites (LPSRC and FGSC), the growing seasons were favorable for the production of jalapeños. The marketable yields at LPSRC and FGSC differed between the years. Overall, the yields

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at the FGSC were reduced in the second year as compared to the first year. No obvious factors can be accorded for the reduction in yield. Of course, cultivar by year interactions are common in cultivar trials, and most of the time the exact factors causing the significant change in yields cannot be deduced.

With most comparisons, the F₂ hybrid populations' plant and fruit characteristics were not different from their F₁ hybrid parent (Tables 1 and 2). For the characteristics, fruit width, fruit wall thickness, and pungency, none of the F₂ hybrid populations differed from their F₁ hybrid parent. At the LPSRC, the F₁ hybrid 'Grande' did not differ from its F₂ hybrid population for any of the eight characteristics examined. At the FGSC, 'Grande' and its progeny differed only in fruit length (0.92 cm) and in fruit weight (4.7 g), however, this did not affect the marketable yield.

When plant height and plant width were examined at both locations, only 'Tula' differed from its F₂ hybrid population. At the LPSRC, it was for plant height and at FGSC it was for both plant height and plant width. The F₂ hybrid population was taller than the F₁ hybrid cultivar parent, and was wider at the FGSC. However, these differences would be insignificant for production of the crop.

When the fruit characteristics are examined, the single fruit weight was the same for 'Mitla', 'Grande', and 'Tula' and their F₂ hybrid populations, respectively, at the LPSRC. Only 'Perfecto' differed from its F₂ hybrid population at LPSRC. At the FGSC, 'Mitla', 'Perfecto', and 'Tula' had the same single fruit weight as their F₂ hybrid population, respectively, but it was 'Grande' that differed from its F₂ hybrid population in single fruit weight. The fruit length

of 'Grande' and 'Tula' were the same as their F₂ hybrid population at the LPSRC, and at the FGSC, 'Mitla', 'Perfecto', and 'Tula' had the same fruit length as their F₂ hybrid population, respectively. 'Mitla' and 'Perfecto' differed from their F₂ hybrid population at the LPSRC, and 'Grande' differed from its F₂ hybrid population at FGSC. Overall, these differences in fruit lengths are insignificant in commercial production.

Marketable yield, which is the most important characteristic for commercial production, was the same for 'Grande' and 'Tula' and their F₂ hybrid population for both locations and for both years. In the first year at the LPSRC, 'Mitla' had about 30% greater yield than its F₂ hybrid population, however in the second year, the marketable yield was the same for both populations. For 'Perfecto' the first year's yield was equivalent to its F₂ population, but the second year produced a significant yield reduction in the F₂ population. In the first year at FGSC, 'Mitla' and 'Perfecto' had yield reductions as compared to their F₂ hybrid population. While in the second year, 'Mitla' had the same yield as its F₂ hybrid population, and 'Perfecto' had a yield reduction with its F₂ hybrid population.

Some of the yield reduction in 'Perfecto' can be traced to male-sterile plants in the F₂ progeny. At each location and in each year, the F₂ hybrid population of 'Perfecto' had male-sterile plants. These male-sterile plants did not set fruit, and when they did, the fruit were too small to be commercially acceptable.

Discussion

The results demonstrate that F₂ hybrid cultivars of jalapeño have the potential for providing acceptable marketable yield for com-

mercial production. The results further support that fruit quality characteristics important to the jalapeño processing industry can be met with F₂ hybrid jalapeño cultivars. In fact, the F₂ hybrid populations producing similar yield with acceptable fruit quality characteristics as the F₁ hybrid parent validates the use of F₂ hybrid cultivars of jalapeño for commercial production.

The results also indicate that plant height, plant width, single fruit weight, fruit length, fruit width, wall thickness, pungency, and marketable yield may or may not differ between the F₁ hybrid parent and their F₂ populations depending on year and location. This implies that multiple year and location studies are necessary before an F₂ hybrid cultivar of jalapeño could be released, just as would be expected of an F₁ hybrid cultivar.

Disease resistance could be another limitation to the use of the F₂ hybrid cultivars. If the F₂ hybrid cultivar is derived from an hybridization between a resistant parent and a susceptible parent, the F₂ hybrid cultivar would segregate for resistance. Depending on the inheritance of the disease resistance trait, 25% or more of the individuals would be susceptible and given a conducive environment for disease development, a significant yield loss could occur.

Hybrid seed production in chile peppers is labor intensive, particularly emasculation of flowers on the female parent. The use of male-sterility facilitates the production of F₁ hybrid cultivars. If emasculation is eliminated, the cost of seed production should also be reduced. In this study, the F₁ hybrid 'Perfecto' seems to be produced using a male-sterility system. Male sterility is a recessive trait allowing the F₁ hybrid cultivar to be fully fertile, while in

Table 1. Comparison of plant and fruit characteristics, and marketable yield among four commercial jalapeño first generation (F₁) hybrids and their second generation (F₂) progeny at the Leyendecker Plant Science Research Center, Las Cruces, N.M.

	Plant		Fruit					Marketable yield	
	Ht ^z	Width ^z	Wt	Length	Width	Wall thickness	Pungency	(kg·ha ⁻¹)	
	(cm)	(cm)	(g)	(cm)	(cm)	(cm)	(SHU)	Year 1	Year 2
Grande F ₁	41.8	39.0	21.72	6.96	2.82	0.52	37,240	10,867	11,989
Grande F ₂	40.4	39.1	20.34	6.64	2.78	0.52	57,675	10,673	9,663
Mitla F ₁	35.0	36.8	19.66	6.62*	2.74	0.58	51,755	10,461*	8,123
Mitla F ₂	37.0	36.4	16.94	6.00*	2.56	0.54	41,845	7,355*	6,432
Perfecto F ₁	36.8	36.9	21.40*	6.90*	2.86	0.52	45,375	10,991	12,806*
Perfecto F ₂	38.5	37.8	16.50*	6.20*	2.68	0.50	61,320	9,107	6,297*
Tula F ₁	37.6*	35.4	23.72	7.18	3.08	0.46	73,379	12,671	9,367
Tula F ₂	43.7*	34.5	21.14	6.80	2.98	0.52	72,096	10,930	10,027

^zPlant height and width was averaged from six plants each of five replications.

*Significant difference at $P < 0.05$ in value between the F₁ parent and the F₂ progeny using Student's *t* test.

Table 2. Comparison of plant and fruit characteristics, and marketable yield among four commercial jalapeno first generation (F₁) hybrids and their second generation (F₂) progeny at the Fabian Garcia Science Center, Las Cruces, N.M.

	Plant		Fruit					Marketable yield	
	Ht ^z	Width ^z	Wt	Length	Width	Wall thickness	Pungency	(kg·ha ⁻¹)	
	(cm)	(cm)	(g)	(cm)	(cm)	(cm)	(SHU)	Year 1	Year 2
Grande F ₁	35.1	36.8	21.88*	6.80*	2.70	0.49	81,925	10,507	7,170
Grande F ₂	35.5	36.9	17.18*	5.88*	2.54	0.47	79,497	9,096	7,118
Mitla F ₁	33.0	28.0	17.14	6.22	2.40	0.51	75,844	12,513*	5,530
Mitla F ₂	34.2	29.1	14.38	5.62	2.38	0.47	79,169	9,539*	5,132
Perfecto F ₁	35.0	28.1	19.58	6.46	2.58	0.50	56,655	11,399*	7,990*
Perfecto F ₂	36.6	28.8	17.06	5.94	2.50	0.49	59,919	4,459*	4,603*
Tula F ₁	35.0*	34.1*	20.48	6.28	2.66	0.47	88,431	11,246	8,335
Tula F ₂	40.6*	39.3*	20.12	6.32	2.66	0.49	81,082	9,271	7,540

^zPlant height and width is the mean of six plants from each of five replications.

*Significant difference at $P < 0.05$ in value between the F₁ parent and the F₂ progeny using Student's *t* test.

the F₂ generation, and subsequent later generations, male-sterility manifests itself. The use of male sterility would limit the utility of F₂ hybrid cultivars. Theoretically, 25% of the plants would be male-sterile, and with a self-pollinating crop, pollen would be unavailable to pollinate flowers and allow for fruit set, thus contributing to a 25% reduction in yield. On the other hand, a satisfactory male-sterility system could help reduce the cost of F₁ hybrid seed. This would allow growers access to less expensive F₁ hybrid seed.

In conclusion, it is clear that F₂ hybrid cultivars can have an important role not only in hybrid flowers, but also in jalapeño production. Based on the results of this study, seed producers now have another seed class, in

addition to F₁ hybrids, that will provide good yielding cultivars for growers. The F₂ hybrid cultivar seed of jalapeño could be exploited by seed companies as a hybrid that produces a uniform and high yielding crop, but at a lower seed cost to the grower.

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