Discoveries in Agriculture and Food Sciences - Vol. 13, No. 03
Publication Date: May 25, 2025
DOI:10.14738/tnc.1303.18838.
Akter, L., Hossain, M. M., Quamruzzaman, A. K. M., Habibur Rahman, M., Abdur Rahim, M., & Khatun, R. (2025). Expression of Standard Heterosis for Productive Traits in Sweet Pepper Hybrids. *Discoveries in Agriculture and Food Sciences*, 13(03). 51-63.

Expression of Standard Heterosis for Productive Traits in Sweet Pepper Hybrids

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ABSTRACT

To gather data on the degree of heterosis for various features, the current study was conducted under the net house at the research farm of the Olericulture division, Horticulture Research Centre, Bangladesh Agricultural Research Institute, Gazipur. Winter 2019–20 saw the examination of 28 crosses and a check variety utilizing a randomized complete block design with three replications. The crosses were constructed in a half-dial method. The current findings also showed that the average fruit weight and the number of fruits per plant were the primary determinants of the overall yield per sweet pepper plant. The range of standard heterosis for days to marketable maturity was 17.93 to 4.41, while earlier hybrids were viz., P_1 X P_2 (-12.14), P_1 X P_3 (-10.91), P_1 X P_5 (-17.93). The range of standard heterosis for the number of fruits per plant was 13.22 per cent to 146.83 per cent,

while higher number was obtained from the hybrids viz., P_2 X P_7 (146.83%), P_2 X P_3 (129.96%), P_4 X P_8 (116.13%), P_6 X P_8 (84.52%), P_4 X P_7 (81.04%). These hybrids offer a high scope for exploiting heterosis to improve horticultural traits. In addition to being used for hybrid breeding, these cross-combinations may be published as hybrids following additional field testing. Twenty F_1 hybrids outperformed the usual yield standard check by a wide margin. Considering the higher standard heterosis the hybrids viz., P_4 X P_6, P_3 X P_4, P_4 X P_5, P_1 X P_3, P_2 X P_3, P_3 X P_6, P_3 X P_5, P_5 X P_8, P_3 X P_7, P_1 X P_2, P_1 X P_5 were outstanding crosses and may be considered for selection. The findings suggest that studying standard heterosis can help us choose better hybrid combinations in terms of greater output, earliness, quantity of fruits, larger fruit, etc. For nearly all 15 yield-contributing characters under investigation, there was a significant amount of standard heterosis. It also demonstrates how standard heterosis can be used to increase yield.

Keywords: Sweet pepper, Heterosis, Productive traits, Hybrids.

INTRODUCTION

The Solanaceae family includes the sweet pepper (*Capsicum annuum* L.), which is indigenous to tropical South America. It is believed that sweet pepper originated in Brazil. Prior to Europe learning about America, it was only known to be widely grown in Central and South America. There are eleven groups within the species *Capsicum annuum,* which are further classified as sweet and hot peppers. The thick flesh of the sweet pepper is comparatively non-pungent. Sweet peppers are low in energy as food. On the other hand, sweet peppers contain 1.29 mg of protein, 11 mg of calcium, 870 I.U. of vitamin A, 175 mg of ascorbic acid, 0.06 mg of thiamine, 0.03 mg of riboflavin, and 0.55 mg of niacin per 100 grams of edible fruit, making them highly nutritious (Joshi and Singh, 1995). One medium green bell pepper contains up to 8% of the daily necessary intake of vitamin A, 180% of vitamin C, 2% of calcium, and 2% of iron. A significant part of our diet, sweet pepper is rich in vitamins A, C (more so than tomatoes), E, B1, B2, and D.

Peri-urban areas of Bangladesh are home to small-scale farming, which is mostly done to feed certain city marketplaces in Bangladesh. In the larger cities, there is a healthy demand for some large hotels. The high export potential exists for this crop. It is essential to make efforts for its successful growth in Bangladesh due to its high nutritional value, export potential, and low production and consumption of vegetables in the nation. The majority of sweet pepper types found in Bangladesh are open-pollinated (OP) varieties. Exotic hybrid cultivars have just recently been launched because of their high potential yield. Those hybrid types have extremely high seed costs. Furthermore, growers of sweet peppers must purchase seeds each year because of the distinctive characteristics of the hybrid type.

In several vegetable crops, the value of heterosis breeding has been generally acknowledged. Heterosis indicates if the F1 hybrids are more or less vigorous than their parents. Allelic interactions, such as dominance or overdominance, non-allelic interactions, such as epistasis, and maternal interactions, can all contribute to the manifestation of heterosis. Heterosis breeding is a frequently utilized technique in developed nations that yields hybrids in nearly every vegetable. Bangladesh is faring poorly in this regard. The F_1 hybrids provide several benefits, including early maturity, high yield, better quality, uniformity, and greater flexibility.

They also aid in the distribution of dominant genes that confer disease and insect resistance. The first filial generation of children from clearly separate parental types is known as an F_1 hybrid. When two distinct plant varieties are purposefully crossed-pollinated, a hybrid vegetable is created, with the goal being an offspring that combines the best qualities of both parents. F1 hybrids are employed in selective breeding and genetics, where they can manifest as F1 crossbreeds. To ensure food security, hybrid seed generation is widely used in modern agriculture. It is principally to blame for the notable spike in agricultural productivity that occurred in the second half of the 20th century.

Agriculture in the 20th century has greatly benefited from the use of heterosis in several commercial crop hybrids, even if its genetic origins are still unknown (McDaniel, R.G. 1986; Rood et al., 1988; Sinha et al., 1988). According to plant breeders, heterosis occurs when an F_1 hybrid has more vigor than its parents in terms of height, leaf area, growth, dry matter accumulation, and yield (Allard, 1960; Brewbaker, 1964; Hageman et al., 1967). Many hybrid kinds of horticultural crops, such as sweet pepper, tomato, eggplant, cabbage, cauliflower, broccoli, cucumber, watermelon, pumpkin, and onion, are routinely grown worldwide today along with a multitude of other hybrid crops. F_1 hybrid sweet pepper is one of the upcoming leading vegetable crops in the subcontinent. Sweet pepper has a lot of potential for using its hybrid vigour. Selection will therefore be quite realistic if it is based on the degree of heterosis of multiple yield components. According to [8], it is a desirable element to exploit heterosis, even to a minor extent for individual component traits. In Bangladesh, there is a good chance to gain from heterosis. Thus, the goal of the current study is to use a heterosis study to identify superior sweet pepper hybrids.

MATERIALS AND METHODS

Experimental Site

During 2018–19, the Olericulture Division of the Bangladesh Agricultural Research Institute (BARI) served as the experiment site. Under the agro-ecological zone (AEZ) 28, the field was located at 23.992º N Latitude and 90.413º E Longitudes, with a height of 8.2 m above sea level (Annon, 1995).

During the trial, the farm, which was located in a sub-tropical climate zone, had little rainfall. The pH range of the sandy clay loam soil in the experimental field was approximately 6.20, while the moisture content ranged from 13% to 25%. Figure 1 lists the maximum and minimum air temperatures (ºC), total rainfall (mm), sunlight hours (hrs), and maximum and minimum relative humidity (%).

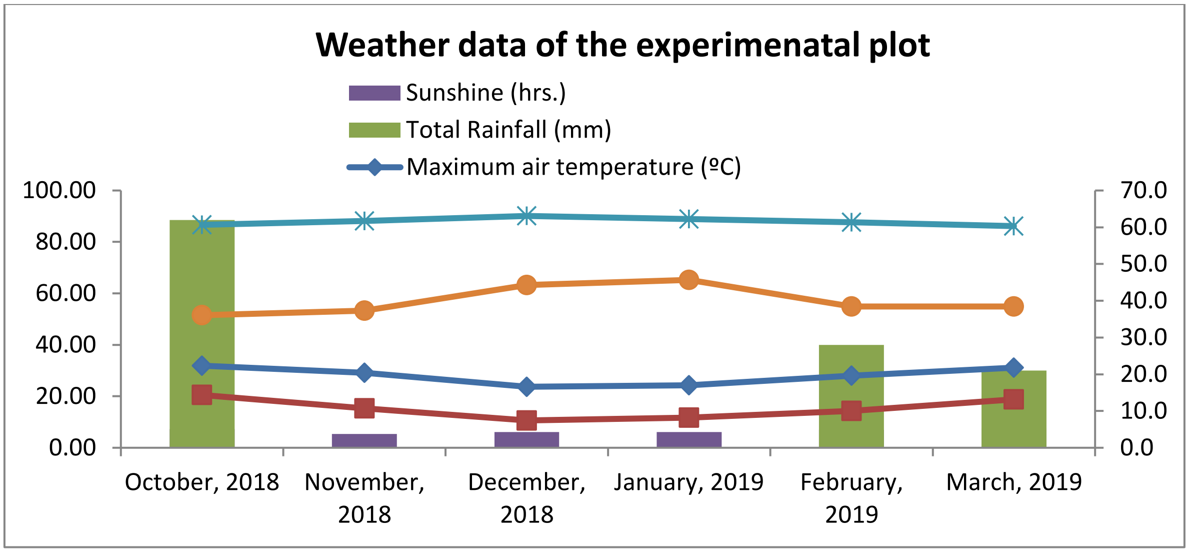

Fig 1: Maximum air temperature (ºC), minimum air temperature (ºC), total rainfall (mm), sunshine (hrs.), maximum RH (%) and minimum RH (%)

Plant Materials

The seedlings of 28 F_{1s} along with one commercial hybrid named Syam (as a check) i.e., seedlings of 29 hybrids were used for the heterosis study.

On October 5, 2018, the seeds of these 29 hybrids were planted on the seedbed. On October 25, 2018, planting materials that were thirty days old were positioned in the main field.

Experimental Design and Layout

The 29 hybrids of sweet pepper generated from an 8 × 8 diallel cross (excluding reciprocals) along with check variety viz., Syam were placed in an RCBD (Randomized Complete Block Design) with three replications. Every planting material was represented by a double row of 3 m length bed. With a 0.5 m drain, the row-to-row and plant-to-plant distances were 60 cm and 50 cm, respectively.

Land, Pit Preparation and Fertilization

The N, P, K, S, B, Zn, and organic manure were applied to the experimental area at rates of 3000, 80, 45, 88, 25, 1.8, and 4.5 kg/ha, respectively. Fertilization was carried out by applying half of the organic manure and all of the S, Zn, and B (P and K) at a rate of 30 kg/ha during the last stages of field preparation. The remaining organic manure, along with 15 kg/ha of P and K, were added as base material to the pit. The remaining N and K were added in 4 equal installments, beginning at 20-day intervals, following 20 days after transplantation.

Intercultural Operation and Plant Protection

To ensure a successful crop, the suggested essential agronomic procedures and plant protection measures (particularly against fruit borer, thrips, mites, stem blight, and little leaf) were implemented. The plants that were growing were supported by bamboo sticks. Watering was done when it was necessary.

Data Recorded

Green fruits were harvested when they were relatively firm and crispy (Shoemaker and Teskey, 1955). Harvesting of mature fruits was started at 60-65 DAP and continued up to 100-125 DAP. Harvesting was done manually with the help of secateurs.

Plant height, the number of primary branches, days to 50 per cent flowering, the days to harvest, the number of fruits per plant, the length and diameter of the fruits, the average weight of the fruits (g), the number of lobes per fruit, the thickness of the pericarp, the length of the harvest period, the ascorbic acid and capsicin content, and other parameters were all noted.

Analysis of Variance (ANOVA)

ANOVA was applied to all of the collected quantitative data. Each character's total variations were divided into differences related to blocks, genotypes, and errors. The F-test was used to compare the variations among the effect classes.

Estimation of Heterosis

Percent heterosis was estimated as:

$$H(SH) = \{[(F_1 - SH) \times 100] / SH\}$$ [when SH for Standard hybrid, H for heterosis]

Where:

- F_1 = Mean of F_1 generation,
- SH = Mean of Standard hybrid

The significance test for heterosis was calculated by Critical difference (CD) for heterobeltiosis over better parent

$$CD(SH) = \frac{\sqrt{(2MSE)} \; x \; t}{r}$$

Where,

- MSE= Error mean square,
- r= Number of replications
- t= Tabulated value of t at 1% and 5% level of significance.

The CD was used to compare the observed differences among different treatments. If the difference was greater than the CD value it was considered significant or vice-versa.

RESULTS AND DISCUSSION

A possible way to increase sweet pepper output and production that can't be accomplished with the current conventional ways is through heterosis breeding. Compared to hybrid vigor, heterosis has a slightly wider definition; that is to say, while every hybrid vigor is heterosis, not all heterosis may equally well be referred to as hybrid vigor. Heterosis is the result of cross-breeding rather than interbreeding to improve size, yield, and vigor; heterosis cannot exist without increases.

Significant variation was observed in plant height traits among the 28 hybrids of sweet pepper in this study. Heterosis over the standard check ranged from -21.73 per cent (P_7 X P_8) to 31.17 per cent (P_5 X P_8), while the positive significant heterosis was observed in 26 combinations. Similar findings were also reported earlier by Ahmed et al. (2003) and Rajesh and Gulshan (2001), Sujiprihati et al. (2007).

Heterosis over standard check was in the range of – 24.64 per cent (P_1 X P_7) to 23.83 (P_3 X P_4) per cent for the number of primary branches. Fifteen hybrid combinations *viz* ., P_1 X P_2 (7.74), P_1 X P_4, (11.41), P_1 X P_5, (17.82), P_1 X P_6, (10.08), P_1 X P_8, (16.80), P_2 X P_3 (11.30), P_2 X P_4,(9.47), P_2 X P_7,(9.47)P_3 X P_4(23.83), P_3 X P_6(8.45), P_3 X P_7(10.39), P_4 X P_6 (19.65), P_4 X P_8 (20.37), P_5 X P_6 (9.98) and P_6 X P_8 (4.79) were reported with significant positive heterosis over standard check. The cross Rani Sel-1 × SSP had the largest economic heterosis for the number of branches, 18.74% more than the standard check (Sharma et al., 2013). Joshi (1986) and Sujiprihati et al. (2007) have previously found a considerable heterosis for the number of branches had over better parent and standard check. Significant positive heterobeltiosis for the number of primary branches was reported by Thiruelavanet.al., (2002) whereas; Sharma and Aini (2013) found significant positive commercial heterosis over the check.

In the case of days to 50 per cent flowering, the increase or decrease over the standard check variety ranged from -0.06 per cent (P_1 X P_5) to 23.93 per cent (P_1 X P_4). All the hybrid combinations except P1 X P5 took significantly fewer days for 50 per cent flowering than standard check variety Syam. Top five F_1 hybrids for earliness over standard check were P_1 X P_4, (-23.93), P_1 X P_7, (-23.18), P_5X P_6, (-21.62), P_5 X P_7 (-21.60) and P_2 X P_8, (20.07). Sujiprihati et al. (2007) also reported desirable negative heterosis for days to 50% flowering. Murthy and Deshpande, 1997, Pandey et al., 2002 and Silva et.al.,2014 have also observed significant negative heterosis for 50 per cent flowering.

The range for the per cent increase or decrease over the standard check for days to marketable maturity was 17.93 to 4.41. Twenty F_1 hybrids viz., P_1 X P_2 (-12.14), P_1 X P_3 (-10.91), P_1 X P_5 (-17.93), P_1 X P_6, (-8.43), P_1 X P_7 (-3.04), P_1 X P_8 (-7.19), P_2 X P_3(-7.90), P_2 X P_4 (-5.08), P_2 X P_5 (-10.51), P_2 X P_6 (-6.37), P_2 X P_7(-5.13), P_2 X P_8 (-2.64), P_3 X P_4 (-3.48), P_3 X P_5 (-4.72), P_3 X P_6 (-4.58), P_3 X P_7 (-3.07), P_3 X P_8(-5.50), P_6 X P_7(-4.67), P_6 X P_8(-5.92), P_7 X P_8(-4.71) were found to be significantly better over the standard check (Syam). Sharma et al., 2013 got similar results with - 11.87% standard heterosis for this trait.

The data for per cent increase or decrease over the standard check for the number of fruits per plant was in the range of 13.22 per cent to 146.83 per cent except for one F_1 all the F_{1s} were found to be significantly better for the number of fruits per plant over standard check Syam. The higher standard heterosis was found in P_2 X P_7 (146.83%), P_2 X P_3 (129.96%), P_4 X P_8 (116.13%), P_6 X P_8 (84.52%), P_4 X P_7 (81.04%). According to Sharma et al. (2013), there was a 31.43% increase in fruit pickings in the cross Rani Sel-1 × SP-316 compared to the standard variety, which had the highest economic heterosis. Similar results have also been reported by

Joshi (1986) and Prasad et al. (2003). The number of fruits per plant contributes directly to yield per hectare in sweet pepper (Kumari et.al., 2014) therefore; positive heterosis is desirable for several fruits per plant. Geleta and Labuschagne (2004), Pandey et al. (2002), Murthy and Deshpande (1997), Maya et al. (2007), Sharma and Sharma (2006), and Pandey et al. (2002) have also noted hybrid vigor in numerous hybrids for the number of fruits per plant.

Table 1: Standard heterosis for 15 traits of 28 hybrids of sweet pepper

Parents/Crosses	Plant height	Number of primary branches	Days to 50 per cent flowering	Days to marketable harvest	Number of fruits per plant
P_1 X P_2	14.44 **	7.74 *	4.59 *	-12.14 **	51.48 **
P_1 X P_3	24.11 **	3.26 ns	9.34 **	-10.91 **	37.91 **
P_1 X P_4	22.00 **	11.41 *	-23.93 **	1.88 ns	22.65 **
P_1 X P_5	24.67 **	17.82*	-0.06 ns	-17.93 **	17.35 **
P_1 X P_6	22.46 **	10.08 *	11.56 **	-8.43 **	17.96 **
P_1 X P_7	9.09 **	-24.64 *	-23.18 **	-3.04 **	36.13 **
P_1 X P_8	10.17 **	16.80 *	12.93 **	-7.19 **	13.22 *
P_2 X P_3	12.16 **	11.30 **	13.12 **	-7.90 **	129.96 **
P_2 X P_4	7.27 **	9.47 *	14.65 **	-5.08 **	61.13 **
P_2 X P_5	17.52 **	-18.23 *	14.63 **	-10.51 **	60.35 **
P_2 X P_6	12.13 **	6.62 ns	11.54 **	-6.37 **	63.13 **
P_2 X P_7	13.43 **	13.54 *	10.85 **	-5.13 **	146.83 **
P_2 X P_8	16.27 **	-8.35 *	-20.07 **	-2.64 *	38.87 **
P_3 X P_4	22.23 **	23.83 *	13.88 **	-3.48 **	31.70 **
P_3 X P_5	9.51 **	6.21 ns	16.21 **	-4.72 **	28.30 **
P_3 X P_6	6.30 **	8.45 *	17.86 **	-4.58 **	48.74 **
P_3 X P_7	-3.53 **	10.39 *	11.94 **	-3.07 **	32.17 **
P_3 X P_8	28.19 **	-12.63*	16.15 **	-5.50 **	8.35 ns
P_4 X P_5	27.84 **	-8.35 *	11.65 **	3.13 **	30.35 **
P_4 X P_6	6.87 **	19.65 **	12.29 **	3.11 **	55.78 **
P_4 X P_7	9.65 **	-0.51 ns	9.23 **	4.41 **	81.04 **
P_4 X P_8	23.88 **	20.37 *	9.96 **	1.06 ns	116.13 **
P_5 X P_6	21.84 **	9.98 *	-21.62 **	0.61 ns	70.22 **
P_5 X P_7	5.99 **	-11.00 **	-21.60 **	3.56 **	45.09 **
P_5 X P_8	31.17 **	-8.55 *	18.53 **	-1.42 ns	54.74 **
P_6 X P_7	1.97 *	2.24 ns	11.65 **	-4.67 **	49.43 **
P_6 X P_8	20.21 **	4.79 *	9.41 **	-5.92 **	84.52 **
P_7 X P_8	-21.73 **	0.41 ns	11.71 **	-4.71 **	58.04 **
Range	-21.73 to 31,17	-24.64 to 23.83	-0.06 to 23.93	-17.93 to 4.41	13.22 to 146.83

The range of standard heterosis for fruit length was 8.44 to 15.92%, while the maximum standard heterosis to the extent of 88.59 % was recorded in the hybrid combination $P_4 \times P_7$, followed by P_5 X P_7 (40.96%), P_3 X P_7 (40.01%), P_2 X P_6 (39.26%), P_1 X P_8 (36.26%), P_3 X P_4 (36.65 %). Fruit diameter showed positive significant standard heterosis in ten hybrid combinations: P1 X P4 (25.84), P1 X P5 (43.21), P2 X P4 (26.20), P2 X P6 (32.60), P2 X P8 (30.65), P3 X P6

(25.96), P3 X P8 (26.32), P4 X P8 (28.22), P5 X P7 (35.57), and P5 X P8 (26.73). There was notable heterosis for fruit diameter in earlier studies by Ahmed et al. (2003), Rajesh and Gulshan (2001), and Prasad et al. (2003).

Data for per cent increase or decrease over the standard check for average fruit weight ranged from -44.57 (P_2 X P_7) per cent to 30.79 (P_4 X P_5) per cent; Eleven F_1 hybrids viz., P_1 X P_3 (12.99), P_1 X P_4 (9.79), P_1 X P_5 (24.42), P_3 X P_4 (25.21), P_3 X P_5 (12.56), P_3 X P_6 (3.44), P_3 X P_7 (5.61), P_3 X P_8 (9.88), P_4 X P_5 (30.79), P_4 X P_6 (5.16) and P_5 X P_8 (10.28) reported with significant positive heterosis over the standard check. The cross combination PRC-1 × Rani Sel-1 has the highest economic heterosis for fruit weight (49.50%) when compared to the conventional check (Sharma et al., 2013). Gomide et al. (2008) previously reported on heterobeltiotic effects on fruit weight in bell peppers.

Per cent increase or decrease over the standard check for fruit yield per plant data ranged from -13.74 (P1 X P8) per cent to 70.69 (P5 X P8) per cent, while the other significant cross combinations were P_4 X P_5 (70.49%), P_3 X P_4 (65.06%), P_4 X P_6 (63.91%), P_2 X P_3 (62.04%), P_1 X P_3 (55.85%), P_3 X P_6 (53.98%), P_1 X P_5 (46.10%), which showed higher positive values (Sood and Kumar, 2010b). According to Shrestha et al. (2011), a hybrid of 5AVS7 × SP32 showed the greatest heterosis in terms of yield (141.2%) and fruit number (104.0%) per plant. In sweet peppers, yield per plant positively and significantly correlated with plant height (Rong 2008). These findings are in agreement with those of Joshi (1995), Thakur (1987), Thomas and Peter (1988), Zhang et al., 2013, Milkova (1997), Sanchez et al.,2003, Maurya (2010) and Geleta and Labushagne (2004).

Twenty F_1 hybrids showed significantly better performance over the standard check for yield per hectare, while the range was -9.55 to 66.54 per cent. The higher standard heterosis was observed in P_4 X P_6 (66.54%), P_3 X P_4 (63.09%), P_4 X P_5 (55.97%), P_1 X P_3 (54.17%), P_2 X P_3 (54.57%), P_3 X P_6 (53.07%), P_3 X P_5 (51.09%), P_5 X P_8 (50.39%), P_3 X P_7 (48.48%), P_1 X P_2 (47.69%), P_1 X P_5 (45.63%). Furthermore, notable desirable heterosis was previously documented by Zecevic (1997), Ahmed et al. (2003), Milerue and Nikornpun (2006), and Sujiprihati et al. (2007).

Table 1 (contd.)

Parents/Crosses	Fruit length	Fruit diameter	Average fruit weight	Fruit yield per plant	Fruit yield ton per hectare
P_1 X P_2	26.70 **	23.06 ns	-4.44 **	44.84 **	47.69 *
P_1 X P_3	19.12 *	24.90 ns	12.99 **	55.85 **	54.17 **
P_1 X P_4	13.86 ns	25.84 *	9.79 **	42.35 **	43.98 *
P_1 X P_5	9.76 ns	43.21 **	24.42 **	46.10 **	45.63 *
P_1 X P_6	16.31 ns	21.34 ns	-4.84 **	12.27 **	24.69 ns
P_1 X P_7	32.94 **	5.81 ns	-31.30 **	-6.23 ns	1.39 *
P_1 X P_8	36.26 **	7.65 ns	-23.85 **	-13.72 **	-9.55 ns
P_2 X P_3	20.42 *	9.43 ns	-29.53 **	62.04 **	54.57 **
P_2 X P_4	15.13 ns	26.20 *	-38.55 **	-0.92 ns	22.05 **
P_2 X P_5	22.51 *	5.10 ns	-23.63 **	22.44 **	16.42 *

P_2 X P_6	39.26 **	32.60 *	-46.62 **	-12.88 **	-0.98 *
P_2 X P_7	34.56 **	4.98 ns	-47.57 **	29.43 **	18.77 *
P_2 X P_8	27.21 **	30.65 *	-37.22 **	-12.84 **	3.26 *
P_3 X P_4	36.65 **	0.41 ns	25.21 **	65.06 **	63.09 **
P_3 X P_5	26.86 **	24.48 ns	12.56 **	44.50 **	51.09 *
P_3 X P_6	33.29 **	25.96 *	3.44 **	53.98 **	53.07 **
P_3 X P_7	40.01 **	3.97 ns	5.61 **	39.68 **	48.48 *
P_3 X P_8	16.94 ns	26.32 *	9.88 **	19.11 **	27.91 ns
P_4 X P_5	24.49 **	19.26 ns	30.79 **	70.49 **	55.97 **
P_4 X P_6	20.77 *	20.98 ns	5.16 **	63.91 **	66.54 **
P_4 X P_7	88.59 **	15.65 ns	-42.70 **	0.04 ns	23.80 *
P_4 X P_8	9.52 ns	28.22 *	-40.39 **	28.94 **	20.94 *
P_5 X P_6	21.01 *	12.39 ns	-29.24 **	20.53 **	19.59 *
P_5 X P_7	40.96 **	35.57 **	-28.07 **	4.40 ns	12.31 ns
P_5 X P_8	32.74 **	26.73 *	10.28 **	**70.72 ****	50.39 *
P_6 X P_7	18.48 *	24.48 ns	-24.76 **	12.42 **	8.81 ns
P_6 X P_8	16.43 ns	22.53 ns	-31.34 **	26.72 **	22.78 ns
P_7 X P_8	28.40 **	20.27 ns	-42.05 **	-8.37 *	-9.35 ns
Range	9.52 to 88.59	0.41 to 43.21	-44.57 to 30.79	-13.72 to 70.72	-9.55 to 66.54

The data about standard heterosis showed that the number of lobes per fruit varied between -5.62 and 65.04 per cent. On the other hand, the pericarp thickness ranged from 0.53 to 56.72 per cent, with the highest thickness found in P1 X P5 (56.10%), P1 X P7 (46.62%), P4 X P6 (46.27%), and P4 X P7 (46.09%). According to Geleta and Labuschagne (2004) and Kumar and Nandapuri (2001), there has also been positive heterosis for pericarp thickness.

For the duration of harvest, the percentage of heterosis exceeding the standard check ranged from 7.81 to 15.47 per cent. Except for the crosses P5 X P6 and P1 X P5, which had considerable negative (-0.10%) and -7.81%) heterosis, all of the F1 hybrids produced significant positive heterosis. Previous researchers Joshi (1995), Sharma (1998), Murthy and Deshpande (1997), and Singh et al. (2013) also reported significant positive heterosis for this characteristic. Variable heterosis for this attribute has also been documented by Prasath et al. (2008) and Maurya (2010).

The ascorbic acid content heterosis ranged from -52.25 to 20.16 per cent over the standard variety. The hybrids P4 X P6 (20.16), P6 P1 X P2 (16.84), P6 X P7 (16.50), P4 X P5 (15.15), and P3 X P4 (10.10) showed the highest heterosis. PRC-1 × California Wonder displayed the highest useful heterosis for the trait, measuring 37.61% over the standard check (Sharma et al., 2013). For ascorbic acid, Vandana et al. (2002) and Gomide et al. (2008) also reported similar results.

Data on the content of capsicin for standard heterosis varied from -37.04 to 114.81 per cent. P2 X P5 (114.81%), P5 X P8 (114.80%), P2 X P3 (103.70%), P3 X P5 (103.70%), P2 X P7 (96.30%), P4 X P8 (92.59%), and P6 X P8 (92.59%) had the highest contents of capsicin.

Table 1 (contd.)

Parents/Crosses	Number of lobes per fruit	Pericarp thickness	Harvest duration	Ascorbic acid content	Capsicin content
P_1 X P_2	33.96 ns	38.89 *	6.38 **	16.84*	25.93
P_1 X P_3	49.81 ns	28.97 ns	15.87 **	-24.70*	11.11
P_1 X P_4	32.71 ns	56.72 **	2.83 *	-23.42*	-14.81
P_1 X P_5	65.04 ns	56.10 **	-7.81 **	9.22*	-37.04*
P_1 X P_6	12.36 ns	35.56 *	6.95 **	-5.27	37.04*
P_1 X P_7	29.96 ns	46.62 **	5.14 **	9.72*	33.33*
P_1 X P_8	28.59 ns	44.95 **	4.05 **	-8.13	-14.81
P_2 X P_3	-4.49 ns	17.65 ns	8.15 **	-2.83	103.70*
P_2 X P_4	26.97 ns	44.60 **	6.38 **	-32.55*	0.00
P_2 X P_5	22.85 ns	4.74 ns	7.54 **	-21.82*	114.81*
P_2 X P_6	-5.62 ns	34.24 *	5.11 **	-8.67	11.12
P_2 X P_7	-4.74 ns	14.05 ns	6.97 **	-22.61*	96.30*
P_2 X P_8	-2.50 ns	2.19 ns	4.60 **	-26.47*	66.67*
P_3 X P_4	31.59 ns	40.56 **	4.02 **	10.10*	22.22
P_3 X P_5	32.71 ns	30.55 *	3.31 *	-22.55*	103.70*
P_3 X P_6	32.21 ns	22.91 ns	9.92 **	-41.57*	22.22
P_3 X P_7	33.08 ns	0.53 ns	14.08 **	-13.03	51.85*
P_3 X P_8	29.84 ns	19.75 ns	17.01 **	-35.41*	22.23
P_4 X P_5	31.34 ns	21.60 ns	6.38 **	15.15*	-18.52
P_4 X P_6	-0.62 ns	46.27 **	9.31 **	20.16*	-14.81
P_4 X P_7	30.71 ns	46.09 **	7.53 **	-11.98*	14.81
P_4 X P_8	27.72 ns	27.22 ns	5.24 **	-45.14*	92.59*
P_5 X P_6	13.86 ns	30.03 *	-0.10 ns	-12.59*	70.37*
P_5 X P_7	13.48 ns	26.78 ns	5.25 **	-43.55*	70.36*
P_5 X P_8	31.21 ns	19.75 ns	9.92 **	-25.52*	114.80*
P_6 X P_7	27.47 ns	27.48 ns	8.16 **	16.50*	-3.70
P_6 X P_8	49.19 ns	33.89 *	9.28 **	-52.25*	92.59*
P_7 X P_8	26.97 ns	34.24 *	6.39 **	6.06	18.52
Range	-5.62 to 65.04	0.53 to 56.72	-7.81 to 15.47	-52.25 to 20.16	-37.04 to 114.81

CONCLUSIONS

The results of this study provided evidence in favor of using hybrids to speed up the creation of tropical sweet pepper cultivars. The current findings also showed that the average fruit weight and the number of fruits per plant were the primary determinants of the overall yield per sweet pepper plant. Fruit size (fruit length, fruit diameter) and vegetative vigor (vine length and number of branches per plant) affected the number of fruits produced per plant. For the majority of the characteristics that contributed to yield, these cross-combinations also exhibited substantial heterosis. These hybrids provide a great deal of opportunity to use heterosis to enhance horticultural features. After more field testing, these cross-combinations may be issued as hybrids or used for hybrid breeding. Twenty F1 hybrids performed noticeably better than the typical yield check. The hybrids P4 X P6, P3 X P4, P4 X P5, P1 X P3, P2 X P3, P3 X P6, P3 X P5, P5 X P8, P3 X P7, P1 X P2, and P1 X P5 were excellent crosses and might be chosen in light of the higher standard heterosis. The findings suggest that studying heterosis can help us choose better hybrid combinations in terms of greater output, earliness, quantity of fruits, larger fruit, etc. For nearly all 15 yield-contributing characters under investigation, there was a significant amount of typical heterosis.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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