ISSN 0258-7122 (Print), 2408-8293 (Online)
Bangladesh J. Agril. Res. 47(1): 1-12, March 2022

HETEROSIS STUDIES IN SNAKE GOURD (*TRICHOSANTHES CUCUMERINA* VAR. *ANGUINA* L.)

M. R. ISLAM[1], M. M. RAHMAN[2], S. PRAMANIK[3] AND J. FERDOUSI[4]

Abstract

An investigation was carried out on snake gourd at the research farm of the Department of Horticulture, Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Bangladesh during March to June 2019. Significant heterosis was observed for most of the characters studied to find out high heterotic combination for better hybrids. Both positive and negative heterosis were found for different characters of the F_1 hybrids over better parents. The best better parent heterotic performance was exhibited by early flowering and fruit fly infestation in P_2 x P_7 and P_6 x P_7, respectively while P_3 x P_7 for higher individual fruit weight; P_1 x P_3, P_2 x P_6, P_3 x P_7, P_4 x P_6 for number of fruit bearing; P_1 x P_3, P_2 x P_3, P_2 x P_7, P_3 x $P_{7,}$ for higher fruit yield per plant and hectare; P_1 x P_3, P_2 x P_3, P_2 x P_6, P_3 x P_7 for maximum fruit length P_2 x P_6, P_4 x P_6, P_4 x P_7 for fruit diameter as well as for increasing 100-seed weight the cross combinations were P_2 x P_3, P_4 x P_6. Based on all the characters and heterotic performance, the crosses combinations viz., P_1 x P_3, P_2 x P_6, P_3 x P_7 and P_6 x P_7 can be selected to exploit improved hybrid lines.

Keywords: Snake gourd, heterosis, heterobeltiosis, genotypes, hybrids.

Introduction

Snake gourd (*Trichosanthes cucumerina* var. *anguina* L.) is an annual, day-neutral climbing type herbaceous vegetable crop and belongs to the cucurbitaceae family. It is grown throughout Bangladesh and is a popular summer vegetable in this region. At the end of winter and early summer seasons, there is a lean period when there is always a shortage of vegetables in this region. During that gap time, vegetable shortage can be mitigated to some extent through improvement of cucurbitaceous crops such as snake gourd. There is a diversified cultivars of snake gourd in this country with a wide range of variability in fruit size, shape and color (Rashid, 1993). In Bangladesh, vegetable production has increased five times in the past 40 years which has scored third in global vegetable production, next to China and India (FAO, 2015). Summer vegetables typically cover about 44 percent of the total vegetable area, of which snake gourd is a prominent vegetable crop in this country (BBS, 2020). Snake gourd is monoecious in nature and heavily cross-pollinated. Such

[1]Horticulture Research Centre, Bangladesh Agricultural Research Institute (BARI), Gazipur. [2]Department of Horticulture, Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Gazipur. [3]Rice Farming Systems Division, Bangladesh Rice Research Institute (BRRI), Gazipur. [4]Department of Horticulture, Sylhet Agricultural University (SAU), Sylhet, Bangladesh.

pollination mechanism can be exploited for the development of hybrid variety. Heterosis or hybrid vigor can play a pivotal role in increasing the yield and quality of vegetable crops. Focused on the above opinions, heterosis studies are considered as excellent tools in any breeding programme. These include the desired genetic explanation relating to crop improvement or heterotic commercial advantage exploitation. Diallel analysis was also used to be properly informed about the heterosis in crosses to generate a suitable segregating population for selection (Glover, 2005 and Singh and Asati, 2011). Several workers have documented heterosis in cucurbits for various characteristics (Banik, 2003 and Rahman, 2004). There is minimal information available on the extent and existence of heterosis for yield and yield contributing characters in snake gourd as it is an underutilized crop. Due to monoceous , much scope for exploitation of heterosis in snake gourd exists virtually. The F_1 hybrids offer many benefits, such as earliness, high yield, uniformity, broader adaptability, and also help to establish dominant genes for disease and pest resistance (Riggs, 1988). Therefore, the main purpose of the present study was to select a high heterotic parental combination to produce hybrid lines with good quality fruits.

Materials and Methods

The experiment was performed at the experimental farm of the Department of Horticulture, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur, Bangladesh, during March to June 2019. Seven diverse genotypes were selected based on their performance with respect to different horticultural traits, genetic diversity, and heritability. The parental genotypes TC 01, TC 05, TC 24, TC 33, TC 02, TC 46 and TC 53 were identified as P_1, P_2, P_3, P_4, P_5, P_6 and P_7 respectively. The seven parents were grown and crossed in all possible combinations, excluding reciprocals during August to November, 2018. The parents were grown together with their F_1s during March to June 2019. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Fifteen days old seedlings were transplanted on 20 March 2019, in well-prepared pit in an experimental plot. A total of 84 (28 × 3) unit plots were found, each measuring 7.5 m × 1.5 m plots hosted 5 plants with row spacing of 1.5 m and 1.5 m, respectively. It was carefully designed to have better drainage, beds, and pits. Approximately 25 cm deep drain was dug around the plot for proper drainage. Fertilizers were applied @ 5000-50-24-40-14-1.5-1.0 kg/ha of cowdung-N-P-K-S-Zn-B according to FRG (2012). The N, P, K, S, Zn and B origins were Urea, Triple Super Phosphate (TSP), Muriate of Potash (MoP), Gypsum, Zinc Sulphate and Boric Acid (Laboratory Grade). During the final land preparation, the entire amount of cowdung, P, S, Zn, B and one-third of K as well as N and the remaining part of K were applied in four equal installments at 7, 21, 35 and 49 days after transplantation. Days to male flower open, days to female flower open, node number to first male flower open, node number to first female flower open, vine length (cm), nodes on main vine, primary branches per plant, days to 1st harvest, fruit fly infestation (%), fruits per plant, fruit yield/plant (kg), fruit yield/hectare (ton), fruit weight (g), fruit length (cm), fruit diameter (cm), fruit flesh thickness (cm), locules per fruit, seeds per fruit, 100-seed weight (g). Percent better parent heterosis (BP) for each character was calculated as follows H (BP) = $\frac{\overline{F1}-\overline{BP}}{\overline{BP}} \times 100$; Where, BP is the mean value of the better parents in a particular cross. Mean error variance from the combined analysis of variance of parents and F1s were used for calculating the SE of difference. The mean values over replications were used for comparison. For heterosis, the difference between F1 and the parent used for estimation of heterosis was taken into account cross wise. When the difference was greater than CD, it was considered significant and vice versa. Critical difference (CD) = SE × t at 5% and 1%.

Results and Discussion

The estimation of better parent heterosis as identified in the F_1 generation are presented in Table 1 to 4. Among the cross combinations, fifteen crosses were earlier than their better parents for days to 1st male flower anthesis (Table 1). Negative heterosis ranged from -0.66 to -35.81% over better parents. The highest significant negative heterosis observed in the cross P_2 x P_5 and P_5 x P_7 (-35.81% for each cross) followed by P_5 x P_6 (-34.93%), P_3 x P_5 (-27.95%) and P_1 x P_5 (-22.27%). However, the cross P_3 x P_4 (19.75%) showed the highest significant positive heterobeltiosis for days to 1st male flower anthesis followed by P_1 x P_3 (18.82%) and P_1 x P_4 (14.12%). These results are in consonance with the results of Banik (2003) in snake gourd and Ahmed (2016) in pumpkin who observed negative better parent heterosis for early male flower open. Among the cross combinations, eleven crosses for days to 1st female flower open were earlier than their better parents (Table 1). Negative heterosis ranged from -1.20 to -32.17% over better parents. The highest significant negative heterosis observed in the cross P_2 x P_5 (-32.17%) followed by P_3 x P_5 (-30.87%), P_5 x P_6 (-30.87%), P_5 x P_7 (-28.26%) and P_1 x P_5 (-26.96%), indicating desirable combinations. On the other hand, the cross P_3 x P_4 (11.59%) showed the highest significant positive heterobeltiosis for days to 1st female flower anthesis followed by P_2 x P_4 (10.84%) and P_4 x P_7 (10.30%). These results are in agreement with the findings of Banik (2003) and Varghese (1991) in snake gourd and Ahmed (2016) in pumpkin who found negative heterobeltiosis for early female flowering. Out of twenty-one crosses, eleven were earlier than their better parents for earlier node order to 1st male flower initiation (Table 1). From all the hybrids eleven performed significant heterosis. Heterosis for earlier node order to 1st male flower initiation varied from -2.08 to -51.06%. The cross combination P_5 x P_6 (-51.06%) exhibited the highest significant negative heterosis for this trait followed by P_2 x P_5 (-44.68%) and P_1 x P_7 (-37.50%), P_6 x P_7 (-29.17%), P_2 x P_7 (-25.00%), P_3 x P_5 (-19.15%) and P_5 x P_7 (-18.75%). On the contrary, the highest significant positive heterosis was observed in the cross P_3 x P_4 (58.33%) followed by P_1 x P_3 (41.03%) and P_1 x P_6 (30.77%). These results corroborate with the findings of Banik (2003) in snake gourd and Ahmed (2016) in pumpkin who found negative heterobeltiosis for node number to 1st male flower initiation. Out of twenty one crosses, eleven were earlier than their better parents for node order to 1st female flower initiation (Table 1). From all the crosses, seven hybrids performed significant heterosis. Heterosis for earlier node order to 1st female flower initiation varied from -1.89 to -17.46%. The cross combination P_1 x P_4 (-17.46%) exhibited the highest significant negative heterosis for this trait. However, the highest significant positive heterosis was observed in the cross P_4 x P_5 and P_4 x P_7 (47.17% for each cross) followed by P_2 x P_4 (33.96%) and P_2 x P_3 (31.82%). These results support the reports of Banik (2003) in snake gourd and Ahmed (2016) in pumpkin who found negative better parent heterosis for node number to 1st female flower emergence.

Table 1. Percent heterosis over better parent for flowering characters in snake gourd

Crosses	Days to 1st flower open		Node number to 1st flower initiation	
	Male	Female	Male	Female
P_1 x P_2	-1.18	-3.13*	15.38	14.29*
P_1 x P_3	18.82**	0.52	41.03**	15.87*
P_1 x P_4	14.12**	2.08	2.56	-17.46*
P_1 x P_5	-22.27**	-26.96**	0.00	-9.52
P_1 x P_6	2.35	-9.38**	30.77**	-12.7
P_1 x P_7	-17.06**	-6.77**	-37.50**	-4.76
P_2 x P_3	-4.32*	3.01*	-11.11	31.82**
P_2 x P_4	-2.01	10.84**	-14.29	33.96**
P_2 x P_5	-35.81**	-32.17**	-44.68**	-1.89
P_2 x P_6	-3.29	-1.20	10.34	-3.77
P_2 x P_7	-6.71**	-1.20	-25.00**	-1.89
P_3 x P_4	19.75**	11.59**	58.33**	11.32
P_3 x P_5	-27.95**	-30.87**	-19.15*	-1.89
P_3 x P_6	-8.02**	4.27**	-8.33	-9.43
P_3 x P_7	1.83	8.48**	-2.08	1.89

Table 1. Cont'd

Crosses	Days to 1st flower open		Node number to 1st flower initiation	
	Male	Female	Male	Female
P_4 x P_5	-14.85**	-13.04**	14.89	47.17**
P_4 x P_6	-0.66	1.23	5.71	13.21
P_4 x P_7	7.93**	10.30**	18.75*	47.17**
P_5 x P_6	-34.93**	-30.87**	-51.06**	-9.43
P_5 x P_7	-35.81**	-28.26**	-18.75*	-3.77
P_6 x P_7	-6.71**	2.42	-29.17**	7.55

** Significant at 1% level, * Significant at 5% level, without star indicates non-significant

Among twenty-one cross combinations, ten hybrids performed significant heterosis for main vine length (Table 2). Positive heterosis for main vine length varied from 1.09 to 55.69%. The highest significant positive heterosis was found in the cross P_4 x P_6 (55.69%) followed by P_4 x P_5 (39.02%), P_1 x P_4 (38.21%), P_4 x P_7 (31.71%), P_3 x P_5 (28.95%), P_2 x P_4 (23.98%) P_5 x P_6 (23.50%), P_3 x P_4 (21.95%) and P_2 x P_3 (20.00%). The present study is in consonance with the results of Banik (2003) in snake gourd who got positive better parent heterosis for long vine. Among all the cross combinations, only four hybrids performed significant heterosis for primary branches per plant (Table 2). The positive heterobeltiosis varied from 8.33 to 80.00%. The highest significant positive heterosis found in the cross P_2 x P_3 (80.00%) followed by P_1 x P_3 (40.00%) and P_3 x P_7 (27.27%). The only significant negative heterosis found in the cross P_3 x P_6 (-27.27%). The present study is in agreement with the report of Banik (2003) in snake gourd who appeared positive better parent heterosis for the increasing number of primary branches per plant. For nodes on main vine seven hybrids exhibited significant positive heterosis (Table 2). Heterobeltiosis was the highest positive in the cross P_2 x P_3 (28.46%) followed by P_4 x P_6 (27.42%), P_4 x P_5 (16.67%) and P_2 x P_4 (16.13%). The range of positive heterosis was 1.92 to 28.46% for this character. The highest significant negative heterosis was found in the cross P_5 x P_7 (-40.79%) followed by P_2 x P_7 (-13.82%). The present study corroborates with the findings of Banik (2003) in snake gourd, who illustrated positive better parent heterosis for the increasing number of nodes on main vine. Among the cross combinations, fourteen crosses were performed earlier harvest than their better parents (Table 2). Negative heterosis ranged from -0.94 to -16.37% over better parents. The highest significant negative heterosis was observed in the crosses P_2 x P_5 and P_3 x P_5 (-16.37% for each cross) followed by P_2 x P_7 (-12.05%), P_5 x P_7 (-9.29%), P_1 x P_5 (-8.41%), P_2 x P_6 (-7.59%) and P_5 x P_6 (-6.19%), indicating desirable combinations for early harvest. On the other hand, the cross P_1 x P_3 (5.07%) showed the highest significant positive heterobeltiosis for days to 1st harvest followed by P_1 x P_4 and P_1 x P_7 (4.15% for each cross). Varghese (1991) in snake gourd noticed the extent of negative heterosis for days to first fruit harvest which supports the present findings. These results support the reports of Islam (2008) in hyacinth bean who found negative better parent heterosis for early harvest. Negative heterosis ranged from -0.77 to -60.77% over better parents for minimum fruit fly infestation (Table 2). The highest significant negative heterosis observed in the crosses P_1 x P_4 (-60.77%) followed by P_3 x P_7 (-38.10%), indicating desirable combinations for minimum fruit fly infestation. On the other hand, the cross P_4 x P_5 (86.08%) showed the highest significant positive heterobeltiosis for this trait followed by P_2 x P_5 (56.19%) and P_4 x P_6 (36.92%).

Table 2. Percent heterosis over better parent for growth, harvest and fruit fly infestation (%) characters in snake gourd

Crosses	Vine length (m)	Primary branches per plant	Nodes on main vine	Days to 1st harvest	Fruit fly infestation (%)
P_1 x P_2	-14.00	10.00	0.00	1.79	10.79
P_1 x P_3	10.74	40.00**	-0.82	5.07**	13.82
P_1 x P_4	38.21**	-16.67	13.98*	4.15**	-60.77**
P_1 x P_5	18.42	8.33	-6.25	-8.41**	-7.73
P_1 x P_6	1.09	-9.09	-10.9	-4.61**	9.76
P_1 x P_7	2.70	9.09	-9.21	4.15**	0.68
P_2 x P_3	20.00*	80.00**	28.46**	0.89	17.27
P_2 x P_4	23.98**	8.33	16.13**	-5.36**	-17.27
P_2 x P_5	1.97	0.00	-6.92	-16.37**	56.19**
P_2 x P_6	-4.37	18.18	4.49	-7.59**	-29.5
P_2 x P_7	-21.62**	9.09	-13.82*	-12.05**	-12.24
P_3 x P_4	21.95**	-8.33	3.23	0.00	-0.77
P_3 x P_5	28.95**	-8.33	13.28	-16.37**	-3.61
P_3 x P_6	-12.57	-27.27*	-7.69	-0.94	22.5
P_3 x P_7	10.81	27.27*	15.79*	-1.90	-38.10*
P_4 x P_5	39.02**	16.67	16.67**	0.00	86.08**
P_4 x P_6	55.69**	0.00	27.42**	-2.36	36.92*
P_4 x P_7	31.71**	-8.33	13.44*	-3.30*	17.01
P_5 x P_6	23.50**	8.33	8.33	-6.19**	1.03
P_5 x P_7	-4.32	-8.33	-40.79**	-9.29**	11.34
P_6 x P_7	7.57	-9.09	1.92	-3.30*	40.82

** Significant at 1% level, * Significant at 5% level, Without star indicates non-significant.

Nine out of twenty-one crosses showed significant positive and seven hybrids showed significant negative heterosis individual fruit weight (Table 3). Positive heterosis was ranged from 2.41 to 25.00% over better parents. Maximum positive heterosis was observed in the cross P_3 x P_7 (25.00%) followed by P_4 x P_5 (20.73%), P_5 x P_6 (15.81%), P_3 x P_5 (15.41%), P_5 x P_7 (15.41%). However, the cross P_1 x P_7 (-25.60%) showed the highest significant negative heterobeltiosis for individual fruit weight followed by P_1 x P_4 (-23.74%) and P_1 x P_5 (-16.05%). The present study is in agreement with the findings of Banik (2003) in snake gourd, Jha *et al.* (2009) and Ahmed (2016) in pumpkin as well as Pandey *et al.* (2005) in ash gourd, who obtained positive better parent heterosis for increasing fruit weight.

Table 3. Percent heterosis over better parent for fruit and yield characters in snake gourd

Crosses	Fruit			
	Weight (g)	Number/ plant	Fruit yield/ plant (kg)	Fruit yield/ ha (t)
P_1 x P_2	4.64	7.20	12.19*	12.19*
P_1 x P_3	7.43**	18.12**	40.26**	40.27**
P_1 x P_4	-23.74**	-23.03**	-28.84**	-28.85**
P_1 x P_5	-16.05**	-3.20	-18.84**	-18.83**
P_1 x P_6	-5.70*	-21.50**	-12.62**	-12.63**
P_1 x P_7	-25.60**	11.20	-17.22**	-17.23**
P_2 x P_3	-10.23**	21.01**	20.13**	20.12**
P_2 x P_4	-12.78**	-23.03**	-21.73**	-21.73**
P_2 x P_5	2.41	24.00**	27.27**	27.30**
P_2 x P_6	10.09**	7.00	29.70**	29.67**
P_2 x P_7	-14.35**	44.80**	24.20**	24.20**
P_3 x P_4	10.95**	-21.71**	-13.01*	-13.02*
P_3 x P_5	15.41**	8.70	39.55**	39.55**
P_3 x P_6	-4.54	-17.00**	-20.98**	-21.00**
P_3 x P_7	25.00**	13.04*	41.20**	41.20**
P_4 x P_5	20.73**	7.89	30.22**	30.23**
P_4 x P_6	13.46**	-38.00**	-29.77**	-29.79**
P_4 x P_7	-0.50	-44.08**	-44.25**	-44.24**
P_5 x P_6	15.81**	-22.50**	-10.25*	-10.28*
P_5 x P_7	15.41**	16.13**	76.46**	76.42**
P_6 x P_7	-4.38	-21.50**	-24.99**	-25.01**

** Significant at 1% level, * Significant at 5% level, Without star indicates non-significant.

Six crosses exhibited significant positive and nine hybrids showed significant negative heterosis for fruits per plant (Table 3). Positive heterosis ranged from 7.00 to 44.80% over better parents. The highest positive heterosis was found in the cross P_2 x P_7 (44.80%) followed by P_2 x P_5 (24.00%), P_2 x P_3 (21.01%) and P_1 x P_3 (18.12%). On the other hand, the cross P4 x P7 (-44.08%) showed the highest significant negative heterobeltiosis for fruits per plant followed by P_4 x P_6 (-38.00%), P_1 x P_4 (-23.03%), P_2 x P_4 (-23.03%), P_5 x P_6 (-22.50%), P_3 x P_4 (-21.71%) and P_6 x P_7 (-21.50%). These results support the findings of Banik (2003) and Varghese (1991) in snake gourd, Hussien *et al.* (2015) and Jahan *et al.* (2012) in pumpkin as well as Pandey *et al.* (2005) in ash gourd who displayed positive better parent heterosis for improving fruits per plant. Among the snake gourd cross combinations, ten hybrids showed significant positive and eleven showed significant negative heterosis for yield of fruits per plant (Table 3). Positive heterosis ranged from 12.19 to 76.46% over better parents. The maximum positive heterosis was observed in the cross P_5 x P_7 (76.46%) followed by P_3 x P_7 (41.20%), P_1 x P_3 (40.26%), P_3 x P_5 (39.55%), P_4 x P_5 (30.22%), P_2 x P_6 (29.70%), P_2 x P_5 (27.27%), P_2 x P_7 (24.20%) and P_2 x P_3 (20.13%). On the contrary, the cross P_4 x P_7 (-44.25%) showed the highest significant negative heterobeltiosis for yield of fruits per plant. These results are in consonance with the findings of Podder *et al.* (2018) and Ahmed *et al.* (2000) in snake gourd, Kumari *et al.* (2020) in bitter gourd who recorded positive better parent heterosis for enhancing fruit yield per plant.

Out of twenty-one snake gourd crosses, ten hybrids showed significant positive and eleven showed significant negative heterosis for yield of fruits per hectare (Table 3). Positive heterosis ranged from 12.19 to 76.42% over better parents. The highest positive heterosis was observed in the cross P_5 x P_7 (76.42%) followed by P_3 x P_7 (41.20%), P_1 x P_3 (40.27%), P_3 x P_5 (39.55%), P_4 x P_5 (30.23%) P_2 x P_6 (29.67%), P_2 x P_5 (27.30%), P_2 x P_7 (24.20%) and P_2 x P_3 (20.12%). On the contrary, the cross P_4 x P_7 (-44.24%) showed the maximum significant negative heterobeltiosis for yield of fruits per hectare followed by P_4 x P_6 (-29.79%), P_1 x P_4 (-28.85%), P_6 x P_7 (-25.01%), P_2 x P_4 (-21.73%) and P_3 x P_6 (-21.00%). The present study corroborates with the findings of Podder *et al.* (2010) in snake gourd, Chauhan *et al.* (2018) in sponge gourd, Ene *et al.* (2019) and Mule *et al.* (2012) in cucumber who illustrated positive better parent heterosis for increasing yield of fruits per hectare. Fourteen snake gourd crosses showed significant negative heterotic effect but three combination exhibited non-significant positive heterosis for fruit length (Table 4). The combination P_1 x P_7 (-38.10%) had the highest significant negative heterobeltiosis for fruit length followed by P_1 x P_5 (-28.57%), P_1 x P_4 (-27.89%), P_2 x P_7 (-22.48%), P_3 x P_7 (-15.93%), P_1 x P_6 (-15.65%), P_6 x P_7 (-15.38%), P_3 x P_4 (-15.04%). These results are in agreement findings of Banik (2003) in snake gourd. Out of twenty-one crosses, only two hybrids showed significant positive and six showed significant negative heterosis for fruit diameter (Table 4). Positive heterosis ranged from 0.41 to 11.11% over better parents. The maximum positive heterosis was observed in the cross P_4 x P_7 (11.11%) followed by P_2 x P_5 (7.88%). On the contrary, the cross P_3 x P_6 (-15.60%) showed the highest significant negative heterobeltiosis for fruit diameter followed by P_5 x P_6 (-11.35%), P_1 x P_6 (-9.93%), P_1 x P_5 (-9.40%), P_6 x P_7 (-7.80%) and P_2 x P_6 (-6.38%). The present study is in agreement with the findings of Podder *et al.* (2018) in snake gourd, Quamruzzaman *et al.* (2019) in bottle gourd, Hussien *et al.* (2015) in pumpkin, who obtained both positive and negative better parent heterosis for fruit diameter. Among all the crosses, only two hybrids showed significant positive and four exhibited significant negative heterosis for fruit flesh thickness (Table 4). Positive heterosis ranged from 0 to 23.53% over better parents. The maximum positive heterosis was observed in the cross P_1 x P_7 (23.53%) followed by P_5 x P_6 (20.00%). On the other hand, the cross P_2 x P_4 (-22.22%) showed the highest significant negative heterobeltiosis for fruit flesh thickness followed by P_1 x P_5 (-17.65%), P_4 x P_5 (-16.67%), and P_4 x P_7 (-16.67%). The present study corroborates with the findings of Ahmed (2016) in pumpkin, who illustrated positive better parent heterosis for increasing fruit flesh thickness. Among twenty-one the crosses, only one hybrid P_2 x P_5 (33.33%) showed significant positive and three P_1 x P_4, P_4 x P_5, P_4 x P_6 (-18.18% for each hybrids) exhibited significant negative heterosis for locules per fruit (Table 4). The rest of the crosses showed insignificant heterosis for this trait. Positive heterosis is desirable to increase locules per fruit. Among the cross combinations, eight crosses performed lower number of seeds than their better parents for number of seeds per fruit (Table 4). Negative heterosis ranged from -1.13 to -32.57% over better parents. The highest significant negative heterosis observed in the crosses P_3 x P_4 (-32.57%) followed by P_2 x P_3 (-23.12%) and P_5 x P_7 (-17.84%), indicating desirable combinations for minimum seeds per fruit. On the other hand, the cross P_2 x P_4 (45.70%) showed the highest significant positive heterobeltiosis for seeds per fruit followed by P_4 x P_5 (35.14%), P_1 x P_4 (28.25), P_4 x P_7 (24.26%), and P_3 x P_6 (21.14%). These results are in consonance with the findings of Banik (2003) in snake gourd, who recorded negative better parent heterosis for reducing number of seeds per fruit. Three of the crosses showed significant positive heterotic effect for 100-seed weight and the combination P_4 x P_6 had maximum 100-seed weight (32.10%) followed by P_3 x P_4 (26.88%) and P_2 x P_3 (25.69%). Positive heterosis ranged from 0.22 to 32.10%. However, the combination P_1 x P_4 (-19.20%) had the only significant negative heterobeltiosis for 100-seed weight. Banik (2003) reported similar results in snake gourd for 100-seed weight for increasing the seed weight.

Table 4. Percent heterosis over better parent for fruit and seed characters in snake gourd

Crosses	Fruit				Seeds	
	Length (cm)	Diameter (cm)	Flesh thickness (cm)	Locules	Number/ fruit	100-seed weight (g)
P_1 x P_2	-0.68	0.41	0.00	10.00	-1.61	1.85
P_1 x P_3	-9.52**	5.04	0.00	-10.00	5.08	-2.74
P_1 x P_4	-27.89**	-4.76	-5.56	-18.18*	28.25**	-19.20*
P_1 x P_5	-28.57**	-9.40**	-17.65**	-10.00	3.78	-7.01
P_1 x P_6	-15.65**	-9.93**	0.00	0.00	-9.03	1.38
P_1 x P_7	-38.10**	-4.92	23.53 **	0.00	-1.13	-0.45
P_2 x P_3	-8.53**	-1.24	-11.76	11.11	-23.12**	25.59**
P_2 x P_4	-14.73**	-2.38	-22.22 **	9.09	45.70**	-0.68
P_2 x P_5	-13.18**	7.88*	0.00	33.33**	6.45	-7.54
P_2 x P_6	3.10	-6.38*	-5.88	11.11	2.15	-1.93
P_2 x P_7	-22.48**	-2.46	5.88	11.11	-6.99	1.58
P_3 x P_4	-15.04**	5.16	0.00	9.09	-32.57**	26.88**
P_3 x P_5	-7.08*	5.88	6.67	0.00	8.11	2.97
P_3 x P_6	4.42	-15.60**	0.00	0.00	21.14**	0.22
P_3 x P_7	-15.93**	1.64	12.5	0.00	8.57	-0.71
P_4 x P_5	-2.02	-2.38	-16.67 **	-18.18*	35.14**	-8.75
P_4 x P_6	4.81	-4.96	5.56	-18.18*	0.00	32.10**
P_4 x P_7	-13.13**	11.11**	-16.67 **	9.09	24.26*	-8.48
P_5 x P_6	-0.96	-11.35**	20.00 **	0.00	-10.27	-6.5
P_5 x P_7	-6.45	-1.64	0.00	11.11	-17.84*	-9.17
P_6 x P_7	-15.38**	-7.80**	6.25	11.11	15.60	-3.14

** Significant at 1% level, * Significant at 5% level, Without star indicates non-significant.

Conclusion

Heterosis study can play a pivotal role in increasing the yield and quality of vegetable crops. So, to find out high heterotic combination for better hybrids, significant heterosis was observed for most of the characters of snake gourd. Considering days to 1st female flower open, fruit weight, fruits per plant, fruit yield per plant, fruit yield per hectare, fruit length and fruit diameter, the best heterotic crosses were P_1 x P_3, P_2 x P_6, P_3 x P_7 and P_6 x P_7. Such crosses could also be used for the exploitation of better parent heterosis and evaluation in the desirable direction for developing improved hybrids.

References

Ahmed, B. 2016. Combining ability and heterosis in pumpkin (*Cucurbita moschata* Duch Ex Poir.). PhD Dissertation. Department of Horticulture, BSMRAU, Salna, Gazipur, Bangladesh.

Ahmed, M. S., M. G. Rasul, M. K. Bashar and A. S. M. Mian. 2000. Variability and heterosis in snake gourd *(Trichosanthes anguina* L.). *Bangladesh J. Pl. Breed. Genet.* **13**(1): 27-32.

Banik, B. R. 2003. Variability, gene action and heterosis in snakegourd (*Trichosanthes anguina* L.). PhD Dissertation. Department of Genetics and Plant Breeding, BSMRAU, Salna, Gazipur, Bangladesh.

BBS. 2020. Yearbook of Agricultural Statistices-2019. Bangladesh Bureau of Statistics. Ministry of Planning. Govt. of the Peoples Republic of Bangladesh. Dhaka.

Chauhan, V. B. S., D. K. Singh and H. Choudhary. 2018. Studies on heterosis for yield and its contributing traits in sponge gourd (*Luffa cylindrica* Roem.). *Int. J. Curr. Microbiol. App. Sci.* **7**(12): 223-230.

Ene, C. O., P. E. Ogbonna, C. U. Agbo and U. P. Chukwudi. 2019. Heterosis and combining ability in cucumber (*Cucumis sativus* L.). *Info. Process. Agril.* **6**: 150-157.

FAO. 2015. Food and Agriculture Data. Food and Agricultural Organization, Rome, Italy.

FRG. 2012. Fertilizer Recommendation Guide. Bangladesh Agricultural Research Council (BARC). Farmgate, Dhaka 1215. p.274.

Glover, M. A., D. B. Willmot, L. L. Darrah, B. E. Hibbard and X. Zhu. 2005. Diallel analyses of agronomic traits using Chinese and US maize germplasm. *Crop Sci.* **45**(3):1096–1102.

Hussien, A. H. and A. A. Hamed. 2015. Diallel analysis for studying heterosis and combining ability of some economical yield traits in pumpkin. *J. Pl. Prod.* **6**(3): 261-270.

Islam, M. S. 2008. Genetic diversity, combining ability and heterosis in hyacinth bean. PhD Dissertation. Department of Horticulture. BSMRAU, Gazipur, Bangladesh.

Jahan, T. A., A. K. M. A. Islam, M. G. Rasul, M. A. K. Mian and M. M. Haque. 2012. Heterosis and qualitative and quantitative characters in sweet gourd (*Cucurbita moschata* Duch ex. Poir.). *African J. Food Agril. Nutri. Dev.* **12**(3): 6186-6198.

Jha, A., S. Pandey, M. Rai, D. S. Yadav and T. B. Singh. 2009. Heterosis in relation to combining ability for flowering behavior and yield parameters in pumpkin. *Veg. Sci.* **36**(3 suppl.): 332-335.

Kumari, M., J. Kumar, K. Kant, B. K. Singh, C. K. Bagchi, A. Kumari, R. kumari, M. Kumar, V. K. Singh, S. Shree, A. Bhardwaj and A. Kumar. 2020. Heterosis in bitter gourd (*Momordica charantia* L.) for yield and yield related traits. *J. Pharmacogn. Phytochem.* **9**(1): 1235-1239.

Mule, P. N., V. Khandelwal, V. A. Lodam, D. A. Shinde, P. P. Patil and A. B. Patil. 2012. Heterosis and combining ability in cucumber (*Cucumis sativus* L.). Madras Agric. J. **99**(7-9): 420-423.

Pandey, S., M. Rai, B. Singh and A. K. Pandey. 2005. Heterosis and combining ability in ash gourd (*Benincasa hispida*). *Veg. Sci.* **32**(1): 33-36.

Podder, R., A. K. M. Aminul Islam, M. G. Rasul, M. A. K. Mian and J. U. Ahmed. 2018. Heterosis in snake gourd (*Trichosanthes cucumerina* L.). *Ann. Bangladesh Agric.* **22** (1): 29-35.

Podder, R., M. G. Rasul, A. K. M. A. Islam, M. A. K. Mian and J. U. Ahmed. 2010. Combining ability and heterosis in snake gourd (*Trichosanthes cucummina* L.). *Bangladesh J. Pl. Breed. Genet.* **23** (2): 01-06.

Quamruzzaman, A. K. M, M. M. R. Salim, L. Akhter, T. Hasan, K. Mazed and M. A. Z. Chowdhury. 2019. Genetic architecture of yield in bottle gourd (*Lagenaria siceraria* (Mol.) Standl.). *Agril. Sci.* **10**: 567-576. [https://doi.org/10.4236/as.2019.104045].

Rahman, A. K. M. M. 2004. Genotype-environment interaction, heterosis and sex modification in snake gourd (*Trichosanthes anguina* L.). PhD Dissertation. Department of Genetics and Plant Breeding, BSMRAU, Salna, Gazipur, Bangladesh.

Rashid, M. M. 1993. Shabjibiggyan (In Bengali). 2nd ed. Rashid Publishing House, 94, Old DOHS, Dhaka-1206. p.344.

Riggs, T. J. 1988. Breeding F_1 hybrid varieties of vegetables. *J. Hort. Sci.* **63**: 362-69.

Singh, A. K. and B. S. Asati. 2011. Combining ability and heterosis studies in tomato under bacteria wilt condition. *Bangladesh J. Agril. Res.* **36**(2): 313–318.

Varghese, P. 1991. Heterosis in snake gourd (*Trichosanthes anguina* L.). MS Thesis. Kerala Agril. Univ. Kerala. India.