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Journal of Agricultural Studies
ISSN 2166-0379
2017, Vol. 5, No. 3

Heterosis and Combining Ability of Pumpkin (*Cucurbita moschata* Duch. Ex Poir.)

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Received: August 24, 2017 Accepted: September 8, 2017 Published: September 27, 2017

doi:10.5296/jas.v5i3.11920 URL: https://doi.org/10.5296/jas.v5i3.11920

Abstract

Combining ability and heterosis studies carried out using half diallel method with six parents for nine characters. The analysis revealed that none of the parents was found good general combiner for all the characters consistently, however the parents P_2, P_3, P_4 and P_5 were best general combiner's for yield and flowering traits. The gca variance for node order to first female flower open, fruit length, fruit diameter, flesh thickness, average fruit weight, fruits per plant, yield per plant and TSS was higher than the sca variance. While the days to first female flower open had lower gca value than the sca variance indicating the predominance of non-additive gene effects. Five crosses $P_1 \times P_4$, $P_3 \times P_6$, $P_4 \times P_2$, $P_5 \times P_3$ and $P_5 \times P_6$ found

promising and should be maintained for development of future hybrid varieties for their sca effect and desirable level of heterosis.

Keywords: Pumpkin, combining ability, gca effect, sca effect, heterosis

1. Introduction

Pumpkin (*Cucurbita moschata* Duch. Ex Poir.) is one of the major cucurbitaceous fruit vegetables grown all over Bangladesh. The crop is variously known as 'Misti kumra' or 'Misti lau' or 'Misti kadu' in different parts of Bangladesh. It is consumed by most of the people of the country. It is popular among the people owing to its good taste, high nutritive value, good storability, long time of availability and better transport potential (Hazra *et al*., 2007; Rashid, 1999). About 14% (8% in rabi and 6% in kharif son) of the total vegetable production in Bangladesh comes from pumpkin (BBS, 2013). It is rank third in area of cultivation and production next to brinjal and radish. It occupies an area of 27,500 ha with an annual production of 2,18,000 tons and an average yield of 7.93 t/ha (BBS, 2013).

Pumpkin is becoming an important ingredient in the daily diet as vegetable, but relatively little attention has been made towards development of hybrids/varieties rich in carotenoids with high yielding capacity. There are reports of high heterosis to the extent of 181.5% for yield, 68.7% average fruit weight and 150% for number of fruits per plant (Mohanty and Mishra; 1999 Pandey *et al*., 2002). Heterosis or hybrid vigor can play a vital role in increasing the yield and quality of pumpkin.

Combining ability is one of the important and powerful tools to identify the best combiners that may be used in crosses to exploit heterosis. It helps to know the genetic architecture of various characters that enable the breeder to design effective breeding program for improvement of the available materials. This information is also useful to the breeder for selection of diverse parents for hybrid. Information regarding the general combining ability (gca) and specific combining ability (sca) in breeding program for species are amenable to development of F1 hybrid cultivar. Such basic information on combining ability in pumpkin would aid the breeder to improve on pumpkin cultivars (Tasdighi and Baker, 1981). The present investigation therefore was undertaken to identify potential parental combinations in order to develop superior hybrids.

2. Materials and Methods

The materials comprised of six inbred lines namely, PK01, PK06, PK07, PK08, PK09 and PK10, which were designated as P_1, P_2, P_3, P_4, P_5 and P_6, respectively. These lines were developed by the Olericulture Division, Horticulture Research Centre, Bangladesh Agricultural Research Institute (BARI), Gazipur. The lines were crossed in all possible combinations (15 F1) excluding reciprocals. The F1s and their parents evaluated using RCBD in three replications. The work was carried out from October, 2012 to May, 2013.

The planting spacing was 2.5 m × 2.5 m, respectively. Twenty five days old seedlings were transplanted in well prepared experimental plot. Fertilizers were applied at a rate of 5000-35-75-18-4.3-2 kg/ha of cowdung-N-P-K-S-Zn-B. The sources of N, P, K, S, Zn and B were urea, triple super phosphate, muriate of potash, gypsum, zinc sulphate and boric acid (laboratory grade). The entire amount of cowdung, P, S, Zn, B and a third of K were applied during pit preparation as basal. The rest of the K was applied in two equal installments at 20 and 35 days after transplanting (DAT). Nitrogen was applied in four equal installments at 7, 20, 35 and 50 DAT.

Necessary intercultural operations were done during the crop period for proper growth and development. Observations were recorded from all the plants in each plot for nine characters. Data were recorded for days to first female flower open, node order to first female flower open, fruit length, fruit diameter, flesh thickness, average fruit weight, fruits per plant, yield per plant and total soluble solid (%). Combining ability variance and effects were worked out according to Griffing (1956) and heterosis was recorded as mid parent heterosis (Hm) and better parent heterosis (Hb) form mean values according to the formula adopted by Falconar and Mackay (1996) and was estimated following Mather and Jink (1971). Student's t-test was used to test the significant ($p<0.05$) differences of F1 mean over better parent and mid parent (Singh and Chaudhary, 2006).

3. Results and Discussion

Combining Ability

The analysis of variance (ANOVA) showed significant differences among the parents and the crosses for all the characters studied (Table 1). The significant mean sum square for general combing ability (gca) and specific combining ability (sca) for all the characters indicates that both additive and non additive gene actions played dominant role in the expression of these characters. Pandey *et al*. (2010) also reported highly significant variance for both general and specific combining ability for all characters studied. The gca variance were higher than the sca variance for node order to first female flower open, fruit length, fruit diameter, flesh thickness, average fruit weight, fruits per plant, yield per plant and TSS (%). This indicated the limited scope of heterosis breeding for these characters and population improvement through recurrent selection should be adopted for exploiting the genetic variance (Pandey *et al*., 2005). The lower gca variance than the sca variance of days to first female flower may be improved through hybridization (heterosis), which indicate the predominance of non-additive gene effects. The information regarding gca effect of the parent is of prime importance as it is difficult to pick up good general combiner for all the characters.

Table 1. Analysis of variance for combining ability of pumpkin

Source of variation	d.f.	Mean sum of square								
		DFF[1]	NFF[2]	FL[3] (cm)	FD[4] (cm)	Fl. T[5] (cm)	Av. FWt.[6]	Fruits/ Plant	Yield/ plant	TSS (%)[7]
gca	5	24.8**	16.4**	17.8**	19.3**	0.6**	1.9**	3.1**	56.5**	3.1**
sca	15	29.2**	11.3**	9.6**	5.5**	0.1**	0.8**	1.1**	17.3**	0.6**
Error	40	1.4	2.1	1.0	1.6	0.1	0.1	0.1	0.9	0.2

**Significant at 1% level, [1]Days to first female flower open, [2]Node order of first female flower open, [3]Fruit length, [4]Fruit diameter, [5]Flesh thickness, [6]Average fruit weight, [7]Total soluble solid (%)

The findings revealed that the parent P_2 for days to first female flower open, fruits per plant and yield per plant; P_3 for fruit length, fruit diameter and flesh thickness; P_4 for node order of female flower open and TSS (%); P_5 for fruits per plant and yield per plant. These indicated that the parents like P_2, P_3, P_4 and P_5 contributed maximum to its progenies. So in the present study, the parents P_2, P_3, P_4 and P_5 were the best combiners for yield and most of the yield related traits (Table 2). It was observed that the parents which were high performing, were also good general combiners for respective characters. It can be inferred that the potential parents for breeding to improve the yield and its contributing characters in pumpkin may be judge on the basis of *per se* performance. The sca effect is considered as a measure of heterosis, it was inferred that the heterosis for yield was the cumulative or synergistic effect of heterosis for component characters. It would be possible to achieve yield improvement in this crop by manipulating any or a number of specific component characters. With regard to specific combining ability (sca) effects, the cross $P_1 \times P_4$ was best for fruits per plant and yield per plant; $P_4 \times P_2$ was best for days to first female flower open, flesh thickness and yield per plant; $P_5 \times P_3$ was best for fruits per plant and yield per plant; $P_5 \times P_6$ was best for fruits per plant and yield per plant; $P_3 \times P_6$ was the best for days to first female flower open, fruits per plant and yield per plant (Table 3). The results showed that four crosses ($P_1 \times P_4$, $P_3 \times P_6$, $P_4 \times P_2$, $P_5 \times P_3$ and $P_5 \times P_6$) could be exploited for improvement of yield and its components in pumpkin.

Table 2. Estimation of general combining ability (gca) effects of parents for different traits in pumpkin

Parents	Days to first female flower open	Node order to first female flower open	Fruit length (cm)	Fruit diameter (cm)	Flesh thick. (cm)	Av. Fwt. (kg)	Fruits /plant	Yield /plant (kg)	TSS (%)
P_1	1.4*	0.3	-0.8	-1.7**	-0.3**	-0.7	-0.1	-2.8**	0.8
P_2	-2.6**	-0.6	0.9	-0.5	-0.1	0.4	1.0**	4.56**	-0.9**
P_3	-0.8	0.1	2.1**	2.3**	0.1*	0.4	-0.7	-1.6**	0.1
P_4	0.2	-2.3**	-1.6**	-1.0*	-0.1	-0.2	-0.3*	-1.5**	0.6**
P_5	2.4**	2.1**	-1.5**	-0.6	-0.1	-0.3	0.4**	1.2*	-0.2
P_6	-0.6	0.4	0.8	1.6*	0.5**	0.4	-0.3**	0.2	-0.4*
SE ±(gi)	0.4	0.5	0.4	0.4	0.1	0.1	0.1	0.3	0.1

**Significant at 1% level, *Significant at 5% level

Table 3. Estimation of specific combining ability (sca) effects of crosses for different traits in pumpkin

Parents	Days to first female flower open	Node or. to first female flower open	Fruit length (cm)	Fruit diameter (cm)	Flesh thick. (cm)	Av. Fwt. (kg)	Fruits /plant	Yield /plant (kg)	TSS (%)
$P_1 \times P_2$	10.0**	2.7*	-7.7**	-0.4	-0.6**	-1.5**	1.9**	-1.8*	0.9*
$P_1 \times P_3$	-4.2**	0.8	1.7	0.7	-0.2	0.5	-0.3	0.6	0.5
$P_1 \times P_4$	6.6**	-0.3	-0.9	-2.2	-0.1	0.3	1.3**	5.05**	0.2
$P_1 \times P_6$	-2.2*	2.4	1.5	1.2	-0.0	0.3	-0.4	-0.1	-0.3
$P_3 \times P_2$	-2.1	-6.4**	3.4**	3.2*	0.3	1.0**	-1.6**	-4.2**	0.1
$P_3 \times P_6$	-5.8**	-2.1	-3.7**	-1.7	-0.3	-0.6	1.2**	3.2**	0.7
$P_4 \times P_2$	-5.5**	2.5	-1.5	-3.4**	0.3*	0.5	-0.0	2.2*	0.5
$P_4 \times P_3$	3.9**	3.0*	-1.6	1.5	0.3	-0.2	0.1	0.0	0.4
$P_4 \times P_6$	-6.0**	-7.0**	1.6	3.2*	0.3*	1.0**	-0.5*	-0.1	-0.3
$P_5 \times P_1$	-1.7	-4.1**	1.5	1.3	0.2	0.2	-0.5*	-1.3	-0.1
$P_5 \times P_2$	1.6	0.3	-0.6	-1.5	0.3*	0.4	1.0**	7.3**	-0.8
$P_5 \times P_3$	-0.9	1.8	-0.8	0.5	-0.1	0.4	1.1**	5.5**	-0.9*
$P_5 \times P_4$	-1.0	-2.6	4.3**	2.7*	-0.1	0.8**	-0.6**	-0.5	0.3
$P_5 \times P_6$	-2.1	2.8*	-2.5*	-2.9*	0.1	-0.0	1.1**	3.7**	-1.0*
$P_6 \times P_2$	-2.6*	1.6	3.1**	2.9*	0.1	1.3**	-0.8**	1.5	0.8
SE ±(gi)	0.6	0.5	0.6	0.6	0.1	0.1	0.1	0.3	0.2

Heterosis (%)

The hetrotic response of F_1 hybrids over mid-parent (Hm) and better parent (Hb) for nine characters are presented in Table 4. The minimum days required for first female flower open, lowest order of nodes for first female flower open, higher flesh thickness, higher average fruit weight, higher number of fruits per plant, higher yield and higher TSS were desirable for better parent. Both positive and negative heterosis was observed for different quantitative characters in F_1 hybrids of pumpkin. For days to first female flower open the mid-parent heterosis and heterobeltiosis varied from -17.2 to 21.1 % and -13.9 to 25.7% respectively. The hybrids $P_3 \times P_6$ showed the highest significant negative mid-parent heterosis (-17.2**) and heterobeltiosis (-13.9 **). In case of node order to first female flower open the hybrid $P_4 \times P_6$ showed the highest significant negative mid-parent (-39.3**) and better parent (-33.0**) heterosis. For fruit length and fruit diameter the hybrid ($P_5 \times P_4$) showed significant positive

Journal of Agricultural Studies
ISSN 2166-0379
2017, Vol. 5, No. 3

mid-parent (39.0** and 16.8*) and better parent (38.5** and 11.5*) heterosis. None of the hybrids showed significant positive better parent heterosis for flesh thickness. There was a significant variation for both mid-parent heterosis and better parent heterosis for average fruit weight. The hybrids $P_5 \times P_4$ (82.2** and 78.3**), $P_4 \times P_6$ (73.4** and 39.7**), $P_6 \times P_2$ (61.0** and 57.1**) and $P_3 \times P_2$ (42.4** and 36.8**) showed the significant positive mid parent and better parent heterosis. The significant positive mid-parent and better parent heterosis for fruits per plant was exhibited by the hybrids viz., $P_3 \times P_6$ (79.4** and 46.8**), $P_5 \times P_6$ (64.7** and 44.8**) and $P_1 \times P_4$ (88.6** and 65.0**). Jahan *et al*. (2012) reported highest mid-parent heterosis and better parent heterosis for fruits per plant. The hybrids $P_1 \times P_4$ (146** and 132.1**), $P_3 \times P_6$ (91.6** and 64.9**), $P_5 \times P_2$ (98.6** and 35.3*), $P_5 \times P_3$ (170.9** and 152.4**), $P_5 \times P_4$ (81.5** and 63.6**) and $P_5 \times P_6$ (129.4** and 110.5**) showed the significant mid-parent and better parent heterosis respectively for yield per plant. The highest mid-parent value (170.9%) and that of the better parent (152.4%) heterosis was observed in this trait. Jahan *et al*. (2012) reported maximum value of 48.5% for mid-parent heterosis while Jha *et at*. (2009) reported maximum value of 65.5% for better parent heterosis for yield per plant. None of the hybrids showed significant positive mid-parent and better parent heterosis for TSS.

Table 4. Heterosis over mid-parent and better parent for nine traits of fifteen hybrids of pumpkin

Parents	Days to first female flower		Node no. to first female flower		Fruit length (cm)		Fruit diameter (cm)		Flesh thick. (cm)		Av. Fwt. (kg)		Fruits /plant		Yield /plant (kg)		TSS (%)	
	Hm (%)	Hb (%)	Hm (%)	Hb (%)	Hm (%)	Hb (%)	Hm (%)	Hb (%)	Hm (%)	Hb (%)	Hm (%)	Hb (%)	Hm (%)	Hb (%)	Hm (%)	Hb (%)	Hm (%)	Hb (%)
$P_1 \times P_2$	21.1**	25.7**	15.6	19.9	-49.3**	-53.1**	-0.1	-5.5	-17.1*	-18.6**	-38.5*	-48.9**	78.1**	22.0	0.0	-37.1	16.6	-38.6**
$P_1 \times P_3$	-6.6	-3.3	2.2	6.3	2.0	-8.1	9.5	-4.3	-9.1	-14.6*	21.2	-2.4	18.8	5.6	48.1*	7.9	9.6	3.6
$P_1 \times P_4$	13.2**	15.8**	-4.8	0.5	-10.0	4.5	-8.8	-7.2	2.1	-3.6	33.2*	25.2	88.6**	65.0**	146**	132.1**	6.8	4.8
$P_1 \times P_6$	-7.2*	0.2	9.8	14.5	2.5	-1.1	9.9	-3.0	-6.0	-17.0**	24.6	5.6	15.0	4.5	41.3*	7.9	-1.0	-9.1
$P_3 \times P_2$	-6.6	0.6	-31.1*	-25.5*	10.7	8.0	21.2**	11.5*	10.7	2.2	42.4**	36.8**	-41.5**	-62.3**	-13.8	-43.4**	7.7	-4.8
$P_3 \times P_6$	-17.2**	-13.9**	-16.5	-16.3	-19.7*	-13.2	0.5	-0.6	-2.7	-8.9	6.5	0.0	79.4**	46.8**	91.6**	64.9**	8.8	5.5
$P_4 \times P_2$	-10.9**	-5.4	8.1	9.9	-33.2**	-45.1	-40.5**	-42.8**	16.9*	12.4	38.5**	9.5	16.5	-13.0	45.9**	-5.9	15.9	-0.9
$P_4 \times P_3$	1.8	3.1	5.9	16.6	-8.2	-26.2**	17.5*	4.3	15.1	2.4	20.6	-7.3	15.8	-8.3	54.5*	49.1*	8.8	4.7
$P_4 \times P_6$	-16.6**	-12.1**	-39.3**	-33.0**	12.2	-4.4	21.4**	8.7	15.9*	-2.6	73.4**	39.7**	-11.7	-15.4	55*	29.5	-0.7	-7.3
$P_5 \times P_1$	-0.9	5.9	-16.6	-6.8	6.4	23.0*	8.0	15.3*	2.8	2.8	25.0	20.0	23.4	0.0	54.0*	31.8	-4.5	-4.5
$P_5 \times P_2$	1.5	12.8**	0.3	16.6	-5.7	-22.3**	-6.1	-6.6	15.1	13.1	41.4**	13.8	44.3*	15.2	98.6**	35.3*	-11.8	-25.7**
$P_5 \times P_3$	-6.1	-3.2	2.9	10.2	-3.5	-22.3**	7.7	-0.3	0.0	-6.1	36.6*	6.6	81.4**	34.5	170.9**	152.4**	-13.6	-18.3
$P_5 \times P_4$	-3.7	0.4	-16.9	-1.5	39.0**	38.5**	16.8*	11.5*	5.9	0.0	82.2**	78.3**	-1.9	-10.3	81.5**	63.6**	-0.9	-2.7
$P_5 \times P_6$	-11.0**	-10.2**	7.3	14.7	-12.6	-25.3**	-10.1	-16.0**	5.3	-7.0	33.2*	9.2	64.7**	44.8**	129.4**	110.5**	-17.1*	-23.9**
$P_6 \times P_2$	-10.9**	-5.4	5.8	14.6	10.9	6.1	17.7*	9.4	6.5	-7.4	61.0**	57.1**	-15.0	-38.3**	36.3*	-2.3	13.6	3.3
SE ± (gi)	2.2	1.8	2.9	2.4	1.8	1.4	1.5	1.2	0.3	0.2	0.5	0.4	0.5	0.4	1.5	0.8	0.8	0.6

4. Conclusion

Male and female inbred parents of five crosses $P_1 \times P_4$, $P_3 \times P_6$, $P_4 \times P_2$, $P_5 \times P_3$ and $P_5 \times P_6$ should be maintained for development of future hybrid varieties since they gave higher estimates of sca effects and desirable level of heterosis for fruit yield and its component characters upon combination. Performance of these hybrids needs to be evaluated in multi-locational and on-farm trial prior to commercial use.

Acknowledgements

Dr. M.A.T. Masud, PSO, Olericulture Division, HRC for providing valuable pumpkin inbred lines from his breeding program under the division. The work has been carried out in Ph.D program under the financial support of BARI, for professional fellowship through Integrated Quality Horticulture Development (IQHDP) program.

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