COMBINING ABILITY ANALYSIS IN PUMPKIN (*Cucurbita moschata* Duch Ex Poir)

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Received: 01/08/2017 | **Edited: 10/08/2017** | **Accepted: 17/08/2017**

Abstract: *The genetic constitution of yield and its components of pumpkin were investigated using the diallel analysis technique. A 6X6 full diallel cross combinations were developed and experiment was conducted to estimate the genetic information of thirteen quantitative characters including general combining ability (GCA) and specific combining ability (SCA) for yield and component traits. The variance due to GCA, SCA and reciprocal effects were significant for maximum characters. The higher magnitude of GCA than SCA variance for the characters suggested that the inheritance of these characters is predominantly governed by additive gene effects. The higher magnitude of SCA variance than that of GCA variance signified a predominant role of non-additive gene action in the inheritance attributes. Good general combining ability for earliness, number of male and female flowers per plant, fruit diameter, single fruit weight, flesh thickness, number of fruits per plant, yield per plant, number of seeds per fruit, and brix were observed in the parent CM-1. The parent BARI MISTIKUMRA-1 showed desirable GCA effects specially for flesh thickness and seed characters. Finally, on the basis of different attributes total four parents (CM-1, BARI Mistikumra-1, CM-20 and CM-8) were found as good general combiners. Out of that none of the parents was good general combiner for yield and its all component characters. Cross between good general combiners (good-good) for yield did not produce good specific crosses but poor-good and poor-poor produced. So, selection of parents for good combining abilities might be good for improvement of pumpkin. The SCA effects of almost all the crosses were significant, but none of the cross was significant for all the traits. The specific combining ability indicated that the cross combination CM-20 X CM-1, CM-1 X CM-8 and CM-1 X BARI MISTIKUMRA-1 had significant effects for different important characters including earliness, single fruit weight, number of fruit per plant, yield, seed characters and brix%. Results indicated over dominance and epistatic gene actions for these traits. Therefore, selection of parents for good combining abilities might be good for improvement of pumpkin. Thus, these combinations could be used for exploitation of heterosis of pumpkin*

Key words: *Pumpkin (Cucurbita moschata Duch Ex Poir), diallel, GCA and SCA.*

Introduction

Pumpkin (*Cucurbita moschata* Duch Ex Poir) is the most important seed propagated monoecious climbing vegetable crop that belongs to the family Cucurbitaceae, with the chromosome number 2n=40 (Katyal and Chadha, 2000). It is one of the most common fruit vegetables in Bangladesh and is locally known as "Misty kumra" or "Misty lau" or "Misty kadu" (Jahan *et al.*, 2012). Pumpkin is grown in all over the Bangladesh and in most areas; local land races are cultivated. The yield of these land races is very low (Mohsin *et al.,* 2017). During 2010-2011, average yield was 3.05 t/ac (BBS, 2012) which is much lower than our neighboring country India. During 2010-2011, the average pumpkin production was 9.3 t/ha in India, 18.4 t/ha in China, 18.6 t/ha in

Russia, 16.3 t/ha in Mexico, 29.4 t/ha in Italy and 21.4 t/ha in USA (FAO, 2010).

Very limited progress has been achieved in the improvement of fruit yield with quality and associated morpho-agronomic characters in pumpkin varieties suitable for Bangladesh. A study of the genetic potential of parents in expression of yield and component characters on hybrid population is necessary for selection of the best parents. Combining ability analysis is a tool to determine the nature and magnitude of gene action on hybrid population. Being a most common nutritionally rich crop the scientific attempt is needed for the genetic improvement of pumpkin to get higher yield with quality characters through estimation of combining abilities.

Materials and Methods

Six different divergent inbred parents of pumpkin namely CM-20, CM-1, CM-5, BARI Mistikumra-1, CM-8 and CM-14 were used in diallel cross. Materials were collected from different parts of the Bangladesh AVRDC and Thailand. As a full diallel set 30F1 hybrids were developed in 2012. The seeds of six parents, their 15 F_1's and 15 reciprocal F_1s were sown and transplanted using randomized block design with three replications in the experimental field of Research and Development (R&D) of Lal Teer Seed, Gazipur, Bangladesh during 2012-2013. The length and width of raised bed was 10 and 4 meter, respectively. Plant to Plant distance was 2m and row to row distance was 4m. The recommended package of practices was provided to raise a good crop (BARC, 2012). Data were collected on the following traits associated with yield from randomly selected ten plants from each genotype for d**ays** to first male flower opening (MFO), days to first female flower opening (FFO), number of flowers (male and female) per plant (NMF/PL, NFF/Pl), fruit length (FL)and diameter (FD) (cm), single fruit weight (kg) (SFW), flesh thickness (cm) (FLTHK), brix (%), number of fruits per plant (NFRT/PL), number of seeds per fruit (NS/FRT), 100- seeds weight (g) (100-SW) and yield per plant (kg) (YLD/PL). Analysis of variance (ANOVA) was done on a sample mean basis. Estimation of combining ability was done following method 1 of model 1 (fixed effect) of Griffing (1956). The mean squares for GCA and SCA were tested against the error variances of respective characters derived from ANOVA reduced to mean level.

Results and Discussion

Analysis of variance (ANOVA) for combining ability

Significant differences were obtained among the crosses, GCA and SCA for most of the characters (Table 1). Results indicated a wide range of genotypic variation among the parents and their hybrids. The significant general and specific combining ability (GCA and SCA) for the characters indicated both additive and as well as non-additive types of gene actions for the expression of these characters. The GCA variance was significant for all the traits except number of male and female flowers per plant and flesh thickness. Significant SCA variance was observed for all the measured variables. The higher magnitude of GCA than SCA variance for the characters suggested that the inheritance of these characters is predominantly governed by additive gene effects. The higher magnitude of SCA variance than that of GCA variance signified a predominant role of non-additive gene action in the inheritance attributes. Both additive and non-additive effects influenced the performance of the hybrid in all these traits. Vegad *et al*., (2011) noted that variance due to GCA and SCA were highly significant for all the characters except SCA for days to first male and female flower opening. They also explained that both additive and non additive genetic variance were present for inheritance of fruit yield and its components. The ratio of GCA: SCA was greater than unity for most of the traits indicating the importance of additive genetic variance in the inheritance of the traits studied. Singh *et al*., (2013) explained that fruit length and fruit breadth showed significance differences between GCA and SCA variances which indicated additive gene action. Sirohi *et al*., (1986) noticed the predominance of non additive gene action for weight per fruit in pumpkin.

Naliyadhara *et al.,* (2010) estimated that the variance of SCA were higher than GCA for almost all the traits which indicated the predominance of non-additive gene action for most of the characters in sponge gourd.

GCA effect of the parents

Table 2 showed the estimates of GCA effects of all the parents. None of the six parents found to be a good general combiner for yield and its all component characters. The parent CM-20 was found the best combiner for days to male and female flowering, number of male and female flower per plant, number of fruits per plant, number of seed per plant and brix. But poor GCA effects for yield character. CM-1 showed good GCA for significant earliness, number of male and female flowers per plant, fruits diameter, single fruit weight, flesh thickness, number of fruits per plant, number of seed per plant, brix and significantly increasing yield character. The parent CM-5 was the best combiner for fruit length, single fruit weight, flesh thickness, seed per fruit, 100-seed weight and poor GCA effects for fruit yield character. The parent BARI MISTIKUMRA-1 showed desirable GCA for fruits diameter, single fruit weight, flesh thickness and seed characters. But showed as poor general combiner. The parent CM-8 was also found good combiner for number of female flowers per plant, fruit diameter, single fruit weight, number of fruits per plant, yield per plant, and brix. The positive GCA effects for number of fruits per plant and yield per plant indicated that the concerned parent had the ability to produce more fruits with higher yield per plant while the negative GCA effect for days to 50% flowering indicated the parental lines would have to produce early flowering hybrids. The parent CM-14 had significant combining ability for number of seeds per fruit and brix. So, the above parents (CM-20, CM-1, CM-5, BARI MISTIKUMRA-1, CM-8, and CM-14) could be used in hybridization program for quality and yield improvement of pumpkin. Such positive association between the parental performance and significant positive GCA effects in pumpkin was reported by Rahaman (2006), Mohanty (2001), Naliyadhara *et al.,* (2010), Vegad *et al.*, (2011), Singh *et al.*, (2013). Maurya *et al.*(2004) and Mishra *et al.*, (1994) have also detected almost similar results in bottle gourd and bitter gourd respectively.

SCA effect of the crosses

Table 3 showed the estimates of SCA effects for F1 hybrids. None of the cross was significant for all the traits. That is, all the crosses involving good combiners and good combiners did not produces good specific crosses. The SCA estimates for various studied characters indicated that the cross combination CM-20 X CM-1 had significant for single fruit weight, yield, seed characters and brix%. The combination CM-1 X CM-8 was suitable for early female flowering, number of fruits per plant, yield and brix. For number of fruits per plant, yield per plant, number of seed per fruit the best combination was CM-1 X BARI MISTIKUMRA-1. Thus, these combinations could be used for exploitation of heterosis.

Good general combiners, CM-20 X CM-1 (good X good) did not produce the best specific cross for DFFO, FD and Flesh thickness. But the poor X poor (CM-5 X CM-14) and good X poor (CM-1 X BMK-1) combiners produced the best specific crosses for DFFO, FD and flesh thickness. The superiority of poor-poor combiners suggested an over dominance and epistatic gene action. Rahaman (2006), Naliyadhara *et al.,* (2010), Vegad *et al.*, (2011), Singh *et al.*, (2013) also reported similar results. Bimal (2008) found in bitter gourd based on sca effects that the cross combination P1 X P2 was superior for average single fruit weight, fruit yield, fruit length, flesh thickness and 100-seed weight. The cross P3 X P5 was best for days to first male and female flower open, number of fruits per plant, single fruit weight and yield per plant. He also noted that P2 X P4 may be selected for the number of fruits per plant and yield per plant. Banik (2003) reported that among 6X6 diallel crosses in snake gourd, P1 X P5 had significant sca effects for days to first male and female flower opening. She also selected the cross P1 X P2 was the best for fruits per plant, fruit length and 100-seed weight. So, poor general combiners have also value to develop improved quality pumpkin.

Reciprocal effect of the crosses

Significant reciprocal effects were observed for the important characters. The cross BARI MISTIKUMRA-1 X CM-1 showed significant negative value for days to female flower opening, number of female flower per plant, single fruit weight, flesh thickness, yield per plant and brix. Such results indicated that this cross could be exploited heterotic effects through nuclear inheritance only. The crosses CM-8 X CM-5, CM-14 X BARI MISTIKUMRA-1 had positive reciprocal effects which can be utilized for flesh thickness, single fruit weight, and yield per plant. These reciprocal effects indicated the to some extent effect of cytoplasmic genes controlling the expression of the characters. Similar findings were also reported by Banik (2003) in snake gourd and Bimal (2008) in bitter gourd.

The study revealed that the parents CM-1, CM-20 and BMK-1 might be good general combiners for yield and component characters. Good general combiners did not always produce good specific crosses with other parents. On the other hand, poor general combiners could produce good specific crosses. The information would be useful to the vegetable breeders in selecting parents for the pumpkin improvement program.

Table 1: Analysis of variance (ANOVA) for combining ability of yield, yield components of Pumpkin (*P<0.05 and **P<0.01, respectively)

Source of variation	Df	Characters (Mean sum of square)												
		Male Flower Open	Female Flower Open	Number of Male Fl/Pl	Number of Female Fl/Pl	Fruit Length	Fruit Diameter	Single Fruit Weight	Flesh thickness	Number of fruits per plant	Number of seeds per fruit	100-seed weight	Brix	Yield per plant
Block	2	13.02**	0.4	6.59**	0.05	0.86	0.72	0.01	0.01	0.03	32.49	0.43*	0.11*	0.13
Crosses	35	113.38**	128.55**	1.17**	1.89**	52.46**	30.26**	3.04**	2.01**	0.58**	15627.97**	20.76**	5.38**	15.10**
GCA	5	140.61**	180.19**	0.39	1.61	59.68**	20.85**	1.47*	0.54	0.53*	6097.97*	18.38**	7.11**	10.68*
SCA	15	19.37**	27.34**	0.54**	0.78**	7.81**	6.23**	0.99**	0.47**	0.21**	4189.60**	3.36**	0.93**	4.59**
Reciprocal	15	21.94**	12.58**	0.24**	0.15**	13.09**	10.35**	0.88**	0.91**	0.07**	5932..83**	6.67**	0.88**	3.60**
Error	70	0.71	0.24	0.07	0.02	0.18	0.21	0.01	0.01	0.01	13.86	0.04	0.02	0.06
GCA: SCA		7.26	6.59	0.72	2.06	7.64	3.35	1.48	1.15	2.52	1.46	5.47	7.65	2.33
Rec: GCA		0.16	0.07	0.62	0.09	0.22	0.5	0.6	1.69	0.13	0.97	0.36	0.12	0.34

Table 2: General combining ability (GCA) effects and mean performance for yield and yield components of six different parental lines in a 6X6 diallel cross in pumpkin

Parents	Days to male flower opening	Days to female flower opening	No. of male flowers per plant	No. of female flowers per plant	Fruit length (cm)	Fruit diameter (cm)	Single fruit weight (kg)	Flesh thickness (cm)	No. of fruits per plant	No. of seeds per fruit	100-seed weight (g)	Brix (%)	Yield per plant (kg)
CM-20	-5.56**	-6.47**	0.20**	0.17**	-0.43**	-1.04**	-0.61**	-0.28**	0.10**	3.07**	-0.74**	0.52**	-0.74**
	-36.2	-43.9	-8.47	-2.73	-14.82	-21.23	-1.2	-4.23	-1.8	-140	-12.62	-11.19	-1.95
CM-1	-2.51**	-0.96**	0.15*	0.52**	-0.06	0.79**	0.43**	0.12**	0.24**	9.04**	1.91**	0.02	1.50**
	-45.3	-57.83	-8.53	-3.37	-17.39	-22.79	-4.6	-4.59	-1.8	-131	-13.25	-9.41	-7.67
CM-5	1.86**	0.90**	-0.1	-0.22**	4.10**	-1.30**	0.02	0.25**	-0.06**	2.99**	0.66**	-1.06**	-0.25**
	-55.8	-59.17	-7.97	-3.57	-21.14	-18.26	-3	-4.02	-2.43	-130	-14.99	-8.88	-6.87
BARI MISKTIKUMRA-1	3.01**	5.48**	-0.11	-0.18**	0.18	1.32**	0.15**	0.17**	-0.04*	12.23**	0.18**	-0.73**	0.07
	-61.2	-77.87	-8.57	-2.33	-16.46	-22.28	-1.9	-4.07	-1.6	-120	-12.55	-7.8	-2.92
CM-8	0.25	-0.14	0.12	0.21**	-1.30**	1.44**	0.13**	-0.06**	0.13**	-44.6**	-0.31**	0.98**	0.56**
	-50.7	-56.13	-9.5	-2.3	-10.44	-20.49	-2.2	-3.25	-1.47	-110	-11.24	-11.62	-2.83
CM-14	2.97**	1.19**	-0.26**	-0.49**	-2.48**	-0.42**	-0.11**	-0.19**	-0.36**	17.30**	-1.71**	0.27**	-1.14**
	-54.1	-59.47	-8.4	-2.57	-8.51	-16.08	-2.5	-3.58	-1.23	-162	-10.68	-11.05	-3.18
S.E(g_i)	0.22	0.13	0.07	0.03	0.11	0.12	0.02	0.02	0.02	0.98	0.05	0.03	0.06
CD(gi) at 5%	0.443	0.256	0.137	0.066	0.224	0.239	0.034	0.036	0.039	1.952	0.11	0.065	0.131
at 1%	0.588	0.339	0.181	0.088	0.294	0.317	0.045	0.047	0.052	2.58	0.146	0.086	0.174

*P<0.05 and **P<0.01, respectively, Lower row of each parent is mean value

Table 3: Specific combining ability (SCA) effects for yield and yield components of different crosses in pumpkin

Crosses	Days to male flower opening	Days to female flower opening	No. of male flowers per plant	No. of female flowers per plant	Fruit length (cm)	Fruit diameter (cm)	Single fruit weight (kg)	Flesh thickness (cm)	No. of fruits per plant	No. of seeds per fruit	100-seed weight (g)	Brix (%)	Yield per plant (kg)
CM-20 X CM-1	-1.78**	0.29	-0.49**	0.33**	-2.40**	0.03	0.29**	0.05	0.22**	43.31**	0.76**	0.37**	0.81**
CM-20 X CM-5	-1.30*	-0.4	-0.03	0.01	3.47**	-1.29**	0.54**	-0.31**	-0.23**	59.04**	-0.03	0.38**	0.2
CM-20 X BARI MK-1	-2.64**	-1.54**	-0.43**	-0.48**	-1.55**	-1.99**	-0.01	-0.66**	-0.31**	-10.93**	-0.89**	0.39**	-0.70**
CM-20 X CM-8	1.85**	0.61*	0.17	0.29**	0.84**	2.01**	0.51**	-0.12**	0.29**	-6.92**	-0.28*	-1.5**	1.60**
CM-20 X CM-14	8.21**	-1.74**	0.91**	-0.04	-0.85**	-1.85**	-0.57**	-0.01	0.07	-28.58**	-0.77**	0.24**	-0.42**
CM-1 X CM-5	-0.62	-0.13	0.40*	-0.97**	-1.49**	-2.58**	-1.04**	0.14**	-0.37**	47.80**	-0.90**	-0.51**	-2.65**
CM-1 X BARI MK-1	4.15**	-5.98**	0.54**	0.69**	-0.25	0.57*	0.24**	0.17**	0.30**	6.24**	2.82**	-0.05	1.38**
CM-1 X CM-8	0.73	-3.21**	-0.45**	0.98**	1.67**	-0.24	0.41**	-0.50**	0.43**	-6.07**	1.83**	0.87**	2.20**
CM-1 X CM-14	-1.21*	3.35**	-0.04	-0.85**	2.15**	1.20**	-0.42**	-0.48**	-0.27**	-14.24**	-1.08**	0.003	-1.52**
CM-5 X BARI MK-1	-0.93	-0.99**	0.02	-0.21**	1.17**	2.39**	0.17**	-0.11**	-0.13**	-9.17**	-0.64**	-0.20**	-0.05
CM-5 X CM-8	0.79	-1.08**	-0.19	-0.49**	1.53**	1.23**	0.52**	0.96**	-0.25**	-39.19**	0.06	-0.29**	-0.15
CM-5 X CM-14	1.58**	-0.69*	-0.16	0.16*	-0.41	-0.42	-0.01	-0.46**	0.05	7.94**	0.74**	-0.32**	0.21
BARI MK-1 X CM-8	-0.43	0.49	0.05	-0.02	-1.48**	-1.80**	-0.27**	0.05	0.12**	17.44**	-0.54**	1.19**	-0.06
BARI MK-1 X CM-14	-3.65**	-4.81**	-0.77**	-0.17*	1.21**	1.38**	1.41**	0.65**	-0.01	81.29**	-0.04	-0.53**	1.57**
CM-8 X CM-14	-1.53**	0.86**	-0.66**	-0.14	-0.39	1.39**	0.07	0.08*	-0.16**	15.86**	-0.05	0.12	-0.39*
SE (Sij)	0.5	0.29	0.15	0.076	0.25	0.27	0.03	0.041	0.045	2.23	0.12	0.07	0.15
CD 5%	1.01	0.58	0.31	0.15	0.51	0.54	0.077	0.08	0.089	4.45	0.25	0.14	0.29
CD 1%	1.34	0.77	0.41	0.2	0.67	0.72	0.1	0.1	0.11	5.9	0.33	0.19	0.39

*P<0.05 and **P<0.01, respectively

Table 4: Estimation of reciprocal effects for yield and yield components of different crosses in Pumpkin

Crosses	Days to male flower opening	Days to female flower opening	No. of male flowers per plant	No. of female flowers per plant	Fruit length (cm)	Fruit diameter (cm)	Single fruit weight (kg)	Flesh thickness (cm)	No. of fruits per plant	No. of seeds per fruit	100-seed weight (g)	Brix (%)	Yield per plant (kg)
CM-1 X CM-20	-4.88**	-0.90*	0.18	0.05	-3.35**	-5.04**	-1.09**	-1.28**	-0.07	-54.15**	-2.25**	-0.07	-2.40**
CM-5 X CM-20	6.90**	0.5	0.03	-0.15	-6.07**	1.11**	-0.70**	-0.71**	0.25**	-1.03	-1.90**	-0.27**	-0.32
CM-5 X CM-1	1.67**	-0.75*	0.48*	0.43**	-0.63*	0.6	0.11*	-0.20**	0.30**	1.1	0.48**	0.23*	0.80**
BARI MK-1 X CM-20	-0.58	-5.07**	-0.65**	0.13	1.67**	1.69**	-0.13**	0.28**	0.15**	-12.77**	0.80**	-0.29**	0.12
BARI MK-1 X CM-1	1.68**	-4.35*	-0.23	0.33**	0.6	2.45**	0.87**	0.79**	0.23**	1.85	3.03**	1.56**	2.34**
BARI MK-1 X CM-5	-0.42	0.45	0.37*	-0.38	-3.22**	-2.21**	-0.08	-0.28**	-0.23**	58.82**	-1.68**	0.34**	-0.81**
CM-8 X CM-20	1.33*	2.73**	-0.38*	-0.17	-0.53	-0.79*	-0.38**	-0.24**	-0.07	33.08**	0.62**	0.58**	-1.15**
CM-8 X CM-1	3.00**	3.03**	0.25	-0.55**	-2.68**	-3.78**	-1.25**	-0.24**	-0.17**	1.47	-1.62**	-1.22**	-3.26**
CM-8 X CM-5	-0.27	-2.52**	0.03	-0.33**	5.18**	-0.23	1.09**	1.68**	-0.22**	-18.87**	-2.63**	0.12	0.77**
CM-8 X BARI MK-1	-0.33	1.83**	0.18	0.40**	0.31	-0.53	-0.23**	-0.08	0.38**	-20.12**	2.12**	-1.09**	0.75**
CM-14 X CM-20	6.20**	-3.52**	-0.55**	0.23*	0.24	-0.01	0.06	-0.06	-0.02	119.58**	0.80**	-0.23*	0.07
CM-14 X CM-1	-3.80**	-1.45**	0.28	-0.12	-0.61*	-2.49**	-0.02	-0.06	-0.07	99.03**	2.20**	0.44**	-0.18
CM-14 X CM-5	3.53**	0.27	-0.18	0.02	-0.15	-0.32	0.32**	-0.12*	-0.10*	-102.47**	1.52**	0.16	0.14
CM-14 X BARI MK-1	-2.32**	-2.60**	0.45*	0.02	0.98**	3.89**	1.04**	0.95**	-0.05	-19.50**	0.15	0.73**	1.03**
CM-14 X CM-8	2.30**	-0.52	0.23	0.01	-0.69*	-0.42	-0.03	-0.15**	-0.10*	-33.03**	-2.35**	0.1	-0.32
SE (Rij)	0.59	0.34	0.18	0.08	0.3	0.32	0.04	0.04	0.05	2.63	0.14	0.08	0.17
CD 5%	1.18	0.68	0.36	0.17	0.6	0.64	0.09	0.09	0.1	5.23	0.29	0.17	0.35
CD 1%	1.57	0.91	0.48	0.23	0.79	0.85	0.12	0.12	0.13	6.9	0.39	0.23	0.46

*P<0.05 and **P<0.01, respectively; Note: BARI MK-1 is BARI Mistikumra-1

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