Vegetable Science (2017) 44 (2) : 12-19

Identification of novel genotypes for high yielding hybrid development in ridge gourd [*Luffa acutangula* (Roxb.)L.]

Mangaldeep Sarkar* and Dinesh Kumar Singh

Received: September 2017 / Accepted: November 2017

Abstract

The present investigation detected unique genotypes of ridge gourd for development of high yielding hybrids in respect of general and specific combining ability with heterosis over better parent as well as economic parent. With the aim of recognizing both the phenomenon, 10 quantitative characters for yield and its component traits was examined in 28 hybrids derived from a 8 × 8 diallel mating design excluding reciprocals. The best three parents identified as promising general combiner were PRG 117, PRG 131 and PRG 132 for earliness, vegetative and yield characters. For earliness, vegetative and fruit characters, number of fruits per plant, fruit yield per plant and total fruit yield the crosses like PRG 131 × PRG 132, PCPGR 7256 × PRG 117, PRG 117 × PRG 7 and PRG 132 × PRG 120 were best specific combiners. Regarding fruiting traits PRG 131 × PRG 120, PRG 131 × PRG 132 and PRG 132 × PRG 120 showed highest heterobeltiosis and standard heterosis. For fruit yield the crosses PRG 131 × PRG 132 showed the highest heterobeltiosis and standard heterosis followed by PRG 132 × PRG 7 and PRG 131 × PRG 137 respectively.

Keywords: Ridge gourd, GCA, SCA, heterosis, diallel analysis

Introduction

Ridge gourd [*Luffa acutangula* (Roxb.) L.], 2n=2x=26, the imperative cucurbit is one of the least expensive vegetables to produce (Brown et al. 2005). The *Luffa* is an essentially old world genus, consisting of two cultivated (*Luffa acutangula* and *Luffa cylindrica*) and two wild species (*Luffa graveolens* and *Luffa echinata*). However, an ancestral form known as "*Satputia*" found in Bihar (India), which is hermaphrodite in sex with smooth surface, cluster in bearing and was given a separate taxonomic status as *L. hermaphrodita* (Karmakar et al. 2014). The fruits are 15-30 cm long with prominent ribbed and rough skin. Hence, it is popularly known as ribbed gourd or angled gourd or silky gourd or angled loofah. Hermaphrodite lines have enormous potential to improve plant architecture, earliness and yield traits in monoecious ridge gourd (Karmakar et al. 2014). Beside, hermaphrodite inbreds also provide opportunity to improve nutritional quality in term of mineral and antioxidant content in ridge gourd (Karmakar et al. 2013 and Karmakar et al. 2013). In spite of wide range of variability for yield, fruit characters and maturity in this crop, very little improvement work has been carried out till date. Ridge gourd, being predominantly monoecious and cross pollinated crop provide ample scope for utilization of the hybrid vigour. Single fruit of this vegetable gives large number of seeds and the cost of F_1 seed production is lower in comparison to other cucurbitaceous vegetables. The speedy genetic improvement requires assessment of genetic variability and exploitation of heterosis. In order to make an effective improvement in economically important characters, F_1 hybrid breeding is prominent among all the progressive methods. For development of promising F_1 hybrids, the identification of genetically superior plants is an important pre-requisite. The analysis of combining ability helps in selecting suitable genotypes as parents for hybridization and estimates the combining ability effect to select desirable parents and crosses for further exploitation (Sprague and Tatum 1942; Munshi and Verma 1999). Diallel analysis is widely used to estimate combining ability effects of the parents and the crosses (Griffing 1956b). It is the most balanced and systemic experimental design to examine continuous variation and used to estimate GCA and SCA, which play an important role in control of yield-related components (Virk 1988). Thus, a prompt improvement can be achieved by assembling the genetic variability locating the best combiners and exploiting heterosis. Hybrids under

Department of Vegetable Science, College of Agriculture, GBPUAT, Pantnagar, Udham Singh Nagar, Uttarakhand- 263145
*Corresponding Author; Presently at Hill Millet Research Station, Navsari Agricultural University, Waghai, The Dangs, Gujarat-394370; Email: mangaldeepsarkar@gmail.com

optimum crop production and protection management give economically more yield than the improved varieties and also provide, uniform size, earliness, better keeping quality and resistance to biotic and abiotic stresses (Kalloo et al. 2001). Therefore, this investigation was intended to search novel genotypes of ridge gourd in order to develop high yielding hybrids.

Materials and Methods

The experimental material consisted of 8 parental lines of ridge gourd, in which 7 lines [PRG 117, PRG 142, PRG 131, PRG 137, PRG 132, PRG 120 and PRG 7(Pant Torai 1)] were monoecious and 1(PCPGR 7256) was hermaphrodite in nature. Their 28 F_1s had been developed by crossing them in diallel fashion excluding reciprocals. The seeds of parental lines were obtained from Vegetable Research Centre, G.B.P.U.A&T., Pantnagar, India. Twenty eight F_1 crosses along with parents were evaluated in open field condition for heterosis and combining ability analysis in a Randomized Block Design with three replications. Ten quantitative characters (days to first female flower, node number to first female flower, vine length, number of primary branches, days taken to Ist fruit harvesting, number of fruits per plant, fruit length, fruit weight, fruit yield per plant and total fruit yield) were scored on the individual genotype in this experiment. Five plants were randomly selected from all genotypes in each replication for recording of observations for all the plant traits. The spacing between the rows was kept 3.5 m while within the row it was 0.6 m. The mean values were used for estimating the combining ability according to Griffing (1956a) model I, method II, which was a fixed effect model. Heterosis was calculated as the percentage of F_1's performance in the favourable direction over the better parent and economic or standard or check parent as suggested by Hayes et al. (1955). For calculation of the standard heterosis the genotype PRG 7(Pant Torai 1) was taken as the standard parent. Statistical analysis was performed using Microsoft Excel (2007) and INDOSTAT software.

Results and Discussion

Analysis of variance for combining ability: The general combining ability (gca) and specific combining ability (sca) mean squares calculated from the eight parental lines and twenty eight hybrids using Griffing's Method 2 and Model I are presented in Table 1. The gca mean squares were highly significant for all characters except number of primary branches, which is significant at 5 percent level of significance. The mean squares due to sca were highly significant for all the quantitative traits. The results revealed that the genotypes showed adequate amount of variation for all

Table 1: Analysis of variance for combining ability for various quantitative characters in ridge gourd

Sources of Variation		GCA	SCA	Error
Degrees of freedom		7	28	70
1.	Days to first female flower	16.83**	4.62**	0.45
2.	Node number to first female flower	3.94**	3.56**	0.21
3.	Vine length (m)	1.66**	0.49**	0.01
4.	Number of primary branches	0.29*	0.45**	0.10
5.	Days taken to Ist fruit harvesting	10.88**	4.81**	0.37
6.	Number of fruits per plant	23.27**	4.57**	0.10
7.	Fruit length (cm)	112.30**	9.71**	0.09
8.	Fruit weight (g)	8265.44**	349.48**	3.72
9.	Fruit yield per plant (g)	1596787.38**	193039.11**	2598.49
10.	Total fruit yield (q/ha)	3620.84**	436.95**	5.88

* Significant at 0.05 levels of probability; ** Significant at 0.01 levels of probability

Table 2: Estimates of general combining ability effects of parents for different quantitative traits in ridge gourd

Parents	Days to first female flower	Node number to first female flower	Vine length (m)	Number of primary branches	Days taken to Ist fruit harvesting	Number of fruits per plant	Fruit length (cm)	Fruit weight (g)	Fruit yield per plant (g)	Total fruit yield (q/ha)
PCPGR 7256	2.73**	-0.26	-0.10**	-0.18	2.09**	-0.06	-5.88**	-40.50**	-524.19**	-24.98**
PRG 117	-1.70**	0.54**	-0.12**	0.22*	-1.41**	-1.16**	-1.10**	-23.93**	-401.07**	-19.12**
PRG 142	-0.57**	-1.13**	-0.44**	-0.04	-0.24	-0.65**	-2.03**	-19.40**	-288.66**	-13.76**
PRG 131	0.30	0.77**	0.83**	0.26**	0.02	3.50**	2.87**	8.17**	609.01**	28.98**
PRG 137	-0.70**	-0.49**	-0.09**	-0.14	-0.71**	0.50**	-1.12**	9.70**	157.41**	7.48**
PRG 132	0.53**	0.41**	0.38**	0.09	0.66**	-1.23**	5.17**	54.03**	450.67**	21.44**
PRG 120	-0.47*	-0.16	-0.28**	-0.14	-0.51**	-0.67**	1.39**	10.70**	1.15	0.11
PRG 7	-0.13	0.31*	-0.17**	-0.08	0.09	-0.23*	0.70**	1.23*	-4.32	-0.15
SE (gi)	0.69	0.47	0.1	0.33	0.63	0.33	0.31	2	52.77	2.51

* Significant at 0.05 levels of probability; ** Significant at 0.01 levels of probability

the characters. For parents as well as crosses significant variation was present for all the traits indicating both additive and non additive variances. Similar findings were reported by Rao et al. (2000) in ridge gourd.

General combining ability effects: The estimates of gca effects of eight parental lines for all the ten quantitative characters are presented in Table 2. It would be imperative to mention here that for the traits days to first female flower, node number to first female flower and days taken to Ist fruit harvesting, the negative gca and sca effects were considered to be desirable, as it indicates earliness. The parents identified as promising general combiner were PRG 131 for five characters (vine length, number of primary branches, number of fruits per plant, fruit yield per plant and total fruit yield), PRG 132 for two characters (fruit length and fruit weight) and PRG 117 was good combiner for days to first female flower and days taken to Ist fruit harvesting. PRG 142 was a good combiner for only the trait node number to first female flower. The combining ability variances showed that both additive and non additive gene actions were involved in the expression of all the characters under study. However, the additive gene action was preponderant for most of the traits. These results were in conformity with Zhang et al. (2008); Karmakar et al. (2014) and Tyagi et al. (2010). Considering the above results, it may be concluded that there was predominant role of additive gene action in the inheritance of most of the traits, so for improving of yield and other traits, the conventional breeding methods may be efficient in capitalizing the available genetic variability in ridge gourd.

Specific combining ability effects: The sca effects of crosses for all ten characters are given in Table 3. In present study none of the cross combinations was found to be good specific combiner for all the characters. For earliness (days to first female flower, node number to first female flower and days to first fruit harvest) PCPGR

Table 3: Estimates of specific combining ability effects of crosses for different traits of ridge gourd

Cross Number	Days to first female flower	Node number to Ist female flower	Vine length (m)	No. of primary branches	Days taken to Ist fruit harvesting	Number of fruits per plant	Fruit length (cm)	Fruit weight (g)	Fruit yield per plant (g)	Total fruit yield (q/ha)
C_1	2.60**	2.17**	1.54**	0.76*	2.27**	0.67*	-0.81**	-9.60**	-78.63	-3.73
C_2	5.80**	-4.16**	-0.30**	1.02**	6.44**	0.49	-0.56*	-1.14	-4.30	-0.19
C_3	-2.07**	0.94*	1.03**	-0.61*	-0.16	1.01**	-0.30	31.30**	468.49**	22.32**
C_4	-1.40*	4.54**	-0.51**	-0.88**	-1.10	0.82**	0.72*	-17.57**	-168.37**	-8.00**
C_5	-1.64*	-1.70**	0.72**	0.22	-1.13*	0.01	-0.15	-0.90	54.63	2.62
C_6	0.03	0.20	-0.11	-0.21	1.04	1.25**	0.95**	-1.24	63.09	2.95
C_7	-0.97	-1.26**	0.10	0.06	-0.23	-1.39**	-0.96**	22.56**	116.62*	5.50*
C_8	-1.77**	0.04	-0.58**	0.62*	-0.73	-1.21**	-1.63**	-2.04	-161.09**	-7.65**
C_9	-1.30*	-3.20**	-0.58**	0.32	-0.33	1.64**	1.54**	18.40**	348.37**	16.61**
C_{10}	-0.64	-2.60**	0.10	0.72*	0.07	1.52**	-1.31**	-11.80**	-14.89	-0.70
C_{11}	-1.87**	-1.16**	0.00	-0.84**	-2.30**	-0.22	0.84**	4.20*	-34.49	-1.63
C_{12}	-0.54	0.07	0.79**	-0.28	-1.46*	0.95**	-0.84**	19.86**	362.51**	17.21**
C_{13}	-0.54	-0.06	-0.12	-0.68*	-1.73**	1.64**	5.21**	8.00**	237.43**	11.25**
C_{14}	-1.77**	0.80	-0.47**	-0.74*	-2.50**	1.06**	4.93**	16.20**	266.83**	12.72**
C_{15}	-0.77	-1.26**	0.13	0.32	-1.43*	2.07**	0.60*	25.00**	605.17**	28.84**
C_{16}	-2.00**	0.84	-0.21*	-0.24	-2.46**	0.13	4.26**	-24.67**	-278.29**	-13.24**
C_{17}	-0.34	-0.26	-0.28**	-0.01	-0.96	0.37	4.40**	11.33**	192.43**	9.10**
C_{18}	0.00	-0.06	0.31**	-0.08	-0.56	1.46**	-1.89**	-0.20	113.83*	5.36*
C_{19}	-0.64	-0.83	0.55**	0.02	-0.70	1.19**	1.38**	-0.57	216.97**	10.35**
C_{20}	-3.20**	-1.40**	0.53**	0.79*	-3.06**	4.72**	3.15**	-7.24**	944.77**	45.01**
C_{21}	0.46	-0.16	-0.90**	-0.31	0.77	1.82**	1.82**	-11.57**	116.83*	5.51*
C_{22}	-0.20	0.04	0.44**	0.62*	0.84	0.05	-0.74*	-9.77**	-185.65**	-8.90**
C_{23}	3.80**	2.20**	-0.64**	-0.14	3.67**	-2.94**	4.14**	20.90**	-292.36**	-13.90**
C_{24}	1.80**	-0.56	-0.63**	-0.91**	0.84	1.43**	-2.89**	-0.44	254.90**	12.08**
C_{25}	-0.87	1.64**	1.03**	0.02	-0.76	0.32	2.42**	2.03	96.49*	4.54*
C_{26}	-0.77	-0.80	0.27**	1.86**	-0.20	-1.64**	0.81**	32.56**	-2.90	-0.19
C_{27}	1.23	0.07	-0.62**	-0.21	0.87	2.25**	-0.95**	30.03**	833.49**	39.63**
C_{28}	0.23	1.30**	-0.71**	0.36	0.70	-1.78**	1.12**	-8.97**	-332.38**	-15.24**
SE (Sij)	1.68	1.15	0.23	0.80	1.53	0.81	0.76	4.84	128.07	6.09

*Significant at 0.05 level of probability; ** Significant at 0.01 level of probability

Note: C_1 = PCPGR 7256 × PRG 117, C_2 = PCPGR 7256 × PRG 142, C_3 = PCPGR 7256 × PRG 131, C_4 = PCPGR 7256 × PRG 137, C_5 = PCPGR 7256 × PRG 132, C_6 = PCPGR 7256 × PRG 120, C_7 = PCPGR 7256 × PRG 7, C_8 = PRG 117 × PRG 142, C_9 = PRG 117 × PRG 131, C_{10} = PRG 117 × PRG 137, C_{11} = PRG 117 × PRG 132, C_{12} = PRG 117 × PRG 120, C_{13} = PRG 117 × PRG 7, C_{14} = PRG 142 × PRG 131, C_{15} = PRG 142 × PRG 137, C_{16} = PRG 142 × PRG 132, C_{17} = PRG 142 × PRG 120, C_{18} = PRG 142 × PRG 7, C_{19} = PRG 131 × PRG 137, C_{20} = PRG 131 × PRG 132, C_{21} = PRG 131 × PRG 120, C_{22} = PRG 131 × PRG 7, C_{23} = PRG 137 × PRG 132, C_{24} = PRG 137 × PRG 120, C_{25} = PRG 137 × PRG 7, C_{26} = PRG 132 × PRG 120, C_{27} = PRG 132 × PRG 7, C_{28} = PRG 120 × PRG 7

7256 × PRG 142 and PRG 131 × PRG 132 proved to be good specific combiner. For vegetative character (vine length and number of primary branches) PCPGR 7256 × PRG 117 and PRG 132 × PRG 120 emerged as good specific combiner. For fruit character (fruit length and fruit weight) PRG 117 × PRG 7 and PRG 132 × PRG 120 were promising specific combiner. For number of fruits per plant, fruit yield per plant and total fruit yield the crosses like PRG 131 × PRG 132 followed by PRG 132 × PRG 7 and PRG 142 × PRG 137 were best three specific combiners. These three hybrids are also noted for having significantly higher sca effects for yield contributing characters like days to first female flower, number of primary branches, days taken to first fruit harvesting, number of fruits per plant and fruit weight which concluded in higher total yield. In the present study best general and specific combiners identified in respect of different quantitative traits on the basis of estimates of gca and sca have been presented in Table 4. The crosses showing sca effects involving parent with good gca could be exploited as F_1 hybrid breeding. however, if a cross having high sca has one of its parent as good general combiner and other as poor or average combiner, such crosses are likely to give some segregants, only if additive genetic system is present in a good general combiner and epistatic effects in the cross act in the same direction so as to maximize the desirable expression of the character in consideration (Whitehouse et al. 1958; Lonnquist and Gardner 1961). Maximum F_1 hybrids exhibiting significant sca effects, showed high amount of heterosis for various characters. In many of these hybrids, non additive gene action was involved for almost all the characters. These results are in conformity with the report of Sirohi and Choudhary (1978) in bitter gourd. In ridge gourd, Shaha et al. (1999) found significant high sca effect for most of the characters in several cross combinations. The results of the present study are in agreement with findings of Vashisht et al. (2010) who reported that the components of variance for sca were higher than those of gca for most of the characters. In the present study, the gca and sca effects were highly significant for all the character studied which indicated that both additive and non additive gene actions were important in the inheritance of these characters. Therefore, in improvement of these traits, both selection and heterosis methods of breeding can be adopted. The crosses which showed high sca effects can be best utilized in heterosis breeding and the response to selection is expected to be the best in the crosses involving parents having high gca effects.

Table 4: Three best general combiner and specific combiner for different traits

Traits		Parents	Crosses
1.	Days to first female flower	PRG 117 (-1.70)	PRG 131 × PRG 132 (-3.20)
		PRG 137 (-0.70)	PCPGR 7256 × PRG 131 (-2.07)
		PRG 142 (-0.57)	PRG 142 × PRG 132 (-2.00)
2.	Node number to first female flower	PRG 142 (-1.13)	PCPGR 7256 × PRG 142 (-4.16)
		PRG 137 (-0.49)	PRG 117 × PRG 131 (-3.20)
			PRG 117 × PRG 137 (2.60)
3.	Vine length (m)	PRG 131 (0.83)	PCPGR 7256 × PRG 117 (1.54)
		PRG 132 (0.38)	PCPGR 7256 × PRG131 (1.03)
			PRG 117 × PRG 120 (0.79)
4.	Number of primary branches	PRG 131 (0.26)	PRG 132 × PRG 120 (1.86)
		PRG 117 (0.22)	PCPGR 7256 × PRG 142 (1.02)
			PRG 131 × PRG 132 (0.79)
5.	Days taken to Ist fruit harvesting	PRG 117 (-1.41)	PRG 131 × PRG 132 (-3.06)
		PRG 137 (-0.71)	PRG 142 × PRG 131 (-2.50)
		PRG 120 (-0.51)	PRG 142 × PRG 132 (-2.46)
6.	Number of fruits per plant	PRG 131 (3.50)	PRG 131 × PRG 132 (4.72)
		PRG 137 (0.50)	PRG 132 × PRG 7 (2.25)
			PRG 142 × PRG 137 (2.07)
7.	Fruit length (cm)	PRG 132 (5.17)	PRG 117 × PRG 7 (5.21)
		PRG 131 (2.87)	PRG 142 × PRG 131 (4.93)
		PRG 120 (1.39)	PRG 142 × PRG 120 (4.40)
8.	Fruit weight (g)	PRG 132 (54.03)	PRG 132 × PRG 120 (32.56)
		PRG 120 (10.70)	PCPGR 7256 × PRG 131 (31.30)
		PRG 137 (9.70)	PRG 132 × PRG 7 (30.03)
9.	Fruit yield per plant (g)	PRG 131 (609.01)	PRG 131 × PRG 132 (944.77)
		PRG 132 (450.67)	PRG 132 × PRG 7 (833.49)
		PRG 137 (157.41)	PRG 142 × PRG 137 (605.17)
10.	Total fruit yield (q/ha)	PRG 131 (28.98)	PRG 131 × PRG 132 (45.01)
		PRG 132 (21.44)	PRG 132 × PRG 7 (39.63)
		PRG 137 (7.48)	PRG 142 × PRG 137 (28.84)

Heterosis: In this current study, the extent of heterosis was studied in 28 F_1 hybrids of ridge gourd. The estimates of heterobeltiosis (better parent) and standard heterosis (check parent) have been presented in Table 5 (a and b). It would be imperative to mention here that for the characters *viz*. days to first female flower, node number to first female flower and days taken to I[st] fruit harvesting the negative heterosis was considered to be desirable, as it indicate earliness. For days to first female flower 17 crosses showed negative heterosis over better parent. The cross PRG 117 × PRG 131 showed highest heterobeltiosis. 11 crosses were early as compared to check parent. The cross PRG 117 × PRG 142 exhibited the highest standard heterosis. 19 crosses recorded negative heterosis over better parent for the character node number to first female flower. The cross PCPGR. 7256 × PRG 142 exhibited the highest heterobeltiosis. 6 crosses showed negative heterosis over check parent for the same trait. Here also the cross PCPGR 7256 × PRG 142 stood the first position regarding standard heterosis. For the trait days taken to I[st] fruit harvesting 16 crosses were observed to express the negative heterobeltiosis. The cross PRG 117 × PRG 132 exhibited the highest heterobeltiosis. 14 crosses showed negative heterosis over check parent and the cross PRG 117 × PRG 120 exhibited the highest standard heterosis. For improved vegetative character the vine length and number of primary branches are important aspects to study. In first character 5 crosses showed positive heterosis over better parent. The cross PCPGR 7256 × PRG 117 accounted for highest heterotic value. 15 crosses showed positive standard heterosis for that trait and cross PCPGR 7256 × PRG 131 stood first. Regarding number of primary branches 2 crosses expressed positive heterobeltiosis. The cross PRG 132 × PRG 120 showed the highest value over better parent and in case of standard heterosis 8 crosses showed positive heterosis over check parent. The cross PRG 132 × PRG 120 expressed the highest value over check parent. Number of fruits per plant is highly correlated with fruit yield. 22 crosses exhibited positive heterosis over better parent for this trait. The cross PRG 131 × PRG 132 had the

Table 5 a: Heterosis in ridge gourd for five characters

Genotype	Days to first female flower		Node no. to first female flower		Vine length (m)		No. of primary branches		Days taken to I[st] fruit harvesting	
	BP	CP	BP	CP	BP	CP	BP	CP	BP	CP
G_1	-1.59	8.77**	-7.89	29.63**	59.01**	48.50**	16.67	27.27*	5.43**	5.43**
G_2	8.73**	20.18**	-59.26**	-59.26**	-15.36**	-7.30*	40.00**	27.27*	17.83**	17.83**
G_3	-9.38**	1.75	-15.79**	18.52*	6.90**	59.66**	-23.08*	-9.09	-1.48	3.10
G_4	-8.73**	0.88	56.00**	44.44**	-11.81**	-3.86	-33.33**	-27.27*	-0.78	-0.78
G_5	-6.35**	3.51	-30.30**	-14.81*	5.16	39.91**	20.00	9.09	-4.35*	2.33
G_6	-4.76*	5.26*	0.00	0.00	-15.05**	1.72	0.00	-9.09	4.65*	4.65*
G_7	-6.35**	3.51	-11.11	-11.11	9.87**	9.87**	0.00	0.00	3.10	3.10
G_8	-9.01**	-11.40**	-31.58**	-3.70	-22.41**	-15.02**	16.67	27.27*	-6.98**	-6.98**
G_9	-17.97**	-7.89**	-42.11**	-18.52*	-21.26**	17.60**	7.69	27.27*	-9.63**	-5.43**
G_{10}	-4.59	-8.77**	-47.37**	-25.93**	2.36	11.59**	16.67	27.27*	-3.20	-6.20**
G_{11}	-15.45**	-8.77**	-28.95**	0.00	-9.03**	21.03**	-16.67	-9.09	-14.49**	-8.53**
G_{12}	-3.67	-7.89**	-23.68**	7.41	3.94	24.46**	-8.33	0.00	-6.40**	-9.30**
G_{13}	-7.02**	-7.02**	-21.05**	11.11	3.86	3.86	-16.67	-9.09	-8.53**	-8.53**
G_{14}	-16.41**	-6.14*	-23.68**	7.41	-25.00**	12.02**	-23.08*	-9.09	-11.85**	-7.75**
G_{15}	-3.60	-6.14*	-29.63**	-29.63**	-5.17	3.86	0.00	9.09	-6.98**	-6.98**
G_{16}	-13.01**	-6.14*	-15.15*	3.70	-19.35**	7.30*	10.00	0.00	-12.32**	-6.20**
G_{17}	-1.80	-4.39	-14.81*	-14.81*	-26.16**	-11.59**	10.00	0.00	-5.43**	-5.43**
G_{18}	-2.63	-2.63	-7.41	-7.41	-2.82	6.44	0.00	0.00	-3.10	-3.10
G_{19}	-14.06**	-3.51	-31.58**	-3.70	-1.44	47.21**	-7.69	9.09	-8.89**	-4.65*
G_{20}	-17.19**	-7.02**	-28.95**	0.00	6.32**	58.80**	15.38	36.36**	-13.04**	-6.98**
G_{21}	-10.94**	0.00	-23.68**	7.41	-29.60**	5.15	-15.38	0.00	-5.19**	-0.78
G_{22}	-11.72**	-0.88	-18.42**	14.81*	-4.60	42.49**	7.69	27.27*	-3.70	0.78
G_{23}	0.81	8.77**	3.03	25.93**	-20.97**	5.15	-8.33	0.00	0.00	6.98**
G_{24}	5.50*	0.88	-11.11	-11.11	-26.16**	-11.59**	-33.33**	-27.27*	2.44	-2.33
G_{25}	-5.26*	-5.26*	18.52*	18.52*	22.83**	33.91**	-8.33	0.00	-4.65*	-4.65*
G_{26}	-9.76*	-2.63	-21.21**	-3.70	-7.10**	23.61**	70.00**	54.55**	-7.97**	-1.55
G_{27}	-4.07	3.51	-9.09	11.11	-22.26**	3.43	0.00	0.00	-4.35*	2.33
G_{28}	-1.75	-1.75	18.52*	18.52	-29.75**	-15.88**	9.09	9.09	-0.78	-0.78

Note: G_1 = PCPGR 7256 × PRG 117, G_2 = PCPGR 7256 × PRG 142, G_3 = PCPGR 7256 × PRG 131, G_4 = PCPGR 7256 × PRG 137, G_5 = PCPGR 7256 × PRG 132, G_6 = PCPGR 7256 × PRG 120, G_7 = PCPGR 7256 × PRG 7, G_8 = PRG 117 × PRG 142, G_9 = PRG 117 × PRG 131, G_{10} = PRG 117 × PRG 137, G_{11} = PRG 117 × PRG 132, G_{12} = PRG 117 × PRG 120, G_{13} = PRG 117 × PRG 7, G_{14} = PRG 142 × PRG 131, G_{15} = PRG 142 × PRG 137, G_{16} = PRG 142 × PRG 132, G_{17} = PRG 142 × PRG 120, G_{18} = PRG 142 × PRG 7, G_{19} = PRG 131 × PRG 137, G_{20} = PRG 131 × PRG 132, G_{21} = PRG 131 × PRG 120, G_{22} = PRG 131 × PRG 7, G_{23} = PRG 137 × PRG 132, G_{24} = PRG 137 × PRG 120, G_{25} = PRG 137 × PRG 7, G_{26} = PRG 132 × PRG 120, G_{27} = PRG 132 × PRG 7, G_{28} = PRG 120 × PRG 7

Table 5 b: Heterosis in ridge gourd for five characters

Genotype	Number of fruits per plant		Fruit length (cm)		Fruit weight (g)		Fruit yield per plant (g)		Total fruit yield (q/ha)	
	BP	CP	BP	CP	BP	CP	BP	CP	BP	CP
G_1	8.67*	10.59*	-24.02**	-35.42**	-18.63**	-49.70**	22.65	-44.51**	22.64	-44.51**
G_2	11.56**	13.53**	5.46	-38.83**	-12.77**	-37.88**	16.96	-29.54**	16.96	-29.54**
G_3	22.33**	54.71**	-15.40**	-13.00**	0.79	16.67**	23.20**	80.29**	23.20**	80.29**
G_4	20.79**	26.47**	-9.52**	-27.92**	-42.14**	-26.36**	-30.14**	-6.94	-30.14**	-6.95
G_5	2.31	4.12	-20.60**	-0.75	-32.38**	29.09**	-15.50**	34.44**	-15.51**	34.43**
G_6	17.92**	20.00**	-17.47**	-14.17**	-24.36**	-10.61**	-9.84	-0.91	-9.85	-0.91
G_7	-1.16	0.59	-27.17**	-27.17**	2.42	2.42	2.94	2.94	2.94	2.94
G_8	4.86	-11.18**	-6.18*	-20.25**	7.23*	-23.64**	12.48	-32.24**	12.48	-32.24**
G_9	19.07**	50.59**	16.77**	20.08**	3.66	20.00**	23.36**	80.54**	23.37**	80.54**
G_{10}	17.42**	22.94**	0.98	-14.17**	-26.19**	-6.06*	-13.50**	15.23*	-13.50**	15.22*
G_{11}	10.56*	-7.65	2.47	28.08**	-22.06**	48.79**	-13.79**	37.16**	-13.79**	37.16**
G_{12}	15.82**	7.65	-3.12	0.75	4.62*	23.64**	20.97**	32.95**	20.96**	32.95**
G_{13}	17.65**	17.65**	27.58**	27.58**	4.24	4.24	22.49**	22.49**	22.49**	22.49**
G_{14}	18.60**	50.00**	28.77**	32.42**	5.50*	22.12**	25.05**	83.01**	25.06**	83.01**
G_{15}	26.40**	32.35**	13.91**	-9.25**	3.33	31.52**	30.57**	73.93**	30.57**	73.93**
G_{16}	18.06**	0.00	12.47**	40.58**	-33.65**	26.67**	-20.41**	26.63**	-20.41**	26.63**
G_{17}	15.19**	7.06	17.63**	22.33**	1.54	20.00**	16.76**	28.33**	16.75**	28.32**
G_{18}	20.59**	20.59**	-12.58**	-12.58**	0.91	0.91	21.59**	21.59**	21.59**	21.59**
G_{19}	27.44**	61.18**	15.88**	19.17**	4.76*	33.33**	46.75**	114.76**	46.76**	114.77**
G_{20}	40.00**	77.06**	27.60**	59.50**	-12.22**	67.58**	86.42**	196.60**	86.42**	196.61**
G_{21}	23.72**	56.47**	28.77**	33.92**	5.13*	24.24**	32.71**	94.21**	32.71**	94.22**
G_{22}	14.42**	44.71**	14.42**	17.67**	1.31	17.27**	15.85**	69.53**	15.85**	69.54**
G_{23}	-20.79**	-17.06**	15.60**	44.50**	1.90	94.55**	1.35	61.25**	1.35	61.25**
G_{24}	20.79**	26.47**	-13.06**	-9.58**	6.67**	35.76**	26.93**	69.09**	26.93**	69.09**
G_{25}	15.17**	20.59**	13.50**	13.50**	1.67	29.39**	17.07**	55.95**	17.07**	55.95**
G_{26}	-9.49*	-15.88**	12.31**	40.38**	7.94**	106.06**	8.06*	71.93**	8.06*	71.93**
G_{27}	22.35**	22.35**	2.53	28.17**	2.22	95.15**	49.92**	138.52**	49.92**	138.53**
G_{28}	-8.24*	-8.24*	14.98**	19.58**	1.79	20.30**	-0.77	9.06	0.31	10.25

*Significant at 0.05 level of probability;** Significant at 0.01 level of probability; BP- heterosis over better parent/ heterobeltiosis; CP- heterosis over check parent/ standard heterosis

Table 6: Best three F_1 hybrids for different traits

	Traits	BP	CP
1.	Days to first female flower	PRG 117 × PRG 131	PRG 117 × PRG 142
		PRG 131 × PRG 132	PRG 117 × PRG 131
		PRG 142 × PRG 131	PRG 117 × PRG 137
2.	Node number to first female flower	PCPGR 7256 × PRG 142	PCPGR 7256 × PRG 142
		PRG 117 × PRG 137	PRG 142 × PRG 137
		PRG 117 × PRG 131	PRG 117 × PRG 137
3.	Vine length (m)	PCPGR 7256 × PRG 117	PCPGR 7256 × PRG 131
		PRG 137 × PRG 7	PRG 131 × PRG 132
		PCPGR 7256 × PRG 7	PCPGR 7256 × PRG 117
4.	Number of primary branches	PRG 132 × PRG 120	PRG 132 × PRG 120
		PCPGR 7256 × PRG 142	PRG 131 × PRG 132
			PRG 131 × PRG 7
5.	Days taken to I[st] fruit harvesting	PRG 117 × PRG 132	PRG 117 × PRG 120
		PRG 131 × PRG 132	PRG 117 × PRG 7
		PRG 142 × PRG 132	PRG 142 × PRG 131
6.	Number of fruits per plant	PRG 131 × PRG 132	PRG 131 × PRG 132
		PRG 131 × PRG 137	PRG 131 × PRG 137
		PRG 142 × PRG 137	PRG 131 × PRG 120
7.	Fruit length (cm)	PRG 131 × PRG 120	PRG 131 × PRG 132
		PRG 131 × PRG 132	PRG 137 × PRG 132
		PRG 117 × PRG 7	PRG 142 × PRG 132
8.	Fruit weight (g)	PRG 132 × PRG 120	PRG 132 × PRG 120
		PRG 117 × PRG 142	PRG 132 × PRG 7
		PRG 137 × PRG 120	PRG 137 × PRG 132
9.	Fruit yield per plant (g)	PRG 131 × PRG 132	PRG 131 × PRG 132
		PRG 132 × PRG 7	PRG 132 × PRG 7
		PRG 131 × PRG 137	PRG 131 × PRG 137
10.	Total fruit yield (q/ha)	PRG 131 × PRG 132	PRG 131 × PRG 132
		PRG 132 × PRG 7	PRG 132 × PRG 7
		PRG 131 × PRG 137	PRG 131 × PRG 137

BP- heterosis over better parent/ heterobeltiosis; CP- heterosis over check parent/ standard heterosis maximum heterotic value over better parent. For standard heterosis 18 crosses gave positive heterosis over check parent. Here also the cross PRG 131 × PRG 132 had the maximum heterotic value over check parent. Highly significant heterotic value was also found for the fruit characters like fruit length and fruit weight. For fruit length 14 F_1 hybrids showed positive heterobeltiosis and the cross PRG 131 × PRG 120 gained the highest value. In case of standard heterosis 15 crosses showed positive heterotic value where the cross PRG 131 × PRG 132 accounted the maximum standard heterosis. In case of fruit weight 7 crosses exhibited the positive heterosis over better parent. The cross PRG 132 × PRG 120 showed highest heterobeltiosis and standard heterosis. 19 crosses showed positive heterosis over check parent. The main target of a breeder is to boost the fruit yield per plant. For that character, 15 crosses expressed positive heterosis over better parent and the cross PRG 131 × PRG 132 showed the highest heterobeltiotic value. In case of standard heterosis 21 crosses showed positive significant value. The same cross i.e. PRG 131 × PRG 132 exhibited the maximum heterotic value over the check parent. Regarding the trait total fruit yield 16 crosses showed positive heterosis over better parent. In case of standard heterosis 21 crosses showed positive heterosis over check parent. The cross PRG 131 × PRG 132 exhibited the maximum heterobeltiosis and standard heterosis. Best three F_1 hybrids for different characters have been identified on the basis of estimates of heterosis given in Table 6. High yield in these F_1 hybrids have been attributed to earliness, increased number of fruits per plant and increase in fruit weight. These results give clear indication that from economic point of view it is useful to utilize the promising lines in respect of those important characters associated with higher yield in order to achieve maximum gain in F_1 hybrids of ridge gourd. These results of present investigation are similar to the report of Ram et al. (2004). They noticed 57.5% to 62.1% hybrid vigour for yield in ridge gourd. Hedau and Sirohi (2004), Patel and Desai (2008) and Sonavane et al. (2013) also reported heterosis for high yield and earliness in ridge gourd and sponge gourd respectively. Sharma et al. (1993) recorded significant hetrosis for vine length, fruit weight, fruit length, number of fruits per plant and total yield per plant in bottle gourd over better and top parent. Kadam (1995) reported significant heterosis for number of fruits per plant (19.91%), fruit yield (17.02%) and fruiting nodes per vine (14.1%) in ridge gourd. Prabhakar (2008) noticed 17.81% heterosis for total yield in ridge gourd. Karmakar et al. (2014) reported three hybrids in ridge gourd each having one hermaphrodite parent showing earliness, high number of fruits/plant and confirmed 91.36%, 84.84% and 73.11% heterosis for yield over top parent. On the basis of above results, the best performing hybrids identified in this present investigation could be recommended for commercial exploitation of heterosis and should be tested over other locations and years to further confirm its worth.

Analysis of variance clearly indicated that there was enough variability for the quantitative traits among the ridge gourd genotypes utilized for the present investigation. PRG 131, PRG 132 and PRG 137 can commercially be utilized as parents for high yielding hybrid development. Simultaneously PRG 117, PRG 142 and PRG 131 could be used as materials to get earliness and profuse vegetative growth. In present study none of the cross combinations was found to be good specific combiner for all the characters. For earliness and yield traits PCPGR 7256 X PRG 142, PRG 131 X PRG 132, PRG 132 X PRG 7 and PRG 142 X PRG 137 proved to be good specific combiner. The extent of heterosis was studied in 28 F_1 hybrids of ridge gourd developed by 8 parents in diallel fashion. Analyzing all data PRG 131 X PRG 132, PRG 132 X PRG 7 and PRG 131 X PRG 137 can profitably be exploited as high yielding hybrids in ridge gourd.

Acknowledgement

Studentship support provided by GBPUAT, Pantnagar, Uttarakhand to conduct the present work as a part of Ph.D. thesis is duly acknowledged.

सारांश

तोराई के प्रभेदों को उनके सामान्य संयोजन क्षमता (जी.सी.ए.) एवं विशिष्ट संयोजन क्षमता (एस.सी.ए.) के आधार पर विशिष्ट प्रभेदों की पहचान की गयी। जो उच्च संकर ओज विकसित करने के लिए उपयुक्त उन्नत तथा आर्थिक प्रभेद से उच्च हों। प्रभेदों की क्षमता ज्ञात करने के लिए उनके आठ प्रभेदों को 88 डाइएलील मैटींग डिजाइन में प्रजाति परिवर्तक संकरण को छोड़कर कुल 28 संकरों को उनके 10 उपज संबंधित मात्रात्मक एवं उनके घटक गुणों का परीक्षण किया गया। इनमें से तीन प्रभेद पीआरजी–117, पीआरजी–131 तथा पीआरजी–132 को अगेतीपन, वानस्पतिक तथा उपज के आधार पर सबसे उच्च सामान्य संयोजन क्षमता आंकी गयी है। कुछ संकरणों जैसे पीआरजी 131 × पीआरजी 132, पीसीपीजीआर 7256 × पीआरजी 117, पीआरजी 117 × पीआरजी 7, एवं पीआरजी 132 × पीआरजी 120 को उनके अगेतीपन, वानस्पतिक, फल के गुण, फल संख्या/पौध, फल उपज/पौध और कुल फल उपज के आधार पर उच्च विशिश्ट संयोजक क्षमता मापी गयी। फल गुणों के आधार पर पी.आर.जी. 131; × पी.आर.जी. 120, पी.आर.जी. 131; × पी.आर.जी. 132 तथा पी.आर.जी. 132; × पी.आर.जी. 120 संकरणों के संकर ओज, उनके उन्नत प्रभेद तथा मानक प्रभेद से उच्च है। फल उपज के आधार पर कुछ संकरणों जैसे पीआरजी 131 पीआरजी 132 में उच्च ओजिस्वता तथा मानक ओज, पीआरजी 132 पीआरजी 7 तथा पीआरजी 131 पीआरजी 37 के संकर ओज का स्थान रहा।

Reference

Brown P, Lumpkin T, Barber S, Hardei E, Kreft K, Luther G, Markote P, Paul R, Walter S, Youssefi F and Demet M (2005) Global horticultural assessment. Scripta Hortic No 3, Int Soc Hortic Sci, Leuven, Belgium.

Griffing JB (1956a) A generalized treatment of diallel crosses in quantitative inheritance. Heredity 10: 31-50.

Griffing JB (1956b) Concept of general and specific combining ability in relation to diallel crossing system. Aust J Biol Sci 9: 463-493.

Hayes HK, Immer FR and Smith DC (1955) Methods of Plant Breeding (2nd Edition). Mc Graw Hill Book Company Inc, New York, NY, USA.

Hedau NK and Sirohi PS (2004) Heterosis studies in ridge gourd. Indian J Hortic 61: 236-239.

Kadam PY (1995) Heterosis studies in ridge gourd (*Luffa acutangula*). J Maharastra Agric Univ 20 (1): 119-120.

Kalloo G, Banerjee MK, Kumar S and Parkash C (2001) Hybrid Vegetable Technology in India: An overview. Emerging Scenario in Vegetable Research and Development, pp 104–117. Kalloo G and Singh K (Eds). Research Periodicals and Book Publishing House, New Delhi.

Karmakar P, Munshi AD, Behera TK, Kumar Ravinder, Sureja AK, Kaur C and Singh BK (2013) Quantification and inheritance of antioxidant properties and mineral content in ridge gourd (*Luffa acutangula*). Agric Res 2(3):222–228.

Karmakar P, Munshi AD, Behera TK, Kumar Ravinder, Kaur C and Singh BK (2013) Hermaphrodite inbreds with better combining ability improve antioxidant properties in ridge gourd [*Luffa acutangula* (Roxb.) L.]. Euphytica 191:75–84.

Karmakar P, Munshi AD, Behera TK, Sureja AK and Pati K (2014) Hermaphroditism: A primitive sex form for improving plant architecture, earliness and yield traits in monoecious ridge gourd (*Luffa acutangula* Roxb.). Proc Natl Acad Sci, India, Sect B Biol Sci 84(3):473–480.

Karmakar P, Munshi AD, Behera TK and Sureja AK (2014) Heterosis in ridge gourd (*Luffa acutangula* Roxb.) using hermaphrodite lines. Indian J Hortic 71(1): 61-66.

Lonnquist JH and Gardner CO (1961) Heterosis in inter-varietal crosses in maize and its implication in breeding procedure. Crop Sci 1: 179-183.

Munshi AD and Verma VK (1999) Combining ability in muskmelon (*Cucumis melo*). Indan J Agric Sci 69(3): 214-220.

Patel SR and Desai DT (2008) Heterosis and combining ability studies in sponge gourd [*Luffa cylindrica* (Roem) L.]. Veg Sci 35(2): 199-200.

Prabhakar BN (2008) Combining ability and heterosis for fruit yield and yield components in ridge gourd (*Luffa acutangula* L.). J Res ANGRAU 36(4): 24-32.

Ram D, Rai M, Verma AK and Pandey S (2004) Heterosis and combining ability in satputia (*Luffa hermaphrodita*). Veg Sci 31(2): 129-134.

Rao BN, Rao PV and Reddy YN (2000) Combining ability studies in ridge gourd (*Luffa acutangula* (L.) Roxb.). Intl J Tropic Agric 18(2): 141-146.

Shaha SR, Kale PN and Narale PA (1999) Combining ability analysis in ridge gourd. J Maharastra Agric Univ 24(2): 133-135.

Sharma NK, Dhankhar BS and Tewatia AS (1993) Heterosis in bottle gourd [*Lagenaria siceraria* (Mol.) Standl.]. Haryana J Res 23(1): 8-14.

Sirohi PS and Choudhary B (1978) Heterosis in bitter gourd (*Momordica charantia* L.). Veg Sci 4(2): 107-115.

Sonavane PN, Bhalekar MN, Pawar PK and Bawkar SO (2013) Studies on heterosis and combining ability for earliness and yield in sponge gourd. Bioinfolet 10(2B): 662-666.

Sprague GF and Tatum LA (1942) General versus specific combining ability in single cross of corn. J Am Soc Agron 34: 923-932.

Tyagi SVS, Sharma P, Siddiqui SA and Khandelwal RC (2010) Combining ability for yield and fruit quality in Luffa. Intl J Veg Sci 16(3): 267-277.

Vashisht VK, Sehgal G, Lal T and Gaikwad AK (2010) Combining ability for yield and yield attributing traits in musk melon (*Cucumis melo* L.). Crop Improv 37(1): 36-40.

Virk DD (1988) Biometrical analysis in pearlmillet-A review. Crop Improv 15:1-29.

Whitehouse RNH, Thompson JB and Ribiero MAM (1958) Studies on the breeding of self pollinated cereals- the use of diallel cross analysis in yield prediction. Euphytica 7: 147-169.

Zhang S, Jin H and Xu S (2008) Developmental genetic analysis of fruit shape traits under different environmental condition in Sponge gourd (*L. cylindrica* L.). Genet Mol Biol 31:4-10.